NEW ZEALAND.

MARINE DEPARTMENT.

FISHERIES BULLETIN No. 5.

ON THE DEPRECIATION OF TROUT-FISHING IN THE ORETI (OR NEW RIVER), SOUTHLAND,

With Remarks on Conditions in other Parts of New Zealand.

BY

E. PERCIVAL, B.Sc. (Leeds),

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ON THE DEPRECIATION OF TROUT-FISHING* IN THE ORETI (OR NEW RIVER), SOUTHLAND,

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By E. Percival, B.Sc. (Leeds), Professor of Biology, Canterbury College, Christchurch, N.Z.

The following paper is an account of an investigation into an allegation that a decline had taken place in the well-being of acclimatized trout in New Zealand, and forms part of a general inquiry initiated by the New Zealand Association of Acclimatization Societies.

The introduction of European trout into the waters of New Zealand has provided results of considerable interest in regard to the rate of growth and to apparent modifications in the life-history. In some circumstances the increase in weight is stated to have been phenomenal, particularly where liberations have been made in certain lakes, such as Lake Monowai, Southland. This remarkable growth does not appear to have been maintained, for it has been alleged in various parts of the Dominion that the fish do not grow so rapidly or attain such great weights as they did many years ago. Various views have been expressed as to the cause or causes of this decline, and it is here the object to examine some of the more widely spread ideas regarding the matter, also to bring forward further relevant facts in the hope of determining at least some of the causes.

For the purpose of the investigation it was decided to deal with the Oreti, or New River, in Southland, as it is the only stream from which extensive records are available. While there are many fishing diaries which cover short periods on one or on several rivers, none has been forthcoming which deals so completely with one river over such a long period as that provided by Mr. Neil MacKay, of Dipton, Southland. One of the most valuable features of this diary is the fact that it was commenced at a time when fish growth was said to be very rapid and the rivers to be teeming with food organisms, which are stated to have been very much depleted or to have become extinct.

History of the Stock of Brown Trout in the Oreti River.

According to details published by the Southland Acclimatization Society(3), 154 ova of "sea trout (*Salmo trutta*)" were imported from Tasmania in 1870, and "hatched out well." In 1874 eleven hundred ova were obtained from the above stock and a number, not stated, of the fry was put in the Oreti River. In 1875 fifty adult sea trout were liberated in the Makarewa, a tributary of the Oreti. In 1870, five hundred brown-trout fry were placed in the Makarewa and the Waihopai; in 1872 five hundred brown-trout fry were put into the same two streams along with the Omutu, near Fairfax; and, in 1873, eighty yearlings were put into the Makarewa. Regular stocking of the Oreti with fry appears to have commenced in 1885 with four thousand brown trout, at which time the stream may have contained a stock of fish ranging in age up to ten or more years.

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* The names "trout" and "brown trout", as used in this paper, refer to *Salmo trutta* Linnæus as described by Regan in "British Fresh-water Fishes," London, 1911, p. 55. The specific name includes the various forms of British trout.

General Movement of Fish in the Season in the Oreti River.

It is well known in the locality of Invercargill, Southland, that larger fish usually appear in the river from the middle of January onwards until the spawning season than are to be found before the middle of January. This may be emphasized by reference to the fishing season 1908–9 (see also fig. 4), when the average weight of 374 fish taken before the 15th January was 0·61 lb., while the average weight of 628 fish taken in the same region after that date was 1·1 lb. Similar information may be obtained for many years from Mr. MacKay's records.

The larger fish come in from the estuary and move up stream to spawn in the tributaries during June and July, after which they undoubtedly return chiefly to the salt water before the fishing season commences on the 1st October, since no notice has been received of the occurrence in this river in the early part of the fishing season of fish which have not recovered from spawning.

The meaning of this set of conditions is that the angler deals with two groups of fish essentially different, the one which is still of the fresh water, usually of small size and young, the other having passed through this fresh-water stage now preferring estuarine or marine conditions for a considerable part of the year, and being usually much larger and older. The former group feeds in the fresh water, the latter group may be regarded as deriving a large portion of its food from saline water.

Observations on the Biology of the Brown Trout in New Zealand.

The spawning habits of the brown trout are essentially the same in the Southern Hemisphere as in the Northern, ripe fish moving up into shallows containing stable gravelly beds having a mixture of stones ranging largely between $\frac{1}{4}$ in. and $2\frac{1}{2}$ in. in diameter. The eggs are buried several inches deep where they lie either in groups or singly mixed with the gravel of the spawning bed. Incubation takes place, stimulated by the percolation of oxygenated water through the gravel, and its speed varies with the temperature, as is well known.

When the young fish emerges there is still a large amount of yolk present in a sac on the ventral side of the body, on which the animal is nourished for some three weeks or thereabouts, depending largely upon the temperature. During the period between hatching and the complete absorption of the yolk the young fish is engaged in passing up from its egg-shell to the surface of the gravel where it lies hidden between the stones and making its way to the shallows in which the depth of the water varies from 8 in. to 2 in. or 3 in. Fry may be found in October and November in great numbers between stones and in small shallow pools along the edges of rivers and streams in conditions which are very suitable for the growth of the young larvæ of midges (Chironomidæ), animals which construct slender tubes of fine sand, attaching them to the surface of stones, and feeding upon minute plants growing on the stones, such as diatoms and filamentous algæ.

During the later part of the yolk-sac stage the young fish develops a pigmented skin and takes on the general appearance of the adult fish.

The young fish for several months remains in the region of its birth, but, at the same time, the general population of juveniles appears to become less dense. There are indications that during the period from birth to about the end of May, roughly nine months, there is a very gradual migration first from the egg-shell upwards to the surface and towards the shallows along the bank, then from these shallows of 2 in. or 3 in. depth the young animals proceed gradually into deeper water, so that in May they are commonly found in pools of from 12 in. to 15 in. in depth. Further than this movement to deeper water, there is also a tendency in many to pass to much more rapid water of as much as 10 in. in depth. There is a suggestion of increased strength and confidence as the young fish grows up.

These changes have been noticed from time to time in several places, particularly in the Upper Selwyn and Hororata Rivers and in the Lake Sumner district, all in Canterbury.

It was found (early June, 1930, in the Lower Selwyn, mid-August in the Lake Sumner and Lake Coleridge regions) that in the spawning season there was a complete absence of fish, born in the previous year, from certain streams occupied by spawning fish, streams which in the previous May and December had carried abundance of fish of less than one year of age. Exactly what takes place it is not yet possible to say, but there is evidently a replacement of the smaller fish by the larger. Whether the larger finally drive out the smaller or the movements are independent is not simple to decide. There is an indication that the movement of the small fish is independent of that of the larger since it had taken place in the Upper Selwyn River by the middle of May, 1931, before the appearance of spawning fish. It is possible that it is completed about the time when spawning fish appear.

During this period of readjustment in the small tributaries there appears to be a similar state of affairs farther down. The one-year-old fish have moved into deeper water, either into pools or farther down stream, into regions previously occupied by fish a year older than they. These older fish proceed still farther down, replacing fish of three years which may have gone up to spawn or down to deep water. Thus there is a gradual migratory movement, in effect down-stream, but really in the direction of deep water either alongside the birthplace, as, for instance, in some lakes which afford spawning-beds, or some distance, and usually down stream.

When the spawning is over and the spent fish have gone back, the stream may be visualized as carrying a number of groups, eggs in the upstream shallows, yearlings lower down, two-year-olds lower down still, three-year-olds farther along, and finally a population of fish of various ages in the deep fresh water of the river—*e.g.*, River Manawatu or Waikato—or in the estuary. The groups of fish suggested are by no means distinct, but overlap very much. Two collections of small fish taken in December, one from the Oreti River three miles above Dipton, the other from Stag Creek, which flows into the Oreti at the above-mentioned place, showed very clearly the overlapping in the ranges of one- and two-year-old fish, the sample from Stag Creek containing a preponderance of fish about 1·4 years, while the Oreti collection showed a greater proportion of fish about 2·4 years.

Grouping of fish according to age may be seen to a certain extent in pools—for instance, in early May, 1931, several pools, in the Hororata and Upper Selwyn Rivers, in Canterbury, contained what appeared to be three year classes, fish born in 1930, in 1929, and in 1928. The youngest were most numerous, tending to move in small shoals of about twenty, and keeping chiefly round the edge of the pool where the water was little more than a foot deep. The 1929 fish were much fewer than the 1930 class, they being about 7 per cent. of the total, occupying water round about 2 ft. deep, but cruising over a considerable area. In the deepest water were found fish of the 1928 class, and in a very small proportion of the total number. As the youngest fish moved about in their small shoals the oldest specimens would dart with great speed through them apparently attempting to pick them off one at a time. A pool examined in mid-January, 1931, contained about thirty fish presumably of the 1929 year class and one large fish of about 20 in. in length, probably approaching five years of age. The younger fish moved about in small and loosely composed shoals through which the large one occasionally darted. That the latter was feeding upon the smaller was demonstrated clearly, since it was seen to seize and devour one. It is to be noted that fish born in 1930 had not yet entered into the pool, although in mid-May they were present in high proportion.

In what may be regarded as a state of nature in New Zealand, where a stream, after being once stocked, is left to itself and is unfished, suitable pools contain a population consisting chiefly of large fish. One such pool in the North Branch of the Hurunui River, above Lake Sumner, Canterbury, supported, in the summer 1929–30, a number of fish which varied in weight between 23½ lb. (cleaned) and 7½ lb. (not cleaned). This pool had been known for years to contain large fish. Reports from various parts of the Dominion show a similar state of affairs in circumstances where fishing has little or not at all been practised. Presumably these fish moved from the deep water of the pool to spawn in the shallow tributaries, after which they returned to the same place. Support to this view is lent by the experience of White(31) who found that a marked female trout (*Salvelinus fontinalis*) returned to the same pool on two successive years after tagging. Her absence during the spawning seasons was no doubt concerned with the reproductive function.

There are indications that the larger fish do not move very much during the summer, but stay in and about the localities which they have chosen earlier in the season. This is suggested by the various reports of fish which have been observed in the same place for months together. Fish have been observed to remain for many weeks in the same place in the River Avon, flowing through Christchurch, and which could be easily identified through some peculiarity of coloration.

The fish which retain their position in the manner described would not materially interfere with the gradual and slow movement from shallow to deeper water, which is carried out by the young individuals less than two years of age, as these, particularly those in their first year, lie in water of such little depth that it is usually avoided by the much larger animals.

Reinforcement of the view that the larger fish tend to remain in definite localities during the earlier part of the fishing season, and in some cases all through the season (1st October to 30th April) is lent by data supplied by Mr. Klenner, of Dannevirke, who fished a pool in the Manawatu River, near Dannevirke, in a region containing many such places which were somewhat difficult to approach. The weights taken were as follows : 1st January, 1931, 2½ lb. ; 9th January, 1931, 2½ lb., 2¾ lb. ; 11th January, 1931, 2⅞ lb., 3 lb., 3½ lb. ; 15th January, 1931, 2½ lb. ; 25th January, 1931, 2 lb., 2½ lb. ; 31st January, 1931, 2 lb. ; 3rd February, 1931, 2 lb., 2 lb., 1¾ lb.

After the last-mentioned date the fish varied in weight from $1\frac{1}{2}$ lb. to $1\frac{3}{4}$ lb. The larger fish are said to be more vigorous than the smaller and to take the bait with greater ferocity, so that there would be a tendency for their being more rapidly killed off. The figures indicate that during two months there was no appreciable tendency for the removal of the larger fish to be compensated by the arrival of others from neighbouring pools. Large and suitable pools which are known to have been cleared by the use of explosives have been seen to remain unoccupied for months until the following season, so supporting the view that, apart from the spawning movement, the larger fish do not tend to range over long stretches of water, but rather remain in and about the places which they have chosen at the earlier part of the season.

Consideration of the Food Organisms of Trout.

Phillips(21) has discussed the relations between many of the food-animals of the trout and their habitat and has made determinations of their number per unit area and their variety. He concluded "that stony bottoms are very unproductive compared to boulder ones; that in rapid streams bush-covered banks make for more aquatic fauna than bare ones; that in slow waters it is the amount of aquatic flora which influences the amount of fish-food." He considered that the removal of bush from some of the areas studied by him had brought about the extermination of stone-flies (*Plecoptera*), most of the may-flies (*Ephemeroptera*), the "creeper" (*Archichauliodes dubitatus*), the crayfish (*Paranephrops*). In the Summary of Areas (p. 18) he shows the following total animals taken per square foot:—

Pebble and boulder bottom, bare banks, moderate current	52
Muddy bottom, a little vegetation, very slow current ..	281
Pebble and boulder bottom covered with algæ, no bush, nearly stagnant	288
Gravel and boulder bottom, bushed banks, pools ..	173
Gravel and boulder bottom, bushed banks, rapids ..	246

He states that the methods of collecting employed by him were crude.

He concluded that the food-supply of the trout, in the Wellington District in particular, is very much reduced owing to deforestation, which is considered to have spoiled the stream beds previously affording shelter and good feeding conditions to a great variety and number of invertebrate animals, by bringing about a rapid run-off of surface-water with a consequent greatly increased transportation of heavier detritus.

Tillyard(29), examining the streams in the hot-springs region at Rotorua, also concluded that the largest may-flies had "been practically exterminated, while the smaller ones have been reduced, at a moderate estimate, by over 50 per cent." He considered that the caddis fauna had been reduced to 10 per cent. of the original concentration. This reduction was regarded as due to the introduction of rainbow trout.

It is to be noted that Tillyard has reached a quantitative conclusion although he has presented no quantitative data as evidence. Casual collecting, especially in streams, is often very misleading, particularly when the collector is attempting to compare a present set of conditions containing a number of unknown variables with a past set of conditions which also contained a number of unknown variables. Phillips(20) has also come to certain conclusions on data presented, without apparently taking into account that the nature of the stream varies very considerably owing to the character of the subjacent rocks, the contour of the drainage area and the actual course. It is not the usual nature of streams to be densely and uniformly populated from source to mouth even in New Zealand before the acclimatization of exotic fishes. There is evidence that some streams are inherently incapable of supporting a large fauna owing to the swiftness of their flow—for instance, the Waimakariri.

Quantitative collections of material from streams in various parts of the Dominion, taken personally, do not tend to reinforce the argument that the fauna is seriously impoverished, particularly when the results are compared with those obtained in similar studies carried on in trout rivers in England (Percival and Whitehead(17)). Seventeen such samples, taken from various well-known fishing-streams in all of which the yield is stated to have depreciated, show, on the whole, that the density of the invertebrate population is greater in New Zealand streams than it is in similar circumstances in certain English streams.

It is very clear that conditions change very markedly within a short distance, thus affecting materially the number and variety of organisms per unit area. For instance, in making collections across a stream, Needham(12) found that in some cases there was twice as much animal life (measured as dry matter) in the centre as at the sides, while in other cases the conditions might be reversed. Thus it is possible to reach quite erroneous conclusions owing to injudicious sampling.

Needham (*loc. cit.*) and Percival and Whitehead(17) have shown that there is a close relation between the amount of animal matter and the kind and density of vegetation. This is coupled with the nature of the stream-bed, vegetation being favoured by a stable substratum. The stability of the bed, where it consists of detritus, is determined by the slope, which controls the rate of flow when the width of the channel remains constant. An increase in the amount of water may not bring about such damaging effects when lateral expansion takes place as when the stream is confined. This is well exemplified in the upper portion of the course of the Waimakariri.

The amount of animal life on unit area of the river-bed may not be necessarily a good guide as to the quality of the fishing in the vicinity—*e.g.*, the Opihi River, in South Canterbury, was sampled in the main stream immediately below the bridge on the Main South Road. The bed was hard, covered with flat stones varying in size up to 2 ft. in diameter, with a swift stream which did not permit of the deposition of small material in the particular place. The number of animals taken in the sample was eighty per square foot. The Temuka River, sampled also below the bridge on the South Road, had a bed consisting of material ranging from $\frac{1}{25}$ in. to 6 in. in diameter, the larger stones being chiefly about 2 in. The population in the sample was 2,070 per square foot. The Opihi is well known as a good fishing-stream, and has a much better reputation than the Temuka. These two rivers differ essentially, in the regions under consideration, in their relations to the life-history of the trout. The swift, stony stream is frequented, between spawning periods, by adult fish ; the Temuka is known as a good spawning stream and carries a large number of small fish throughout the season, which are being nursed here prior to their entry into the harder life of the Opihi.

The differences between these parts of the Opihi and the Temuka resemble greatly those between the spawning-grounds, in the headwaters of a large stream where there are shallows consisting largely of small gravel, and the main stream itself, which is liable to big increases in the body of water and the production of conditions which only adult fish can withstand. In the latter case it is probable that much of the food of the resident trout is obtained from material transported from the upper waters whence there is continuously a supply being washed.

Although there is no doubt that the introduction of exotic fishes into New Zealand streams must have had some influence upon the native fauna, particularly the invertebrates, it is not easy to conclude in what direction it has acted. The lower Selwyn River of Canterbury runs over a bed of material varying in size from 9 in. to $\frac{1}{25}$ in. or less. Samples were taken about a quarter-mile below Coe's Ford in a region which provides a considerable number of good fish. Here the bed consists, in places, largely of 2 in. to 3 in. gravel with finer material of $\frac{1}{2}$ in. to $\frac{3}{4}$ in. In other places the latter grades predominate. Although the water rises several feet during wet weather, there are no evidences of serious scouring of the bed (*vide* the deposit). In the years 1926, 1927, 1929, the liberations of brown-trout fry in the twelve miles or so of water above Lake Ellesmere were as follows: 1926, 345,000; 1927, 300,000; 1929, 256,000.

In addition, a large number of fish spawn naturally in the area. A vast fauna of bully (*Gobiomorphus gobioides*) exists, and in the early summer enormous numbers of smelts (*Retropinna retropinna*) enter the river. Besides these fish are very many eels (*Anguilla* spp.) and white-bait (*Galaxias attenuatus*), which also enter the river as young in the spring and early summer. A large eel population is resident in the river. In spite of this enormous fish fauna, all of which feed upon aquatic invertebrates living in the stream-bed, the samples taken below Coe's Ford gave an average of 683 invertebrates per square foot, the numbers ranging from 220 to 986. The samples were taken, as far as possible, from situations representative of the conditions along the stream. From 30 to 55 per cent. of the animals consisted of may-fly nymphs (*Deleatidium* spp.), while caddis larvæ provided from 26 to 51 per cent. (see Appendix B). All the types of organisms found in the samples are known to provide, at one time or another in the life of the trout and other fish, a very great amount of nourishment.

In regard to the persistence of the food-supply, practically nothing is known of the duration of life of any of the food organisms, but there is reason to believe that many of the may-flies and caddis-flies are annual, since there tends to be a disappearance of large nymphs during the autumn and an appearance of an especially large number of eggs and very young motile stages at the same time. Whether any of them, particularly *Deleatidium*, have more than a single generation in the year is as yet unknown. However, very young *Deleatidium* may be found throughout the spring, summer, and early autumn, so that it is possible that this genus has more than one generation per annum. Much more requires to be known concerning these animals.

Many aquatic insects are extremely prolific. The number of ripe eggs counted from the oviducts of females is as follows: *Oniscigaster distans*, 12,000; *Deleatidium lillii*, 1,400 (Phillips(20), 600–800); *Megaleptoperla grandis*, 500; *Archichauliodes dubitatus*, 1,100.

The egg-masses of *Hydrobiosis umbripennis*, a caddis-fly, contained from four hundred to four hundred and fifty eggs, and no cases were observed, in some score of examinations, where eggs failed to produce embryos;

fertilization must have been very complete. Phillips(20) states that *Atalophlebia verisicolor* deposits about two thousand eggs. Generally speaking, it may be said that may-flies, stone-flies, and caddis-flies in New Zealand are more prolific in eggs than are their British relatives (*cf.* Percival and Whitehead(16)).

Percival and Whitehead(15) have shown that the Green Drake (*Ephemera danica*) of European waters requires certain conditions for the successful deposition of its eggs, and that the best development of this species is obtained where the stream-bed is of permanent sand. They show also(16) that a number of may-flies and stone-flies produce egg-masses which break up almost immediately on coming into contact with water, so that the individual eggs fall separately to the bed. Given that oviposition takes place at the water-surface, the nature of the current will determine the resting-place of the egg. It has been found that *Deleatidium lillii* and *Zelandobius confusus* oviposit in this manner.

Siltala(23) has shown that many European caddis-flies creep down the sides of stones and produce egg-masses which adhere to the underside. This was also shown to be the case with a very common may-fly, *Baetis binoculatus* (Percival and Whitehead(16)). *Hydrobiosis umbripennis*, *Hydropsyche* spp., and *Pycnocentria* sp., New Zealand caddis-flies, also deposit their eggs on the underside of stones in water. In May, 1930, the stones along the side of the Waiau River, between Lakes Te Anau and Manapouri, were covered to a varying extent on their lower sides with the egg-masses of a species of *Hydropsyche*. On the larger stones as much as a third of a square foot was covered with gelatinous egg-masses, while along with them were extensive patches of eggs of a sand-fly (*Austrosimulium* sp.). A rough estimate would place 76,000 eggs of *Hydropsyche* on a boulder 1 ft. in diameter. This state of affairs existed along about one hundred yards of river-bank examined. The egg-masses of the sand-fly are not gelatinous. They are cream-coloured or white and consist of about three hundred eggs closely fitting to form a single layer of dimensions about $\frac{3}{8}$ in. by $\frac{3}{16}$ in. In the Waiau were patches of these egg-masses covering as much as $\frac{1}{6}$ square foot.

In this portion of the river, during May, the submerged stones carried very large numbers of the pupal cases of *Hydropsyche*, consisting of small stones cemented together with silk and attached to the substratum. It is probable that this animal contributes materially to the nutrition of the fish in the vicinity, particularly when it is swimming to the surface after the completion of pupation.

Another instance of the very great development of *Hydropsyche* was seen in the Hautapu, a tributary of the Rangitikei River, which flows over a bed of *papa*, a clay-like rock, very friable and easily eroded. In the region examined, about Mataroa, the stream was about five yards wide, one-half of the bed consisting of stable boulders, the other half of *papa*. The erosion here was negligible, since the surface was pitted with myriads of rectangular holes, about $\frac{1}{4}$ in. deep, $\frac{3}{4}$ in. long, and $\frac{1}{4}$ in. wide, lined and roofed by a silken web and carrying, at the up-stream end, a silken net or funnel projecting into the water apparently to act as a sieve, the material, on being caught, ultimately arriving in the pit. These structures were inhabited by the larvæ and pupæ of a species of *Hydropsyche*. Unlike the usual habit of this genus, the larva remained in the pit for pupation, when the funnel was usually broken down. A rough count showed at least six hundred per square foot of these animals besides a large number of *Hydrobiosis*, *Deleatidium*, and *Pycnocentria*. The portion of the bed occupied by boulders carried a dense fauna of *Deleatidium* as well as various caddis larvæ. The whole bed was plentifully covered by a growth of diatomaceous material.

This Hautapu has been fished for many years, is known as a good stream, and is stocked with brown trout. A portion of the trout fry liberated in the Taihape area is placed in this river. In 1928 and 1929 55,000 and 102,000 brown-trout fry were liberated round and about Taihape.

It is possible that the Hautapu carried a vastly greater number of *Hydropsyche* before trout were introduced than it did in February, 1931. It is difficult, however, to decide where the extra number may have been accommodated, since, at the time of observation, the pits were from ¼ in. to ½ in. apart on the piece examined, and had a similar density in the immediate vicinity. From information received regarding the character of the stream over many miles, there is every reason to believe that this dense population of *Hydropsyche* extends over a considerable portion of the bed. This area has been deforested and is well covered with grass.

This type of *Hydropsyche* (probably the same species) was found lying in the *papa* in the bed of the Manawatu River and in the Orua River. Where circumstances were suitable—*i.e.*, lack of erosion—the numbers were similar to those of the Hautapu.

The Pokaewhenua River, in the Auckland Acclimatization Society's district, was sampled in two places. This river, like many in that area, has a bed consisting of water-logged pumice gravel and sand, material which is easily moved, as well as pieces of rhyolite. The stream is well stocked with rainbow trout and is well known to anglers. It flows through rich grazing country. The bed is provided with more or less of a carpet of the filamentous alga, *Chaetomorpha* sp., which forms a thick mat when well grown, so that it binds the substratum. There was a variable development of the plant, some places being bare when the sand and small gravel were carried along like sawdust. A sample taken from one such place yielded five hundred food organisms per square foot. The other sample was taken where the bed was stable, consisting of pumice sand containing stones of rhyolite of from 2 in. to 3 in. in diameter, the latter bearing moss. The fauna here consisted of 1,334 food organisms per square foot. This second sample was taken from a place which could be regarded as typical of the two miles of stream examined. Noticeable in these samples was the high proportion of midge larvæ, approximately 20 per cent. in both cases. Such animals are known to form the bulk of the food of small wild trout, up to 3 in. in length, in Canterbury.

Rivers like the Wanganui, at and above Taumarunui, with their alternating rapids and slacker water containing boulders, with also stretches of shingle, provide alternately relatively barren and fertile areas. One of the latter, at Kakahi, consisted of a large flat of boulders up to 2 ft. in diameter, many projecting from the water, which flowed slowly between them, finally to run off down a rapid before joining the main stream, which has a considerable fall in this district. At high water the flat is covered with swiftly moving water. Two boulders, each about 8 in. by 10 in., and bearing *Cladophora* (a filamentous alga) on their upper sides which also possessed a thin coat of silt caught among the plants, were washed clean of vegetation, animals, and silt. As far as possible all the animals were taken. The total number of animals counted from the two stones was 3,050, of which 61 per cent. consisted of midge larvæ. The boulders were taken as representative of stones in the locality. Liberations of rainbow-trout fry take place in this area, which is a very suitable place for the purpose.

Two samples taken from the Ongarue River, a tributary of the Wanganui, may give the impression that the removal of the bush from the lower portion of the drainage area has been the cause of the diminution in the abundance of invertebrate animals. A stone, about 8 in. by 8 in., lying on the bed of the stream in the natural bush, carried 546 organisms, of which 534 were the larvæ of the caddis, *Pycnocentria*. Only 0·7 per cent. consisted of may-fly nymphs. Another stone, about 7 in. by 4 in., taken from a place in the same river, about nine miles below the former site and three miles above the township of Waimiha, carried 241 animals, of which 133 were *Pycnocentria*. There were 16 per cent. of may-flies, 12 per cent. of other caddis larvæ, and approximately 9 per cent. of midge larvæ. The fauna in this sample was much more varied than in the former, and the casual sampling carried out besides indicated that the special sample was a fair representation of the general conditions. The countryside was covered with a well-grown manuka scrub, and there was not clear indication that the removal of the bush had brought about any alteration in the stream-bed. Further, the presence on the upper surface of the stones of a considerable growth of diatoms and *Nostoc* showed that the bed was stable, while the terrestrial vegetation extended almost to the water's edge. There is no reason to regard manuka scrub as being less efficacious than bush as a means of regulating the flow of water, and the difference in the numbers of organisms in these two samples cannot be charged, in the light of present knowledge, to the removal of the bush.

Samples in the Wellington Acclimatization Society's district showed abundant food organisms in most of the places examined. The Mangatainoka River, a tributary of the Manawatu, flows through an area called the Forty-mile Bush, now an extensive grazing country, deforested some forty years ago. At Hukanui Bridge the bed is stable, the flat stones carrying *Cladophora*, and the grass on the banks extends to the water's edge, often hanging into the stream. A sample showed 240 animals per square foot, 12 per cent. being midge larvæ, 14 per cent. being may-fly nymphs, and 67 per cent. the larvæ of aquatic beetles. The watercress and other aquatic weeds along the bank, and the immersed grass, carried great quantities of the crustacean, *Paracalliope*, and the snail, *Potamopyrgus*.

The Hutt River, at Moonshine Bridge, about fourteen miles above the mouth, had a bed of shingle with little diatomaceous growth on the well-rounded and smoothed stones, indicating that the substratum was disturbed with rising waters. A sample of the shingle showed over three hundred food organisms per square foot, of which 42 per cent. consisted of may-fly nymphs and approximately 15 per cent. of midge larvæ.

The Pahautanui River, two miles and a half from the sea, having a gravel bed, showed over 330 organisms per square foot, of which 16 per cent. were may-fly nymphs, nearly 15 per cent. were caddis larvæ, and 52 per cent. were beetle larvæ. Among the grass and rushes along the bank were great numbers of the fresh-water prawn, *Xiphocaris*, and the crustacean, *Paracalliope*.

The Ohariu River, a stream which had been regarded as of little use for fish-culture, was sampled about one mile and a half above the Makara River. The country has been deforested and is now well grassed. It was reported that either fish would not stay in the stream or that they had been killed off by some substance unknown, or that they had been starved out. The bed, in the locality examined, was stable and consisted of various grades of shingle with small pools containing sand and organic detritus. In the backwaters were large numbers of fresh-water prawns, snails, and caddis larvæ (*Pycnocentria*) among water-cress and other plants. Among the shingle were numerous may-fly nymphs, caddis larvæ, and varying numbers of snails. All the small streams examined in the drainage area were thickly populated with invertebrate animals and there was no indication of serious erosion by flood-water.

Two samples were taken from the stream-bed at this point, one mile and a half from the Makara River. One sample, from a hard bed of stones up to 2 in. in diameter, gave six hundred animals per square foot and contained 16 per cent. of snails, 62 per cent. of beetle larvæ, and approximately 9 per cent. of may-fly nymphs. Another sample taken from sand at the edge of a pool gave 3,150 organisms per square foot, of which 62 per cent. were snails.

It was discovered that the stream had not been stocked for a period of years until recently, when its improvement was undertaken by stocking. At the time of sampling (September, 1930) many trout were seen.

It will serve little further to detail other observations made upon the density of the population in the streams examined. Familiarity with the rivers of the Dominion gives the impression of a considerable variety of conditions within certain limits. The geological youthfulness of the present land-surface of New Zealand accounts for the relative absence of slowly flowing rivers such as, in other countries, give shelter to a great variety of free swimming organisms and allow of the growth of much vegetation on the bed. Rivers such as the Waimakariri, Rangitata, and Waitaki are relatively deserts, since the deposit shifts with every rise in the height of the water. The fall is very great, so that the flow is usually considerably fast, particularly where the river is confined. Speight(25) shows that the Waimakariri leaves the Gorge, thirty-five miles and a half from the sea, at a height of 809 ft. above sea-level, and the fall from there to a point seven miles from the sea varies between 30 ft. and 21 ft. to the mile.

Generally speaking, the rivers of New Zealand are comparable with the portions of the European rivers called by Thienemann(28) " Aschenbach " (Grayling stream), where the bed is stony and liable to flooding through the accumulation of surface-water. There is a relatively poor flora in such European streams, it being largely confined to mosses, which, however, harbour enormous numbers of invertebrate animals (see Percival and Whitehead(17)). Moss is practically absent from streams in this country, so far as the present writer's experience goes, it having been noted only in the Pokaewhenua River in only small quantities. The European aquatic mosses grow largely upon stones and slabs of rock, particularly where the flow is fairly swift. It tends to be replaced, where the current becomes slacker, by a filamentous alga, *Cladophora*, a relative of the filamentous algæ found on stones in many New Zealand streams. Silt accumulates where such growth takes place, allowing the existence of midge larvæ and small aquatic worms.

The Oreti River, Southland, which has a general fall of about 10 ft. per mile from Lumsden, is a shingle river. The bed, some ten miles from the mouth, was found to consist chiefly of material having a diameter of about 2 in. The deposit had the appearance of instability, since there was no diatomaceous growth on the stones visible to the naked eye. Where examined, the bed harboured a rather scanty fauna consisting chiefly of may-fly nymphs of the *Deleatidium* type, with a small proportion of caddis larvæ and beetle larvæ. Along the banks were occasional strips of Canadian water-weed (*Elodea*) sheltering, in the lower reaches, a few fresh-water prawns and bullies. The indications of its previous history, as shown by the banks, suggested that the conditions had not favoured, during very recent time, the development of a fauna of much greater density. The course from Lumsden, as shown on the map, is direct to the sea with small windings in the lower forty miles. There is a probability that this river and the Aparima River, farther west, have never produced a quantity of fish-food comparable with that to be found in the Makarewa, which flows through fertile low country into the Lower Oreti and collects its water from low hills and swampy areas.

Some of the streams of the plains, such as are found in North Canterbury—*e.g.*, the Cam, Main Drain, North Branch of the Waimakariri—in Southland—*e.g.*, the Makarewa—have a more uniform flow than those referred to above, and, besides being largely spring fed, have a stable bed which allows the growth of abundant vegetation sheltering vast numbers of fresh-water shrimps and other crustaceans (*Xiphocaris*, *Paracalliope*, *Ostracoda*), caddis and may-fly nymphs, midge larvæ, dragon-fly nymphs (Agrionidae), snails; and in the silt collected among the stems and roots are to be found the small bivalve molluscs (*Corneocyclas* and *Sphaerium*) and myriads of small aquatic worms (Tubificidae, &c.).

The present writer is not impressed by the contention that the food-supply of fresh-water fishes in New Zealand has been seriously diminished. Clearly there is variation in the amount from place to place and from season to season. It is possible that approximately 80 per cent. of the may-flies, stone-flies, and caddis-flies had been exterminated in the hot-springs region of Rotorua by 1921 (Tillyard, *loc. cit.*) owing to the presence of rainbow trout, yet the Green Stone-fly (*Stenoperla prasina*) is still relatively abundant in the Main Drain and is present in the Lower Selwyn, North Canterbury, streams which are infested with trout, and the Black Stone-fly (*Austroperla cyrene*) is extremely abundant in Lake Taylor, North Canterbury, a lake which also contains very many trout. On the other hand, in the upper drainage area of the Waimakariri, which does not hold a large trout population, *Stenoperla* is not common, and *Austroperla* is usually found in groups in the small creeks flowing through gullies, and particularly near the side of the stream, sometimes among damp stones out of the water. The requirements of these animals are as yet insufficiently known for generalizations to be made regarding the causes of their presence or absence. Percival and Whitehead(17) found that stone-fly nymphs rarely formed more than 2·5 per cent. of the population of trout streams examined by them, and that the large stone-fly genus, *Perla*, was present to the extent of 0·13 per cent., at most, in the winter when the aquatic animals are most widely distributed.

The impression is prevalent among many anglers that the "black creeper," "toe-biter," or "alder-fly" (*Archichauliodes dubitatus*), has been exterminated in places, or has been seriously reduced in numbers.

Hudson(10) has given details of the biology of this insect, and has shown that the larva feeds upon other aquatic insects, such as caddis larvæ, may-fly nymphs, and other stone-haunting animals. It lives as a larva for some time under stones in streams, and in the late spring and early summer leaves the water to bury itself beneath stones and other bodies upon the banks at varying distances from the stream. Some have been found 8 yards from the water's edge. In the earthen cells, which are constructed beneath the stones, they remain some time before pupating. This habit is shared by various relatives—*e.g.*, the genus *Sialis* of the Northern Hemisphere. The eggs have been found to be deposited upon stones and other hard materials overhanging the water. Each egg is ovoid and has a short stalk at one end. It is attached to the substratum along one side. A patch of eggs may contain the total number laid or only a portion. When the young emerge they presumably fall into the water, ultimately making their way beneath the stones.

So far, it would appear that the occurrence of this insect is largely conditioned by the presence of suitable stones on the bank for oviposition, adequate shelter in the stream for the larva and food organisms, and a convenient bank in which pupation may take place. Places in which pupating insects have been found had a matrix of sandy material holding a small amount of moisture. Larvæ and pupæ have not yet been found among clean shingle without "soil." *Archichauliodes* has been found in apparently suitable places irrespective of the presence of trout.

We cannot yet satisfactorily discuss the biological requirements of many of the fluviatile invertebrates, since so little is known of the conditions needed for the successful population of the substratum. It is often evident from a rapid examination of an animal and its habitat what may be the important obvious factor determining its presence or absence. In the trout stream of this country shelter is a primary requirement for the invertebrates which play so important a part in the nutrition of the fish. Some obtain this by burrowing or by clinging to the quiet side of stones—for example, the immature stages of alder-flies, many caddis-flies, may-flies, stone-flies, and midges, the crustacean, *Paracalliope*. Others find it among vegetation, stones not offering adequate shelter, such as the fresh-water prawn (*Xiphocaris*). The snail (*Potamopyrgus*) can exist in the open stream-bed, provided that the current is not sufficient to break its grip. This animal also lives very successfully among vegetation, as does *Paracalliope*. Thus a knowledge of the requirements of an organism will enable the pisciculturist to determine the possibility of the improvement of streams by the introduction of suitable organisms whether plant or animal. It is useless to introduce into shifting shingle rivers animals like the fresh-water prawn and the snail, both of which require stable beds with vegetation for the prawn. Tillyard (*loc. cit.*) has advocated the introduction into New Zealand of the European may-fly, the Green Drake (*Ephemera danica*). Percival and Whitehead(15) have shown that this animal requires, for its best development, beds of permanent sand. Deposits of this kind demand stream conditions which are uncommonly found in the rivers of this Dominion. The relative of this animal, the Grey Drake (*E. vulgata*), is found burrowing in the clay beds and banks of streams more slowly flowing than those containing *E. danica*. A creature of habits similar to those of *E. danica*—viz., *Ichthybotus hudsoni*—is found irregularly distributed in this country, a specimen having been taken at Lake Te Anau by the present writer, another at the Ashley River in North Canterbury, and many from the Wainuiomata in Wellington. The rarity of this animal suggests also rarity of suitable habitat, a matter which should bring a pause in the decision to introduce animals requiring similar conditions.

It may be pointed out here that the usual fauna of the fluviatile waters in New Zealand is benthic—*i.e.*, living on the bed. The occurrence of plankton—*i.e.*, free-floating animals, in rivers in New Zealand, is not known outside estuarine conditions.

Schroeder(21A) found few real plankton species among the diatoms and other algæ taken in tow-nettings from the River Wharfe in Yorkshire, England. There is no mention of plankton animals in his results. This stream is relatively swift, its bed being, in places, subject to erosion, and has been described by Percival and Whitehead(18). Southern and Gardiner(26) have dealt with the plankton of Lough Derg and the River Shannon. The river has an extremely slow current when compared with New Zealand rivers, flood-water taking " from one to four days to travel from Meelick to Hayes Island, a distance of seven miles " (p. 102). This should be compared with the speed of flood-water in the Waimakariri, which takes eight to ten hours to pass from the Gorge Bridge to White's Bridge, a distance of some thirty-three miles. White's Bridge is the tidal boundary, three miles and three-quarters from the sea.

Food Relations in Trout Rivers and Lakes.

Hudson (*loc. cit.*) examined the guts of sixty trout from Wellington and Canterbury streams. Of the contents approximately 87·25 per cent. consisted of may-flies, stone-flies, and caddis-flies in various stages of development. Caddis provided 77 per cent. of the total, may-flies 9·5 per cent., beetles 10·8 per cent., fish, crustacea, and snails were negligible.

Parrott(13) found that the gut contents of 56 trout from the Lower Selwyn River, Canterbury, consisted of caddis larvæ varying in proportion (by number) from 31 per cent. to 100 per cent., the next important food organisms being bullies (*Gobiomorphus*) and water-snails (*Potamopyrgus*). Trout, from the Waimakariri during the period October to February, had fed chiefly upon silveries (*Retropinna*), bullies, and caddis larvæ.

Phillips(19) found that the stomachs of forty-two trout contained 77 per cent. caddis insects, 9 per cent. may-flies, 10 per cent. water-snails. As also found by Parrott and Hudson, Phillips noted the occurrence of a considerable variety of other organisms. It is striking that he found no fish-remains.

Observations by the present writer in back-country lakes and rivers show also the tendency of caddis insects to dominate as trout-food, but, nevertheless, there is a great variety of food consumed, this apparently depending upon the immediate circumstances. Two fish taken from Lake Taylor, North Canterbury, at 10.30 a.m. (25th December, 1929), weighing 3½ lb. and 4½ lb., showed interesting indications of change of surroundings during the previous twelve hours. In the posterior portion of the intestine of one were the remains of several green or manuka beetles (*Pyronota festiva*). The anterior portion of the intestine was packed with the remains of caddis larvæ, and between the two regions was a portion containing no material. The cardiac end of the stomach contained two partly digested bullies, while the pharynx and œsophagus held freshly killed green beetles and (Libellulid) dragon-fly nymphs. The other fish had the remains of several green beetles in the posterior part of its intestine, in the middle region was a mass of caddis larval remains, and at the anterior end was another mass of caddis larval remains. Gaps separated these three masses. In the cardiac end of the stomach were bullies killed much earlier in the day and slightly macerated, while the œsophagus held a freshly dead bully.

The constrictions in the intestine separating the various masses of food-remains suggested the occurrence of different meals in different circumstances, the green beetles being taken at the surface, the caddis larvæ on the in-shore bed among stones, and the bullies in similar places. The dragon-fly nymphs frequent stony places in lakes; they being found singly and in twos beneath stones. No doubt they peregrinate in the vicinity of their shelter, and on such occasions would be liable to be picked up by foraging fish.

FOOD RELATIONS IN INLAND WATERS OF NEW ZEALAND.

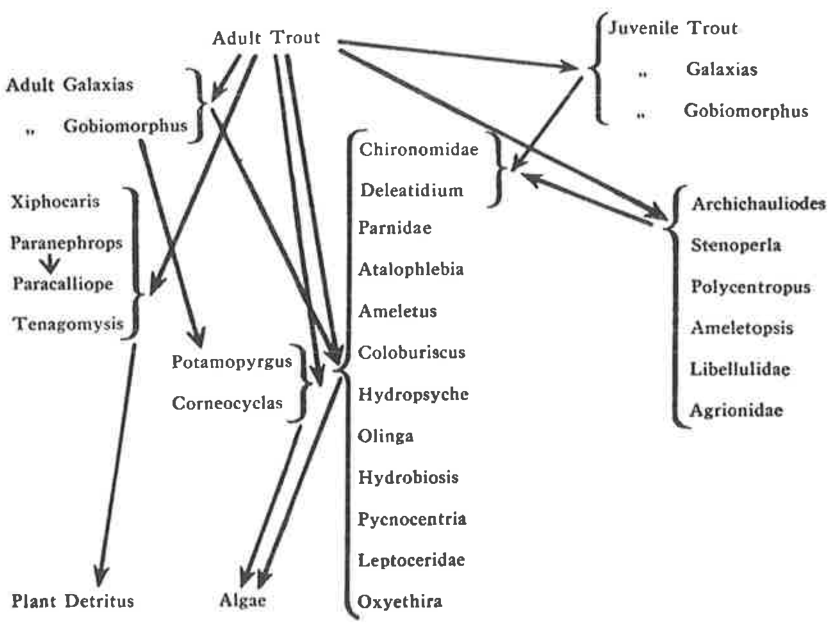

Fig. 1.

At the same period of the year trout taken from Lake Sumner, North Canterbury, showed a diversity of food in different circumstances. Fish taken from the outlet contained chiefly caddis larvæ (*Pycnocentria*, *Hydropsyche*, Leptoceridae), also may-flies (*Deleatidium*) and bullies. Here, as in Lake Taylor, and as found by Phillips, Parrott, and Hudson, *Pycnocentria* formed a very great part of the diet.

Two fish taken at the top end of the lake had their stomachs charged with the nymphs of may-flies (*Deleatidium*) and occasional nymphs of the Green Stone-fly (*Stenoperla*).

The Upper Hurunui River, which flows into Lake Sumner, is a heavy shingle river, and presents conditions which are very difficult for the existence of an invertebrate fauna of any great density or variety. The stones are rounded and polished, and there is no visible vegetation in the main stream. Lateral streams, such as that immediately above Dinner Hill, carry vegetation. It would appear that the trout found in this river, particularly certain large fish observed in a large, deep pool by Dinner Hill, subsist on organisms which are transported from the small feeder-streams farther up. A fish from the pool already referred to was examined and was found to contain approximately one-third of a pint of nymphs of *Deleatidium* and nothing else. Evidence of the consumption of transported food-material was obtained by watching the fish to seize objects in mid-water, never going to the bottom or the sides during the period of observation. This matter is of considerable importance to the student of trout biology since it demonstrates the possibility of the growth of very large fish in conditions which do not show any immediate source of food-supply.

There is considerable evidence now accumulated that the trout in New Zealand obtains the bulk of its food from the water and that the kind of food taken depends largely upon what is to be had. It is well known that a fish will eat one kind of organism for a period and then will turn to something else, or will cease to feed. A single meal may consist of thousands of insects taken singly, for instance the case referred to above. The present writer counted over a thousand identifiable specimens of a may-fly, *Ephemerella ignita*, besides some fifteen hundred partly digested individuals of the same species, from the stomach of a 10 oz. trout taken from the River Wharfe, England.

Although during the summer months, November, December, and January, large numbers of the adults of the beetles, *Odontria* and *Pyronota*, and of cicadas and grasshoppers may be eaten, the food studies referred to above make it clear that these insects are of secondary importance.

Other food organisms of local value are the crayfish (*Paranephrops*) the fresh-water prawn* (*Xiphocaris*), the water-flea (*Paracalliope*), the water-boatman (*Arctocorisa*), the whitebait (*Galaxias attenuatus*), the smelt (*Retropinna*), the phantom shrimp (*Tenagomysis*) which is found in abundance in Lake Ellesmere and Tomahawk Lagoon. These animals have either seasonal value, as the whitebait and the smelt or silvery, which are anadromous in the lower portions of the rivers, or they inhabit special conditions which are not found everywhere. *Xiphocaris* and *Paracalliope* flourish best among vegetation or in slack water with uniform flow, and *Paranephrops* inhabits streams and lakes with clay or stony beds in which it may dig or seek shelter beneath shingle. This latter animal, in the writer's experience, prefers a stable substratum.

It is held (Hope(9)) that the whitebait is not so plentiful now as it was forty years ago, and that this diminution has been responsible for changed habits and reduced growth-rate in the trout. This matter will be referred to later.

Hope (*loc. cit.*) considers that trout feed little or not at all in the winter months. That this is not so throughout the Dominion is evidenced by the fact that freshly spawned female fish taken in early August, from Lakes Taylor and Sheppard, were gorged with *Corneocyclas* (a small bivalve

* Termed "fresh-water shrimps" by anglers.

mollusc), *Potamopyrgus*, various caddis larvæ, chiefly *Pycnocentria*, *Gobiomorphus*, and vegetable fragments. A male and a female newly spawned were gorged with freshly deposited trout-eggs. The water temperature was 7·25° C. (45° F.). The indications were that, in the lakes under consideration, fish commenced to feed voraciously as soon as they had recovered from the act of spawning.

Mention may be made of a female fish caught at the same time as the above, in Lake Sheppard, which contained two partly digested bullies in its stomach. This fish was ripe and on the point of spawning.

Phillips(19) found that six "fingerling" trout contained over 80 per cent. of midge and gnat, or allied, larvæ, and that seven bullies had eaten 142 midge larvæ. Parrott(13) found that a 3½ in. trout had consumed caddis larvæ. Personal observations on young wild trout showed that the diet up to 2½ in. in length consisted chiefly of midge larvæ, after which they took more and more small nymphs of may-flies. Young trout of 5 in. were found to have eaten a higher proportion of may-fly nymphs than of midge larvæ. Small *Galaxias brevipennis* up to 3 in., *G. attenuatus* of 2½ in., taken in fresh water, and *Gobiomorphus gobioides* up to 1 in., were found to have fed entirely upon midge larvæ. Parrott(13) showed that a bully of 3 cm. (1·2 in.), from the Lower Selwyn, had fed entirely upon *Amphipoda* (*Paracalliope*).

It would thus appear that the food of very small fresh-water fishes consists very largely of midge larvæ, a matter which is of importance in connection with the liberation of fry, since midge larvæ require for their best development a stable bed such as is found in good spawning-grounds, and where there is a covering of diatomaceous material on the stones. Percival and Whitehead(17) have shown that the proportion of midge larvæ may be 200 per cent. greater where there is a fine silty deposit on the stones than where this is absent. These insects make tubes of silt and fine sand, which adhere to the substratum, and from which they project their bodies while grazing on the minute plant growth round about them.

Parrott(13) found that the bully (*Gobiomorphus*) taken from the Lower Selwyn, Halswell, and Styx rivers, in Canterbury, fed variously on *Amphipoda* (*Paracalliope*), fresh-water prawns (*Xiphocaris*), *Ostracoda* (minute crustaceans), water-snails (*Potamopyrgus*), small fresh-water bivalve molluscs (*Corneocyclas*), nymphs of may-flies and dragon-flies. There were indications that the food taken varied with the local fauna.

The gut contents of numerous adult specimens of *Galaxias brevipennis*, a species of fish found commonly in the streams and lakes of the South Island, consisted variously of may-fly nymphs and caddis and midge larvæ. The stomachs of three adult *G. attenuatus*, from Westland, 3 in. to 4½ in. long, contained caddis larvæ, adults, pupæ, and larvæ of midges, a portion of a fresh-water prawn, a frog-hopper and a beetle (the last two being terrestrial). In each case the rectum contained the remains of caddis larvæ.

The food of some aquatic invertebrate animals of New Zealand has been noted by Phillips(19) and Parrott(13).

It is remarkable that the genus *Hydropsyche*, in New Zealand, is herbivorous, while in Europe it is decidedly carnivorous. In this country it subsists chiefly upon diatoms, filamentous algæ, and gelatinous algæ. A single carnivorous caddis larva has so far been found here (Hudson, *loc. cit.*)—viz., *Polycentropus puerilis*—the others, like *Hydropsyche*, feeding upon plant-matter. The caddis larvæ are thus of great importance in converting vegetable matter into animal tissue. This applies particularly to *Pycnocentria*, *Olinga*, and *Helicopsyche*.

A single may-fly is known to be carnivorous, a species of no known importance as trout-food. The other may-fly species feed upon diatoms and filamentous algæ. Reference may be made to the discovery of the nymphs of *Ameletus* sp., which were found to be feeding on diatoms in water of 1° C. (33·8° F.) below the Bealey Glacier, above Arthur's Pass, Canterbury.

The small beetle larvæ (Parnidae) are herbivorous as are the water-snails and bivalve molluscs. These two molluscs are responsible for the conversion of a great amount of vegetable material into animal matter.

The water-flea (*Paracalliope*), the fresh-water prawn, and the phantom shrimp (*Tenagomysis*) feed on detrital vegetable matter as well as diatoms and other living plants. The crayfish (*Paranephrops*) has been found to feed upon plant-detritus and microscopic plants. In suitable conditions, where they abound, these crustaceans are very important in producing fish-feed from plant-material.

The creeper (*Archichauliodes*) and the larger stone-fly nymphs are purely carnivorous during the greater portion of their aquatic life, although they commence as herbivores. While the creeper provides food-material for trout to a varying extent, the present writer's experience is that stone-fly nymphs are insignificant in this respect. (See also Hudson, *loc. cit.*)

The Growth of Trout in New Zealand.

It has been alleged that trout do not grow so quickly now as they did in former days. Hope (*loc. cit.*) attributes this, in the South Island, to the diversion of the whitebait runs for human consumption instead of trout consumption, and to a consequent reduction in the stock of inanga (adult *Galaxias attenuatus*). Phillips(21) is of the opinion "that the root cause of the deterioration of our fisheries is the removal of bush from the stream-banks and catchment areas." This latter statement will be discussed later, but the matter of deterioration, which concerns growth, is relevant here.

It is not intended to make an intensive and extensive study of the growth of the trout, but to determine, if possible, whether there has been a decrease in the growth-rate since the fish were first introduced into New Zealand. This country is famous for the size to which the various species of trout attain. Arthur(1), discussing the introduction of brown trout into Otago, cites several cases of fish some of which showed apparently phenomenal growth. Reference may be made to them here:—

Brown trout liberated as fry, caught in 1877:—

River.	Weight.		Length.	Condition Factor.	Sex.	Number of Fry.	Date of Liberation.
	lb.	oz.	In.				
Lee Stream ..	5	0	25	32	♂	98	1869
,, ..	2	0	16	49½	♀	98	1869
Shag River ..	5	2	23	42½	♂	128	1868–69
,, ..	5	5	23½	41½	♂	128	1868–69
,, ..	5	12	21¾	56	♂	128	..
Deep Stream ..	3	4	19	48	♂	100	1869
,, ..	4	10	22	44	♀	100	1869
Broad Creek ..	2	8	17¾	45	♀	..	..

Two remarkable fish were taken from Shag River in 1874, as follows :—

Weight.	Length.	Sex.	Condition Factor.
lb. oz.	In.		
14 0	$29\frac{3}{4}$	♂	54
16 8	$29\frac{3}{4}$	♀	64

These two fish could not have been more than six years old.

Arthur estimates the average annual weight increment as $2\frac{1}{3}$ lb. for the male and $2\frac{3}{4}$ lb. for the female. This is obviously an unsatisfactory method of estimating growth.

Angling commenced in the Lee Stream and Deep Creek in 1875. The heaviest fish taken in that year from Lee Stream was 5 lb. No fish from Deep Creek exceeded 4 lb. during that year, but in 1876 one of 8 lb. was taken. Thus the fish from Lee Stream may have been six years old while the 8 lb. specimen from Deep Creek may have been seven years old. Arthur regarded it as safer to consider these fish as belonging to the original stock.

By the courtesy of Professor W. B. Benham, F.R.S., Curator of the Otago Museum, two samples of scales were received from brown trout placed in the Museum. Mr. A. W. Parrott very kindly examined the material and made the following determinations :—

A. Brown trout, Kariwai, Otago, caught 1889, $15\frac{1}{2}$ lb., $31\frac{1}{2}$ in. long, seven to eight years old. The scales were unsatisfactory.

B. Brown trout, Fulton's Creek, Otago, caught 1884, 17 lb., $30\frac{1}{2}$ in. long. The calculated growth is as follows :—

Year-end	1.	2.	3.	4.	5.
Growth in length (inches) ..	7·2	15·2	22·8*	28·3*	29·5*

* Spawning marks. The scales were in good condition.

A female brown trout was caught in the Scamander Creek, flowing into Lake Coleridge, ripe for spawning, on 11th August, 1931. The details are—weight, $11\frac{1}{2}$ lb.; length, $28\frac{1}{2}$ in. Mr. A. W. Parrott determined the age and growth in length of this fish. The figures follow :—

Year-end	1.	2.	3.	4.	5.
Growth in length (inches) ..	3·8	8·4	18·8	24·2	28·5

The remarkable growth in length in the third year should be noticed.

Godby(8) refers to a 17 lb. brown trout, eight years old, $34\frac{1}{2}$ in. in length, from Lake Coleridge. This fish was captured in October, 1918. An addition of 15 in. in length apparently took place in the fifth year. He includes a less definite case where a fish from the same lake weighed $10\frac{1}{2}$ lb. in November, 1917, but the length given, of $27\frac{1}{2}$ in., was presumed. The animal was three years old.

The following are details of fish from various places, kindly determined by Mr. A. W. Parrott, who also examined certain other scale samples from fish referred to in this paper :—

Water.	Length.	Weight.	Age.	Sex.	Date.
	In.	lb.	Years.		
Upper Hurunui River ..	26½	7½	5+	? ♂	November, 1930.
,, ..	26	7¾	7+	♂	,, ,,
,, ..	25	7	7+	♂	,, ,,
,, ..	27½	7	7+	♂	,, ,,
,, ..	21	5	5+	♂	December, 1929.
,, ..	20½	4	5+	♂	,, ,,
Lake Sheppard ..	19¾	3¼	5+	♀	,, ,,

+ = part of following year. Spawning takes place in July and August.

Godby (*loc. cit.*) gives the details of a female trout, in Table IE, log number B 136, of length 23 in., weight 5¼ lb., six years old, and of another female trout (Table IF, log number A 1) weighing 13½ lb., 28½ in. long, in the sixth year. In Table IE, he gives five fish from 5¼ lb. to 7¾ lb., of six years or less.

Mr. A. W. Parrott has informed the present writer of the existence of records of some twenty-five trout caught in New Zealand since 1927, the weight of which was 5 lb. or over, and the age six years or under.

There is, therefore, ample reason to believe, from the foregoing details, that growth in length and in weight of brown trout has taken place during the past seventeen years just as rapidly as it did during the period 1868 to 1877 in the Shag River, when brown trout were first liberated. If Arthur's figures be examined and compared with measurements and age-determinations at the present time, it will be found that there is generally close agreement between the details relating to the fish taken in 1877 from Lee Stream, Shag River, and Deep Stream, and those obtained at the present, if we believe, with Arthur, that his fish belonged to the original stock.

It is not necessary here to consider the possible migrations of trout in this country ; that has been done by Parrott(14). It is sufficient to recognize that fish often show evidences of accelerated growth during one or several years (see also Godby, *loc. cit.*). There is every reason to believe that this increased growth is due to the movement of the fish into improved feeding-conditions—*e.g.*, the fish taken in the Scamander Creek probably moved into Lake Coleridge during its third year, to a region of more abundant food.

It is probable that the remarkable growth of rainbow trout in Lake Monowai, exemplified by a specimen caught in 1928, weighing 18½ lb., 28 in. long, may have been due to the liberation of fry into conditions of abundant food, so that they commenced immediately to grow rapidly and could be regarded as fish which had migrated as fry. It is stated that such growth has not taken place since. If that be the case a possible explanation is to be sought in the usual habit of the trout to spawn in feeder streams, so that the young fish may spend one or more years in the stream before proceeding to the lake. Nothing is yet known of the quality or the quantity of the animal life in Lake Monowai. The first liberations of rainbow trout took place in the lake itself in 1922, and consisted of two batches of fry and one of eyed ova.

Arthur (*loc. cit.*) states that one of the fry liberated in Mr. Young's mill-race, at Palmerston South, in 1868, was found to have attained a length of 7 in. at the end of the first year. A further fish caught at the end of its first year, in 1869, was also found to be 7 in. long. He refers to Stoddart, who said that English and Scottish trout reached a length of 6 in. or 7 in. by October, they having been hatched in April. This is of interest when considering the calculated first-year growth of trout at the present time in New Zealand. The following are the calculated lengths of the first year of a number of brown trout taken in Canterbury and elsewhere: 1929–30, Lake Sumner and Upper Hurunui River—6 in., $7\frac{1}{2}$ in., $6\frac{1}{4}$ in., $4\frac{1}{2}$ in., $3\frac{1}{2}$ in., $7\frac{1}{4}$ in., $8\frac{1}{4}$ in., $7\frac{1}{2}$ in., $6\frac{1}{4}$ in. 1931, Oreti River, Southland, near Lumsden—$7\frac{1}{2}$ in.

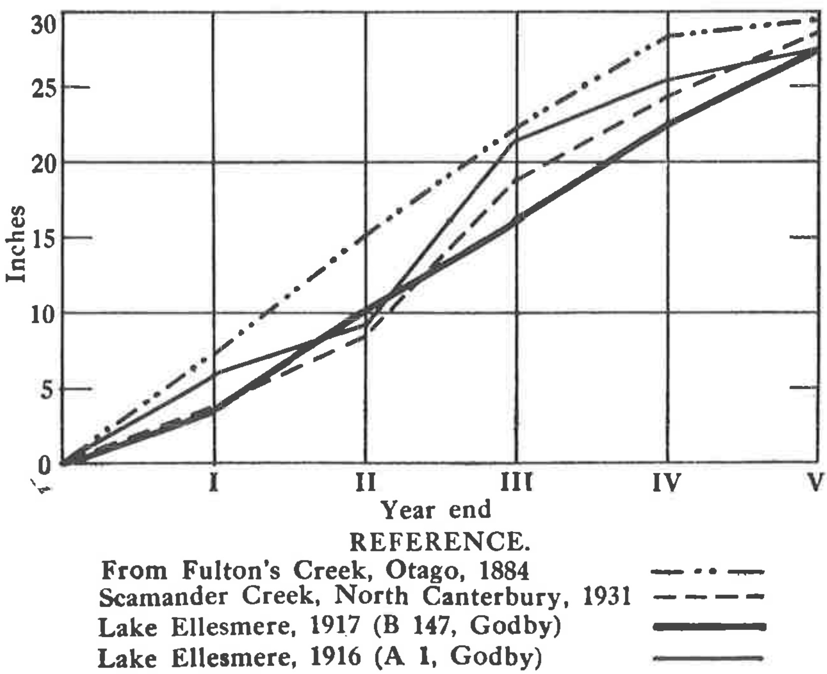

FIG. 2.—Calculated growth in length of certain brown trout.

Godby (*loc. cit.*) in Tables I to IV shows a number of fish which had a calculated length of 7 in. or more at the end of their first year.

It may be inferred from the foregoing that there is no valid reason for believing that fish grew remarkably better from 1868 to 1890 than they have done of recent years, since it has been shown that recorded growth has been made, in recent years, as good as or better than was made in the beginning; and, further, that records, as supplied by Arthur, show that many fish conformed in their growth to the rate which exists at present in the mass.

Fry of *Salmo salar* were liberated in Lake Coleridge in 1928. Two specimens caught on the 23rd November and 1st December, 1930, had lengths 22 in. and 23 in., and weights $3\frac{1}{4}$ lb. and $3\frac{1}{4}$ lb. (gutted) respectively.

The Age of Brown Trout.

Godby (*loc. cit.*) found the average age of thirty-three male trout stripped in the Selwyn River, in June, 1915, to be 5·4 years; that of 139 females and one male, stripped in June, 1917, to be 5·9 years; that of twenty-nine males, stripped in June, 1918, to be 4·8 years; and that of thirty-six females, stripped in June, 1918, to be 6·2 years. The average lengths were 21·3 in., 20·4 in., 22·5 in., and 21·7 in. respectively.

Four male trout from a large pool in the Upper Hurunui River, near Dinner Hill, above Lake Sumner, caught in early summer, 1930, had an average age of 6·75 years and an average length of 26¼ in.

A female fish caught near Lumsden, on the Oreti River, was caught in its eighth year, at a length of 29 in. and weighing 10½ lb.

Parrott(14) gives the following figures:—

Water.	Season.	Average Age.	Average Length.	Average Weight.	
		Years.	In.	lb.	oz.
Hutt River	1927–28	3·32	15·45	1	7
,, ...	1928–29	3·28	14·84	1	3
,, ...	1929–30	3·35	15·05	1	3
Aparima River	1929–30	3·25	16·29	2	0
Lake Sumner	1929–30	4·7	17·9	2	4
Lake Raupo	1929–30	6·6	24·6	4	12
Lake Sheppard	1929–30	5·8	23·3	3	10
Loch Katrine	1929–30	6·4	22·6	3	12

Reference may be made to Spackman(24), p. 38, who gives a list of bags taken from the Wainuiomata, in 1890–91. Eighteen bags ranging from the 15th September, 1890, to the 1st February, 1891, contained fish the average weight of which per bag varied between 1·07 lb. and 1·35 lb.—that is, a little over 1 lb. 1 oz. and about 1 lb. 5 oz. This river, at that time, was subjected to intensive fishing, as it was well known as a fly stream.

The fish which are stripped for ova at the Selwyn River, chiefly consist of animals which spend most of their life sheltered in Lake Ellesmere. The large pool by Dinner Hill may be regarded as virgin water in 1930. Lakes Sumner, Raupo, Sheppard, and Katrine are fished very little, owing to the difficulty of getting there. The Hutt and Aparima Rivers are fished intensively. Mr. Parrott has provided the information that the average age of fish from the Oreti River, which is also fished very heavily along the greater part of its course, is also a little over three years.

Further details regarding the age of fish may be found in the tables given by Godby (*loc. cit.*) in which it is shown that at the time under consideration the back-country lakes of Canterbury contained a high proportion of fish over six years of age.

Deforestation and its Relation to the Depreciation of Fishing.

Phillips(19) has stated that the main factor causing the depletion of the stream fauna in the Wellington District has been deforestation. New Zealand has suffered a tremendous denudation of its natural forest-growth since the settlement of the white man. Miller(11), p. 7, states that "it has been estimated that some 97,200 square miles were under forest before the advent of the first human inhabitants, and that the latter, through the agency of fire, had reduced the forests considerably by the time of European settlement, so that in 1840 the total forest area was about 62,400 square miles" (map 2 and fig. 7). Further, he says, "of the 62,400 square miles of forest existing at the time of the settlement in 1840 only some 17,969 square miles remained by 1922, about 71 per cent. having been wiped out in the course of eighty-two years . . . though pasture and crops, and, to a much less extent, exotic trees, have been established in part of the deforested area, immense tracts, having been left to themselves, have become wilderness" (p. 8). This latter condition can be well seen in the King-country, where enormous areas of manuka scrub have covered the deforested ground. Bates and Henry(6) reporting on a fifteen-year experiment on the relation between deforestation, stream-flow, and erosion, carried out at Wagon Wheel Gap, Colorado, show that the removal of the forest cover in that area resulted in more rapid rises and falls in the stream-level and a greatly increased amount of erosion. The ground was rendered practically bare of living plants and the soil was exposed to the action of water.

Much has been written upon the detrimental effects of deforestation on climatic conditions, stability of land-surface in hilly country, and frequency and intensity of flooding.

Mr. Nelson, of Woodville, provided the following information regarding the Mangaatua River, near Woodville, a tributary of the Manawatu River :—

"About 1890 the bed was silty and the banks were steep, from 6 ft. to 8 ft. deep. About or before this time the forest in the drainage area was largely removed. About 1895 shingle made its appearance in the bed near Woodville, some eighteen miles from the source. By 1900 the whole bed at this place was filled with shingle. At the present day the shingle here is as much as 7 ft. deep and the river-bed is that much above its level in 1890. The upper part of the stream drains an extensive gravel deposit which has been eroded since the removal of the binding roots of the forest-trees."

In spite of the changes which had taken place in this stream near Woodville, there was present in February, 1931, an abundant fauna of caddis (*Hydropsyche*), may-fly (*Deleatidium*), and water-snail (*Potamopyrgus*). On detrital logs were found very many egg-masses of the caddis (*Hydrobiosis*). The fresh-water prawn (*Xiphocaris*) was also found among aquatic weeds along the banks.

Bennett(4) gives the following information (p. 552) :—

"At the Missouri Experiment Station on a 3·7-per-cent. slope of Putnam silt loam 41·2 tons of soil-material was washed off per acre per year, on land ploughed 4 in. (average of six years); 0·3 tons of soil was washed off per acre per year from blue-grass sod on the same soil and slope.

"Missouri Station: Grass held back 137 times as much soil as bare ground. This rate of erosion equals the removal of a 7 in. soil layer in twenty-four years from bare ground and in 3,547 years from sod. Grass retained 88 per cent. of the rainfall (36 in. per annum), while bare ground retained 68·7 per cent.

"Spur Station: At the Spur Station in sub-humid West Texas on a 2-per-cent. slope of Abilene clay loam, 42 tons of soil-matter were lost by erosion per acre per year (27 in. rainfall) from bare ground. Grass (buffalo) retained 82 per cent. of the rainfall, and cotton retained 55 per cent.

"North Carolina Station: In the Piedmont of North Carolina on a 9-per-cent. slope of Cecil sandy clay loam, 25 tons of soil-matter were removed per acre per year by 35·6 in. of rain from uncultivated ground; and 0·06 ton was removed from grass (Bermuda). Grass retained 98·5 per cent. of the rainfall. Cotton retained 74·4 per cent. of the rainfall. Bare ground retained 64·5 per cent. of the rainfall. Grass held back 415 times as much soil as was conserved on untilled ground, and 213 times as much as cotton."

Benskin(5) states that experiments carried out in India showed that grass left uncut and ungrazed during monsoon had an effect on stream-flow considerably greater than forest. There is no precise knowledge to hand regarding the effects of the various land-surface conditions on stream-flow in New Zealand.

It would appear from the foregoing that a grass cover plays a very important part in preventing erosion and absorbing and retaining water. The practice adopted in the removal of bush in New Zealand was to burn the timber and to sow grass seeds on the ashes, thus quickly bringing about the formation of a good turf. This took place very extensively in the North Island. A vast amount of bush country was in this way converted into profitable grazing country such, for instance, as the valley of the Manga-tainoka River and the lower portion of the valley of the Oreti River.

The following statistics* are of interest in this connection :—

	Acres.
Wellington Land District—	
Total area	4,934,689
Total cultivated area	3,652,324
Unimproved area	1,282,365
Of the cultivated area there are in—	
Old pasture	3,506,700
Other crops†	145,624

Southland County, which includes the drainage area of the Oreti River—

	Acres.
Occupied area	2,004,624
Cultivated area	1,011,781
Unimproved area	992,843
Of the cultivated area there are in—	
Old pasture	810,746
Green crops	109,701

It will be seen that five-sevenths of the area of the Wellington District are covered with grass, while two-fifths of Southland have been provided with a covering of largely introduced grasses. Professor F. W. Hilgendorf, of Canterbury Agricultural College, gave the information that the Lower Oreti basin was in brown-top and rye-grass and the Upper Oreti basin was in tussock and Chewing's fescue. He also pointed out that the extensive use of rye-grass in the Lower Oreti region would not be possible if the land were subject to scouring by a heavy run-off of surface-water. There is no evidence whatever, at present, that introduced grasses are less efficient than native grasses for water-regulation.

* Agricultural and Pastoral Statistics, New Zealand, 1930.

† This section includes green crops (mostly turnips), grain, hay, new pasture, market gardens, &c.

These two areas are well provided with a non-forest cover, which may be as good as or better than forest for the purpose of controlling erosion and stream-flow. The Makarewa River, although flowing through a region which has been brought into subjection, still shows no ill effects. Its drainage area is well grassed, and also belongs largely to the low country, while the Oreti takes its origin in fairly high hills, the Eyre Mountains. There is no evidence in this latter drainage area of undue scouring owing to excessive water run-off. Stag Stream and Murray Creek, flowing into the Oreti River between Dipton and Lumsden, have in their lower portions a very profuse growth of aquatic vegetation, and show no signs of erosion.

It is of interest here to note that the fishing in two rivers in the Wellington District has been reported to have seriously declined in recent years. The headwaters of one, the Waingawa, are deforested, while those of the other, the Tauherenikau, still retain their primeval bush cover. The two rivers are both shingle streams, and flow with a fairly steep grade, as is indicated by the nature of the shingle.

A journey from Wellington, touching the streams, Makara, Ohariu, Porirua, Little Wainui, was through hilly country on which grass had replaced bush. All these streams carried an abundant fauna where examined.

The Alleged Depreciation of Trout-fishing in the Oreti River, Southland.

Spackman(24), p. 74, writing in 1892, says, "Of all the rivers, exclusively confined to the Southland District, the Oreti River takes the palm, being the most prolific of trout owing to its superiority as a trout-breeding stream. This arises from its suitable spawning-grounds, from below Dipton here and there upwards towards its source in the Eyre Mountains. It is a shingle, snow-fed river, open and accessible all the way, with a public reserve on each side, with wide open banks only reached in floods, and often changing its course from one bank to the other, with many turns and variations in depth, with swift runs, ripples, and eddies at the heads and tails of a succession of comparatively still pools. A number of lagoons of a crescent or horse-shoe shape are met with on both sides of the river, which are useful nurseries to the trout, and make roving along the bank difficult without waders." This description may be compared with that given in 1929(27), p. 12: "It [the Oreti] flows south through rich grazing and agricultural country, and is supplemented in its course to the Oreti or New River Estuary at Invercargill by many delightful streams noted for their fine trout-fishing. The river flows over shingle and gravel for the greater portion of its course, but, in the higher reaches, the bed is of rocky formation. The banks are clear and the river can be waded without difficulty. Access is easy either by road or rail and good accommodation is to be had at various points." Reference is made to the small size of the trout in various stretches, and it is asserted that one of the chief causes is overfishing, and that this river has probably suffered more from poaching than any other in Southland.

Mr. Neil MacKay, of Dipton, who has fished the region between Dipton, some forty miles directly from the mouth, and Centre Bush, four miles below Dipton, commenced in January, 1888, to record his catches. From the 1st October, 1888, the diary is remarkably complete, it containing the total number and weight of each day's bag, the kind of lure used, the name of the stream and the locality visited. Note is made of fish of unusual size, so that it is possible to obtain an idea of the influx of migrating fish due probably to the occurrence of freshets. A study of the average weight of fish taken each season by him from the Oreti brings out certain changes which it will be interesting to follow. From the season 1888–89 to 1892–93 there is a consistent decline in average weight from 2·7 lb. to 1·03 lb.; from then to 1897–98 a further fall to 0·75 lb., a rise to 1·1 lb. in 1900–1, a fall to 0·8 lb. in 1904–5, a rise to 0·97 lb. in 1910–11. From 1910–11 a decline set in which, with minor fluctuations, ultimately reached its lowest in the season 1928–29, when the average weight was very slightly over 0·5 lb. The season 1929–30 showed, up to February, a rise to 0·54 lb. and that of 1930–31 was 0·61 lb. The lures used by Mr. MacKay were minnow from 1888 to 1889, chiefly minnow from 1889 to 1891, fly with occasional minnow from 1891 to 1901, after which fly alone was used. It will be noticed that the greatest decline took place during the minnow period.

If we accept this record as representing the piscatorial history of that part of the Oreti River, it is necessary to inquire into the cause or causes of such a remarkable falling-off in the beginning of the period, and of the relatively steady decline later, especially since 1910. (See fig. 5).

Owing to the absence of a great deal of data, it is not at present possible to account for the slight fluctuations in the average weight, but information has been gathered which may throw light upon the major changes. It is considered below.

The population of Invercargill, situated by the mouth of the river, shows an increase as hereunder: 1901, 9,014; 1906, 12,500; 1911, 14,170; 1926, 21,890.

The income of the Southland Acclimatization Society derived from the issue of anglers' licenses shows an almost continuous increase from the season 1900–1. Figures for preceding years are not available, except for 1890–91, when the income was £175. The general variations in income are as follows: 1900–1 to 1904–5, between £466 and £516 per annum; 1905–6 to 1918–19, between £624 and £805; 1920–21 to 1929–30, between £1,073 and £1,711.

In the last period the increase was almost continuous. During thirty years, then, there has been a great increase in the number of licensed anglers in the Southland Acclimatization Society's district. Besides these, must be considered the numbers who come into the district from outside, since this area has a certain amount of fame as providing good fly-fishing.

Mr. G. Jaquiery, of Invercargill, has very kindly analysed the fishing-license returns for the season 1929–30, and gives the following results:—

Issued—	Licenses.
Invercargill	569
Oreti River	381
Mataura River	593
Aparima River	202
Waiau River	62
Sundry issues	46
	1,853

Thus 950 licenses, or 51·25 per cent., were issued in the area through which the Oreti flows. Mr. Jaquiery, in a letter dated the 20th November, 1930, stated that "a radius of forty miles from Invercargill will include a considerable part of the Oreti, Mataura, and Aparima."

In the area under discussion, besides there being a public reserve on each side of the river, there is an excellent system of roads, which enables rapid passage to almost any part of the fishing-grounds.

The registration of motor-vehicles in the Invercargill Borough shows an irregular increase from ninety-four in 1909 to 329 in 1925. These figures do not include registrations made with the Southland County Council.

The registrations of motor-vehicles in New Zealand are as follows: 1911, 5,000; 1915, 26,000; 1919, 50,000; 1922, 71,000; 1925, 123,000; 1926, 153,000; 1927, 175,000.

The cost of construction and maintenance of roads throughout the Dominion has risen with irregularity, although with a certain amount of steadiness, and since 1919 with increasing rapidity. In 1891 the cost was about £500,000; in 1914, 2½ million pounds; in 1921, 3½ million pounds; and in 1926, 5½ million pounds. This later increase from 1914 can be correlated with the needs of a greatly increased number of motor-vehicles and an expanding population.

The outcome of this great increase in roading-costs can only be improvement of existing roads and further extension, thus enabling motor-users to travel more quickly and to more remote places. Such improvement and extension have been carried out in the area covered by the Southland Acclimatization Society, the Wellington Acclimatization Society, and other societies throughout the Dominion.

The stocking of the Oreti River and its tributaries has been carried out with fair regularity, only six years having been missed from 1885 to 1927. There was an irregular increase in the number of fry liberated, from 4,000 in 1885 to 362,000 in 1916. After the latter year the fry liberations were largely replaced by eyed-ova, which were planted in the spawning-grounds. The number of ova planted in this area is as follows: 1923, 762,000; 1924, 666,000; 1925, 1,220,000; 1926, 700,000; 1927, 770,000.

The numbers of small trout referred to in 1929(27) can well be understood when considering the population of young fish which must have arisen from the plantations during these years.

Details from the Opuha Gorge, Upper Opihi River.

Mr. E. P. V. Sealy, of Wanganui, kindly provided the following extracts from his fishing-notes :—

" Average weights during four seasons :—

" 1912–13—193 fish	4·3 lb.
" 1913–14—173 fish	4·1 lb.
" 1919–20 (part)—97 fish	5·4 lb.
" 1925–26—93 fish	3·8 lb."

Mr. Sealy gives the following comments in a letter dated the 25th March, 1931: " The Opuha Gorge is ten miles long, guarded on each side by a range of hills, and only accessible in the middle stretches by a two-mile walk and a 1,000 ft. climb over from Cattle Valley Road. Consequently, very few people fish it, and apparently the middle section was left alone during the war, as my first day there in October, 1919, produced eight fish of 6½ lb. average. That average fell quickly, and when I fished it last Christmas holidays I killed nothing but 1½ lb. to 3½ lb. fish, and saw only one in excess of the latter weight. There was much evidence, however, that the river now is frequently fished, whereas years ago few people were possessed of the energy, and had the cars, to cover the thirty to thirty-five mile journey to reach Cattle Valley, and then to walk over the range, finally to swag back 50 lb. to 70 lb. weight of fish."

Reference may be made here to the figures provided by Mr. Klenner (p. 6), which showed a fall in weight during two months, while fishing one particular place in the upper part of the Manawatu River.

Data from Waipukurau, Hawke's Bay.

The following extracts from the diary of Mr. A. Chisholm, of Waipukurau, Hawke's Bay, are worthy of notice. They show an improvement during ten years, particularly in the last four seasons.

FISHING IN THE TUKITUKI AND WAIPAWA RIVERS, HAWKE'S BAY.

Season.	Number of Fishing-hours.	Number of Fish.	Total Weight.	Average Weight.	Largest Fish.
			lb.	lb.	
1921–22 ..	111	56	52¼	0·93	One 2½ lb., two 3 lb.
1922–23 ..	88½	38	38	1·00	One 2 lb.
1923–24 ..	70½	48	42¾	0·89	One 2¼ lb., one 2½ lb.
1924–25 ..	98	61	46¼	0·76	One 1¾ lb.
1925–26 ..	125¾	108	92¼	0·92	Six 2 lb.
1926–27 ..	101½	108	80¾	0·81	One 2½ lb., two 2 lb.
1927–28 ..	133½	78	93¼	1·19	One 4 lb., two 2½ lb.
1928–29 ..	104	28	30¼	1·08	One 2½ lb.
1929–30 ..	171	79	96	1·21	One 4 lb., one 5 lb.
1930–31 ..	208¼	153	196¾	1·29	One 6 lb., one 6¼ lb.

The fishing-area covered by these notes consists of about eight miles of the Tukituki and the Waipawa above their junction and some six to eight miles below their junction. The improvement is remarkably coincident with an intensification in stocking with fry and fingerlings which commenced in 1923.

Mr. J. Anderson, of Dannevirke, very kindly provided the following figures of liberations in the area under consideration and carried out by him :—

	Fry.	Fingerlings.
1923	56,000	..
1924	32,600	40,000
1925	106,000	..
1926	80,000	..
1927	80,000	..
1928	60,000	40,000
1929	110,000	30,000
1930	80,000	..

The maximum output from the hatchery at Dannevirke before 1923 was some 35,000 fry in one year. After that date the output increased to at least 840,000 in one year.

The two rivers, like many others in the Hawke's Bay area, flow through sparsely populated pastoral country, and carry a very good food-supply, while many of their tributaries produce enormous quantities of may-fly nymphs, caddis larvæ, midge larvæ, and snails.

Mr. J. W. Mackie, of Waipukurau, in reference to the issue of fishing licenses in the district, said in a letter dated the 18th May, 1931, "For the past two seasons (1929–30, 1930–31) about seventy licenses have been issued from here (Waipukurau) and about half that number in Waipawa. Of these a large percentage is of boys' licenses. I believe that not more than fifty license-holders in the two towns are regular fishermen."

The river system made up of the Tukituki and its tributaries is very extensive, and must have a high average mileage per angler. Much of it lies on the lower slopes of the Ruahine Mountains, to which very few anglers must go. Further, the number of fry liberated per license undoubtedly has greatly increased, so that the chances of survival of the individual fish will have become greater.

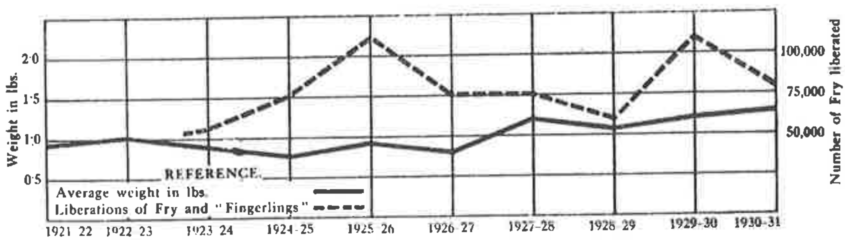

FIG. 3.—Trout from Tukituki and Waipawa Rivers, Hawke's Bay.

Discussion.

Evidence has been presented which shows that, in the experience of one angler, there has been a reduction in the average weight taken from the Oreti River. Reports from various parts of the Dominion also refer to depreciation. It is necessary to decide as to the important cause or causes of this decline in average weight, and to determine whether the charge of reduced food-material due to deforestation or any other cause is valid.

It has been shown that samples taken from various well-known and well-stocked fishing-streams contained over two hundred food organisms per square foot at one time or another, save the Opihi River, a sample from which shewed only eighty per square foot. This stream is still regarded as a good one. Thus in the regions covered by the samples there was evidence of abundant food and to spare at the time of sampling. Qualitative samples in various other streams also showed abundance of food organisms. While the swift shingle rivers (so-called snow rivers) have not so far shown such a high food content as the others dealt with, there is no evidence which proves that they ever contained appreciably more in the history of angling in New Zealand.

Although it has been shown that the removal of forest, particularly from hilly country, may cause serious erosion, with the filling-up of rivers with heavier metal, it has been pointed out that the only one example which has come in the writer's experience had an abundant invertebrate fauna.

Reference has been made to the fact that two shingle rivers, the Tauherenikau and the Waingawa, in the Wellington District, have suffered depreciation, although the headwaters of the former still retain their primeval forest cover, while those of the latter have suffered deforestation. It has been pointed out that the Mangatainoka River system and various others in the Wellington District still provide an enormous number of food organisms in spite of deforestation. The agricultural statistics relating to the Wellington District emphasize the very great amount of grass cover, as do those of the Southland County. Figures obtained from American investigators make clear the very great importance of grass as a means of regulating water flow and evaporation, a grass cover being regarded as good as or better than forest cover in these respects. The Pokaewhenua River, in the Auckland District, suffered depreciation in spite of the fact that it flows through well grassed country without hills of any significance.

In view of the foregoing, it is reasonable to conclude that the removal of the bush has had no important influence in bringing about depreciation—that is, so far as its direct effect upon food-supply is concerned.

The alleged very great reduction in grasshoppers and cicadas by imported birds does not appear to receive support from a consideration of the Southland diary. It has been stated that fish do not grow now so quickly as they did forty years ago—that is, about 1890. The curve of average weights from the Oreti shows a very rapid fall from 2·7 lb. in 1888–89 to 1·05 lb. in 1891–92, three times greater than the decline since 1891–92. If the destruction of grasshoppers and cicadas by introduced birds has been responsible for the decline, then the havoc was worked during the first three seasons covered by the diary. Similarly, any changes in the land-surface in the Oreti drainage area, either of deforestation or drainage, must have operated very violently at that period. Yet we are told that forty years ago conditions were almost ideal. Clearly, then, the effect of imported birds cannot be taken as of primary importance. Regarding the great changes which are alleged to have taken place in the Oreti River resulting from increased flow, increased erosion, and depleted food-material, it has been seen that Spackman's description of the river agrees closely with that of the Southland Anglers' Club, although a period of thirty-seven years had elapsed between the two publications.

At the beginning of the 1888–89 fishing-season on the Oreti the following state of affairs probably existed: a population of brown trout ranging in age from fry to possibly fourteen years of age, the older fish being usually larger than the younger.

As a given year class is followed through its life, its number is seen to diminish, so that the number of aged individuals is very much smaller than that of the juveniles. A collection of fish netted from the Hinds River in Canterbury on the 12th July, 1931, totalling 150 individuals, consisted of 87 per cent. of less than 7 in. in length, these being probably near the end of their first year. A single specimen of more than two years old was found. Observations made on the trout population gave the impression of the following proportion: one hundred fish less than one year old, seven in their second year, one more than two years old. Impressions are always unsatisfactory, but evidence of marked reduction in number in the first year is given by White(30), who found a loss of 95 per cent. during the first three months after liberation as fry among a natural stock of older fish.

The Oreti, at the time under consideration, must have contained a trout population consisting of a small proportion of older fish with increasing proportions of the younger classes. It is generally known that a pool or a locality will be dominated by a strong and usually large fish, which will take up what may be considered to be the best position as regards current and food-supply. The others will be arranged in order of subordination. An expert and assiduous angler working over a limited range throughout a season would undoubtedly take a number of the largest fish, a practice which would, no doubt, continue. It has been shown that the largest and heaviest fish are usually the oldest. If the rate of killing-off is great enough to reduce materially the number of large fish—that is, of usually old ones—then the average weight and average age will similarly be materially reduced. The marked fall in the average weight curve from 1888–89 to 1891–92 may be explained by this killing-off of the relatively small proportion of large and old fish which were present as if in a state of nature.

The annual spawning movement would, in the new circumstances, enable a redistribution of the strong fish remaining. The information given by White(31) regarding the annual return of a marked female fish to the same pool shows the tendency towards restricted range of movement in trout; but there is evidence, from reports, that pools and other localities which are depleted in one season are restocked at a later date, often by large specimens. Active angling in such circumstances could easily kill off the large fish in the whole river population if attention were concentrated on suitable regions. The evidence provided by Mr. Klenner's figures tends to bear this out.

It is thus possible to reduce the average age or weight to any figure if the intensity of destruction be suitably regulated and no limit to size be placed.

The Whakapapa River, a tributary on the right bank of the Wanganui River, flows through a deep gorge for part of its course. The region is thickly forested in places, the sides of the gorge are provided with a dense coat of bush, and it is only with extreme difficulty that access to the river can be obtained. A few adventurous anglers from the vicinity of Taumarunui visit the gorge and secure large fish from the pools. Owing to the arduous nature of the journey visits are not common.

Local information received from Otorohanga, in the Auckland District, shows that as the forest recedes so does the fishing decline. This is to be explained by the fact that adventurous anglers make their way into the bush and kill numbers of large old fish which, no doubt, have long inhabited the places from which they are taken, and the tracks which are made, both by the anglers and through the installation of sawmills, enable the entry of others who carry on the killing at a greater rate than the fish can grow. In a very short time roads fit for wheeled vehicles, particularly motor-vehicles, follow the foundation of sawmills in the valleys. An examination of the local information showed the remarkable coincidence between the depreciation of fishing and the improvement of roads.

The changes outlined with regard to the region behind Otorohanga are a repetition, in a much shorter time, of those which have taken place in the Oreti.

Mr. P. Willson, Chief Ranger to the Wellington Acclimatization Society, stated that the Maungaterere River, near Carterton, had been so depleted as to become finally neglected by anglers. For five years then the stream was stocked with fry. When it was rediscovered to contain good fish angling took place to such an extent that in one season it was reduced to its previous useless condition.

The contention of Hope (*loc. cit.*) that the whitebait fishery has so reduced the number of whitebait ascending the rivers as to bring about a decline in trout-fishing, and to cause brown trout to become migratory, is not in agreement with evidence from the Oreti during the period 1900 to 1911, nor with the view of Arthur(2), who stated (p. 449), "Migration appears to be the refuge of trout in Otago when planted in streams deficient in size and range of water and of food." He (Arthur) cites the case of the disappearance of the largest trout from the Water of Leith, except during the spawning season, and of the occurrence of brown trout in Otago Harbour.

An arbitrary division of the fishing season on the Oreti into two periods, at 13th–14th January, enables the average weight to be determined before and after that time. The weights, when plotted, give curves which show no correlation (fig. 4), indicating that, in effect, two groups of fish are under consideration. It is hardly to be expected that any increase in the second part of the season could be due merely to growth, since in the seasons 1904–5 and 1905–6 the averages for the first part were 0·82 lb. and 0·83 lb. respectively, while those for the second part were 0·76 lb. and 0·77 lb. respectively. It is conceivable that weight had been lost, but it is more probable that the difference may be due to an unusual proportion of young fish in the second part. In those two seasons, and for many years before and after, the diary shows the occurrence of large fish in the second part of the season, the indication being that over thirty years ago, as now, the trout in the Oreti area were migratory. The diary shows a usual appearance of large fish in the second part of the season, but a few years also had them in the first part, as follows: 1896–97, 1901–2, 1903–4, 1910–11, 1920–21, 1923–24, 1924–25.

The depression in the curve of average weights from the Oreti, including 1896–97, 1897–98, 1898–99, may be accounted for, to some extent, as follows: In the season 1896–97 fishing took place during only six days after the 30th January; in 1897–98 fishing took place during only nine days, between the 11th March and the 15th April, after the 28th November; in 1898–99 fishing took place during only seven days, between the 16th March and the 30th April, after the 7th December. In these three seasons the average weight would probably be influenced by the absence of large fish which run into the river during the later portion of the season and which at ordinary times made up a portion of the season's bag. It is probable that the average weights would have approximated more to those before and immediately afterwards if the three seasons had been spent entirely on the Oreti. In 1899–1900 and in 1900–1, for instance, twenty-nine days in each case were spent on the Oreti after the 30th November.

The figures available relating to the growth of brown trout in this Dominion during the past sixty-three years show that growth in length and weight, as good now as formerly, may take place in a season. Due consideration must be given to the remarkably uniform increase in length of the fish taken in 1884 and now preserved in the Otago Museum, but reference must be made to the calculated increase in length of 12¼ in. during the third year for A1, given by Godby (*loc. cit.*) and of 10·4 in. in the third year of the brown trout from Scamander Creek. Further, it should be remembered that a number of fish have in recent years grown in length as much as, or slightly more than, the two yearlings mentioned by Arthur.

We are led to the conclusion that the fishing of whitebait during the last thirty years has had no material effect on the biology of the trout in the Oreti River, since there is evidence of trout migration throughout the period, although the population of Invercargill was about 230 per cent. greater in 1926 than in 1901, and presumably the consumption of whitebait from the Oreti has undergone a similar increase.

It is now time to consider any other possible cause or causes of depreciation.

Reference is made to the very great increase in the income from fishing licenses of the Southland Acclimatization Society, especially since 1918; also to the high proportion of licensed anglers who apparently fish the Oreti. A similar increase in revenue is shown by the North Canterbury Acclimatization Society and the Wellington Acclimatization Society. Mention must be made of the enormous increase in the registration of motor-vehicles in the Dominion generally and of the considerable increase in the Invercargill Borough; of the evidence of very great improvement and extension of roads since 1919, as shown by the curve illustrating the cost of roads and maintenance. In the days of horse and bicycle transport travelling was slow and difficult, very many places, now well known and regularly visited, being known to only a few and rarely visited. An excellent example of this increase in the ease and speed of travel is the journey to Lake Te Anau, one hundred miles from Invercargill, which, a few years ago, was practically unknown, but which, during the last four years, has been brought to no more than a three-hour journey by motor from Invercargill, and is visited by many scores of anglers each season.

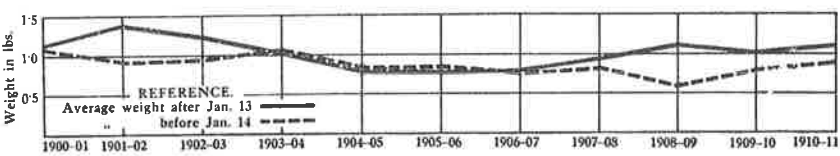

FIG. 4.—Trout from Oreti River, Southland.

It has been said that horse transport for fishing purposes limited the range to a radius of about twenty miles for the single day, and such a journey meant only a few hours' fishing. It also meant much preparation and fatigue, so that it could not be undertaken every day. Now, very many anglers fish streams after the day's work is over at distances greatly in excess of twenty miles, and do so every evening, when possible. Further, the headwaters of a river like the Oreti are within striking distance of any motorist. The good system of roads in this district, as in Wellington, Auckland, and other areas, enables the motoring angler to kill fish in numerous places in minimum time, or allows him to spend more time in one place. The Southland Society's revenue has doubled since 1918, and from shortly after then the steady decline in average weight took place.

It would appear that the primary cause of depreciation in trout-fishing in the Oreti River, in the Wellington District, and in certain other places is greatly increased angling, which may also include the taking of fish by illegal means and at illegal times. Consider that the average age determined for the Oreti, Aparima, and Hutt Rivers, all well fished, is a little over three years, the average age of fish collected in the Upper Hurunui was 6·75 years, in the back-country lakes, Sumner, Katrine, Sheppard, and Raupo, was 4·7, 6·4, 5·8, and 6·6 years respectively. This does not mean that the lakes contained no young fish, but that young fish were sufficiently sheltered that they could become old. The average age of fish taken from the Lower Selwyn and Lake Ellesmere has been shown to be between five and six years. The lake forms a magnificent reserve where fish may be safe from the angler and where they may grow. Very many, no doubt, are never in the angling areas during the fishing season and only come into the river during the spawning runs. The same applies to the sea, which is closed to trout anglers, except from the shore. So long as fish can find protection from the angler they have an opportunity to grow in age and size, but such may not be found in some of the streams which occasionally are literally swarming with anglers.

The improvement of the trout-fishing in the Tukituki and Waipawa may be considered as being due in part to the increased stocks of fry put in. This would give an individual fish a better chance of survival, since the risk of death from the angler is divided among a larger number. A second factor operating is probably the small number of anglers fishing in the area, which is very extensive. Again, the effect is that of affording protection for the individual fish.

A similar problem to the present one is that of the plaice in the North Sea. Garstang(7), in discussing that matter, gave the following figures illustrating the catches by trawlers during certain years. The figures are thousands of tons :—

Year.	Small.	Medium.	Large.
1913	10	8	5
1919	2	13	9
1920	5	12	13
1921	6	11	6
1922	10	10	5
1923	12	6	3
1924	13	5	2

The 1913 figures show the pre-war relation between the size-groups. The North sea was practically closed to trawlers during 1914 to 1919, so that a portion of the plaice population was able to become older and larger than would have been the case if trawling had been freely allowed—that is, the medium and large groups increased greatly in proportion. At the recommencement of trawling in 1919 a situation existed similar to that in the Oreti River in 1888, and in many rivers before and since, and in the Opuha Gorge in 1919. There was approximately a natural population where the larger specimens dominated the situation. As Garstang further points out, there was a great haste to develop trawling owing to the profitable catches of large fish. So well did this proceed that in 1923 the large group was in smaller proportion than in 1913 and was steadily diminishing, as was the medium group, while the small group was rapidly increasing. The average age was very much lowered, since, in effect, the fish were caught before they had time to become old.

When this information is considered in connection with the data relating to New Zealand it becomes clear that the problem centres round the relation between the angler and the fish, which is a more intense pursuit owing to an increased body of hunters moving more rapidly and striking at a very greatly increased number of points. This may be expressed as a very greatly increased number of fishing-hours throughout the area and at any one place.

It might be pointed out that a contributory factor in the production of the very low average weight in the Oreti during 1924 onwards is the liberation of large numbers of fry and the planting of huge quantities of eyed eggs. Resulting from these will be a large population of young fish, many of which will fall to the rod in their third year. It is possible that the increase in average weight in 1929–30 foreshadows a rise to some figure which may indicate an equilibrium between the fish and angling population.

Sherrin (22, p. 216), referring to the report of a meeting of acclimatization societies held in Dunedin in 1883, quotes the following: "The reasons for this loss of fish in the rivers are fishing, poaching, and the natural food-supply being diminished; also the ravages of their natural enemies—shags, gulls, eels, &c."

Conclusions.

The following conclusions may be legitimately drawn from the foregoing account:—

(1) That there is ample evidence to show that growth in recent years, whether in length or weight, is as great as it was when brown trout were first liberated in Otago.

(2) That there is ample evidence of a sufficient food-supply, except in heavy shingle rivers.

(3) That there is no evidence that there has been a marked change in the habits of brown trout, from non-migratory to migratory, in the Oreti during the last thirty years.

(4) That there is no evidence that deforestation has been primarily responsible for a serious reduction in the food-supply. The manner in which deforestation has acted has been in facilitating access to the water and in enabling an increased human population.

(5) That depreciation in trout-fishing has taken place in the Oreti River.

(6) That the primary factors in bringing about depreciation are an increased number of anglers with greater facilities for taking fish, owing to the ease and speed of locomotion, and the almost complete absence of restrictions; so that the killing-power has become constantly greater.

(7) That improvement has taken place in the Tukituki, Waipawa, and Maungaterere Rivers, owing to certain increases in liberations correlated with either no change in the number of anglers or with an absence of anglers.

(8) That liberations of young fish cannot be carried out indiscriminately and yet give the best possible results.

(9) That intensely fished waters show a lower average age than similar regions fished little or not at all.

(10) That, in the present angling system in New Zealand, in a given piece of water it is preferable to have produced a large number of medium-sized fish for a large body of anglers than a small number of large fish for a small number of anglers.

Practical Considerations.

From the evidence presented above it is clear that the absence of protection may result in a very much reduced average weight and average age of a fish population in a given piece of water, and that where protection is given the average weight is raised, as, presumably, is the average age. This protection may be provided in several ways, as follows:—

(1) The closure of streams to angling for several seasons.

(2) The limitation of the number killed per day.

(3) The increase in the minimum-length limit.

(4) Restrictions governing the use of various kinds of lures.

(5) Increased stocking to a degree, at present, undetermined.

(6) The planting of trees along banks in suitable places and the construction of dams and pools as recommended by Phillips(21). These changes may be carried out on small streams, but the modification of large rivers in this way is a matter which would need serious financial consideration.

The measurement of the effect of attempts to control the fish population, as suggested above, can be carried out by means of age, weight, and length determinations made from time to time.

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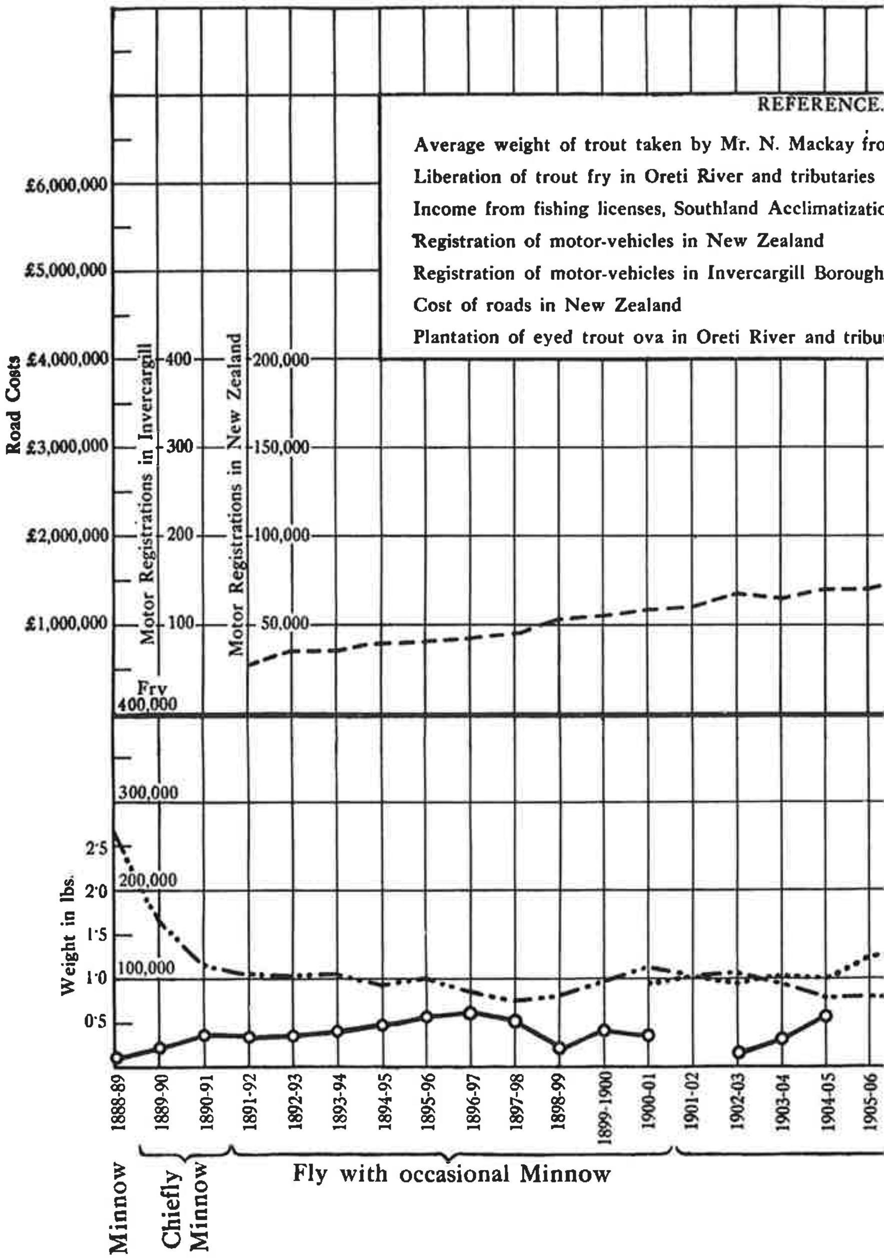
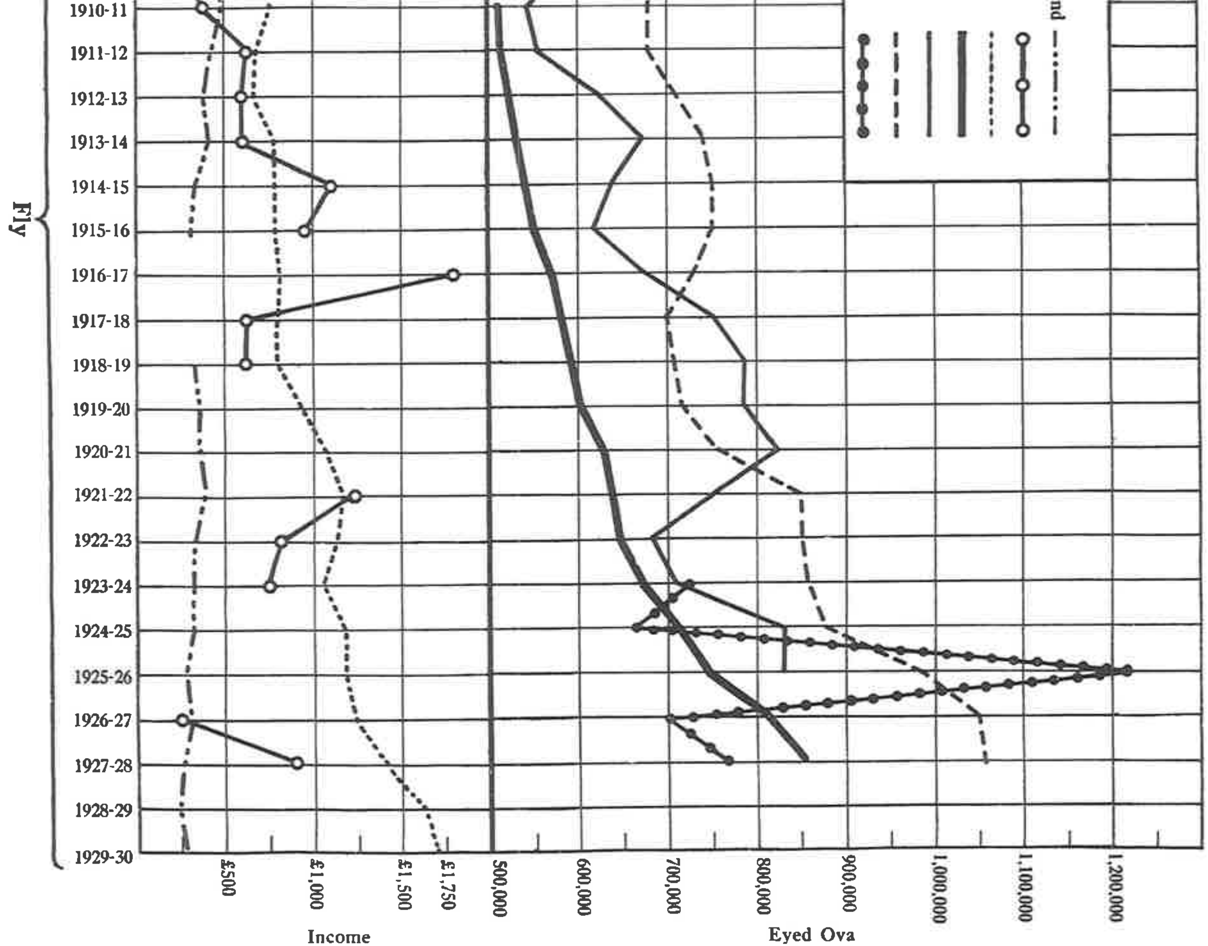


FIG. 5.—Curves based on data relevant to the

Inset—Fisheries Bull. No. 5.

...age weights taken from Mr. N. MacKay's fishing diary.



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APPENDIX A.

Average Weight of Fish taken from the Oreti River, Southland, between Centre Bush and Benmore (from Mr. N. MacKay's Diary).

Season.	Total Number.	Average Weight.	Season.	Total Number.	Average Weight.
		lb.			lb.
1888–89 ..	121	2·7	1910–11 ..	289	0·97
1889–90 ..	269	1·66	1911–12 ..	253	0·83
1890–91 ..	528	1·14	1912–13 ..	281	0·77
1891–92 ..	580	1·05	1913–14 ..	397	0·81
1892–93 ..	640	1·03	1914–15 ..	714	0·65
1893–94 ..	721	1·03	1915–16 ..	892	0·61
1894–95 ..	657	0·93	1916–17 ..	870	..
1895–96 ..	601	0·97	1917–18 ..	890	..
1896–97 ..	988	0·81	1918–19 ..	423	0·67
1897–98 ..	338	0·75	1919–20 ..	277	0·71
1898–99 ..	652	0·80	1920–21 ..	441	0·70
1899–1900 ..	438	0·94	1921–22 ..	572	0·78
1900–1 ..	469	1·10	1922–23 ..	558	0·68
1901–2 ..	402	1·03	1923–24 ..	528	0·63
1902–3 ..	396	1·06	1924–25 ..	547	0·65
1903–4 ..	1,219	0·94	1925–26 ..	329	0·56
1904–5 ..	1,254	0·79	1926–27 ..	371	0·60
1905–6 ..	1,125	0·80	1927–28 ..	343	0·52
1906–7 ..	682	0·77	1928–29 ..	357	0·49
1907–8 ..	882	0·86	1929–30 ..	295*	0·54
1908–9 ..	1,626	0·79	1930–31 ..	462	0·61
1909–10 ..	1,002	0·89			

* To end of February.

APPENDIX B.

Analyses of Samples of Stream-beds.

For methods and apparatus see Percival and Whitehead(15 and 17).

Pahautanui River, 2nd November, 1930, two miles and a half from mouth. Gravel up to 3 in. *Xiphocaris* and *Paracalliope* abundant among grass and rushes along bank. Sample, 4 square decimetres (= $\frac{3}{8}$ square foot).

—	Number.	Percentage of Total.
May-flies—		
Deleatidium	24	16·2
Coloburiscus	1	0·68
Stone-flies—Leptoperlidae ..	1	0·68
Caddis-flies—		
Hydropsyche	1	0·68
Pseudonema	2	1·36
Olinga	15	10·0
Pycnocentria	3	2·0
Hydrobiosis	1	0·68
Helicopsyche	1	0·68
Beetles—Parnidae	77	52·0
Midges and Flies—		
Chironomidae	3	2·04
Limnobiidae	6	4·1
Snails—*Potamopyrgus*	1	0·68
Aquatic worms—		
Eiseniella	2	1·36
Tubifex	2	1·36
Limnodrilus	7	5·1
Phreoryctes	1	0·68
	148	

333 per square foot.

Mangatainoka River, 6th November, 1930, at Hukanui Bridge. Mixed stones with flat stones carrying *Cladophora*. Stable and hard bed, no signs of erosion; weed along bank carrying abundant *Paracalliope* and *Potamopyrgus*. Sample, 4 square decimetres (= $\frac{3}{8}$ square foot).

—	Number.	Percentage of Total.
May-flies—*Deleatidium*	15	14·0
Caddis-flies—		
Hydrobiosis	1	0·9
Polycentropus	2	1·86
Beetles—Parnidae	73	67·5
Midges and flies—		
Chironomidae	13	12·0
Limnobiidae	4	3·7
	108	

243 per square foot.

Pokaewhenua River, 1st November, 1930, near Putaruru. Pumice stream; pumice sand, rhyolite stones carrying moss (*Campylium relaxum*), also *Chaetomorpha* present. Sample, 4 square decimetres (= 4/9 square foot).

—	Number.	Percentage of Total.
May-flies—		
Deleatidium	107	18·00
Atalophlebia	2	0·34
Coloburiscus	2	0·34
Stone-flies—*Zelandobius*	9	1·5
Caddis-flies—		
Hydrobiosis	7	1·18
Pycnocentria	137	23·1
Helicopsyche	4	0·68
Hydropsyche	7	1·18
Oxyethira	11	1·85
Polycentropus	2	0·34
Creeper or alder-fly—*Archichauliodes*	1	0·17
Midges and flies—		
Chironomidae	128	21·6
Hemerodromiidae	7	1·18
Limnobiidae	6	1·01
Aquatic worms—*Nais*	131	22·1
Planaria	33	5·55
	594	

1,334 per square foot.

Pokaewhenua River, 1st November, 1930, near Putaruru. Pumice sand below gravel of rhyolite, chiefly 3/4 in. material; flat stones 2 in. to 3 in. wide, patches of alga (*Chaetomorpha*); steady flow, pumice in motion. Sample, 4 square decimetres (= 4/9 square foot).

—	Number.	Percentage of Total.
May-flies—		
Deleatidium	24	10·90
Coloburiscus	4	1·80
Caddis-flies—		
Hydrobiosis	5	2·28
Polycentropus	1	0·45
Pycnocentria	3	1·36
Helicopsyche	5	2·28
Oxyethira	1	0·45
Stone-flies—Leptoperlidae ..	3	1·36
Beetles—Parnidae	39	17·70
Midges and flies—		
Chironomidae	43	19·60
Hemerodromiidae	12	5·46
Limnobiidae	5	2·28
Aquatic worms—*Nais*	75	34·20
	220	

495 per square foot.

Ongarue River, 29th October, 1930, about three miles above Waimiha. Stone, 7 in. by 4 in.; deforested country, dense manuka scrub; stones carrying diatomaceous growth. Much *Nostoc*.

—	Number.	Percentage of Total.
May-flies—		
Deleatidium	24	10·0
Atalophlebia		
Coloburiscus	15	6·2
Caddis-flies—		
Hydropsyche	13	5·4
Hydrobiosis	7	2·9
Pycnocentria	133	55·3
Helicopsyche	8	3·3
Beetles—Parnidae	3	1·25
Midges, &c.—		
Chironomidae	21	8·75
Limnobiidae	9	3·75
Planaria	8	3·3
	241	

Upper Ongarue River, 29th October, 1930, tributary of Wanganui River. Stone, 8 in. by 8 in., tetrahedral; steady flow, gravel about ⅛ in., flat stones up to 3 in. diameter, large stones up to 8 in. or 10 in., not embedded. Bush stream, natural conditions. About twelve miles above Waimiha.

—	Number.	Percentage of Total.
May-flies—		
Deleatidium	2	0·36
Coloburiscus	2	0·36
Caddis-flies—		
Pycnocentria	534	98·0
Hydropsyche	1	0·18
Stone-flies—*Zelandobuis*	2	0·36
Midges, &c.—		
Chironomidae	2	0·36
Limnobiidae	1	0·18
Beetles—Parnidae	2	0·36
	546	

Wanganui River, 29th October, 1930, near Kakahi, above Taumarunui. Two stones each about 8 in. by 10 in., bearing *Cladophora*; silty surfaces. Shingle down to $\frac{1}{12}$ in. No signs of erosion. Boulders up to 2 ft. diameter projecting from water.

—	Number.	Percentage of Total.
May-flies—		
Deleatidium .. .. .. } *Atalophlebia*	75	2·5
Coloburiscus	10	0·3
Ameletus	1	0·03
Caddis-flies—		
Pycnocentria	15	0·5
Hydrobiosis	32	1·05
Hydropsyche	1	0·03
Pseudonema	6	0·2
Olinga	1	0·03
Helicopsyche	4	0·13
Midges, &c.—		
Chironomidae	1,868	61·2
Hemerodromiidae	3	0·1
Snails—		
Potamopyrgus	3	0·1
Latia (juvenile)	2	0·6
Aquatic worms—		
Pristina	245	8·0
Nais	754	24·8
Chaetogaster	31	1·0
	3,051	

Selwyn River, 15th July, 1930, quarter of a mile below Coe's Ford; small rapid water; stones 6 in. by 12 in. among small gravel of $\frac{1}{12}$ in., containing stones of 2 in. diameter; well washed bed, little alga. Sample, 4 square decimeters (= $\frac{4}{9}$ square foot).

—	Number.	Percentage of Total.
May-flies—		
Deleatidium	40	40·8
Coloburiscus	2	2·0
Caddis-flies—		
Pycnocentria	9	9·2
Hydrobiosis	5	5·1
Hydropsyche	1	1·0
Oxyethira	1	1·0
Beetles—Parnidae	26	26·6
Midges, &c.—		
Chironomidae	3	3·06
Other *Nemàtocera*	2	2·04
Crustacea—*Gammarus*	1	1·02
Aquatic worms—		
Stylodrilus	5	5·1
Nais	3	3·06
	98	

220 per square foot.

Selwyn River, 15th July, 1930, quarter of a mile below Coe's Ford; water 2 ft. deep, edge of pool, gravel ½ in. to ¾ in., with about 5 per cent. of stones of 2 in. to 3 in. diameter. Sample, 4 square decimetres (= ⅜ square foot).

—	Number.	Percentage of Total.
May-flies—*Deleatidium*	73	30·7
Stone-flies—*Stenoperla*	1	0·42
Caddis-flies—		
Pycnocentria	123	51·6
Hydropsyche	1	0·42
Beetles—Parnidae	16	6·7
Midges—Chironomidae	3	1·26
Crustacea—		
*Paracalliope**	4	1·68
*Gammarus**	16	6·7
Aquatic worms—		
Eiseniella	1	0·42
Eiseniella (2 cocoons).		
	238	

* Reproductive females present.

536 per square foot.

Selwyn River, 15th July, 1930, quarter of a mile below Coe's Ford; ½ in. gravel with stones 2 in. to 3 in. diameter; diatomaceous growth, practically no silt; 8 in. deep, relatively slow current. Sample, 4 square decimetres (= ⅜ square foot).

—	Number.	Percentage of Total.
May-flies—*Deleatidium*	170	38·7
Caddis-flies—		
Pycnocentria	216	49·4
Hydrobiosis	5	1·14
Polycentropus	2	0·46
Beetles—Parnidae	14	3·2
Midges—Chironomidae	13	3·0
Crustacea—		
*Paracalliope**	2	0·46
*Gammarus**	15	3·4
Aquatic worms—		
Eiseniella	2	0·46
Eiseniella (15 cocoons).		
	439	

* Reproductive females present.

989 per square foot.

Selwyn River, 15th July, 1930, quarter of a mile below Coe's Ford. Rapid water; chiefly stones 3 in. to 6 in., with small proportion of $\frac{1}{4}$ in. gravel; diatomaceous growth present. Sample, 4 square decimetres (= $\frac{4}{9}$ square foot).

—	Number.	Percentage of Total.
May-flies—		
Deleatidium	133	44·0
Coloburiscus	33	10·9
Stone-flies—*Stenoperla*	1	0·33
Caddis-flies—		
Pycnocentria	63	20·7
Hydrobiosis	9	3·0
Hydropsyche	9	3·0
Beetles—Parnidae	15	5·0
Midges and sand-flies—		
Chironomidae	29	9·6
Austrosimulium	9	3·0
Aquatic worms—*Stylodrilus* ..	3	1·0
	304	

684 per square foot.

Opihi River, 2nd August, 1930, below bridge on main road. Wide stream, hard stony bed, flat stones, no small detritus, swift current. Sample, 4 square decimetres (= $\frac{4}{9}$ square foot).

—	Number.	Percentage of Total.
May-flies—*Deleatidium*	21	58·3
Beetles—Parnidae	1	2·8
Midges—Chironomidae	12	33·3
Aquatic worms—		
Nais	2	5·6
Eiseniella (1 cocoon).		
	36	

81 per square foot.

Temuka River, 2nd August, 1930, below bridge on main road. Mixed bed, material up to 6 in. diameter, chiefly about 2 in., with much small about $\frac{1}{4}$ in.; no indication of heavy erosion. Algal growth on stones. Sample, 4 square decimetres (= $\frac{4}{9}$ square foot).

—	Nnmber.	Percentage of Total.
May-flies—*Deleatidium*	40	4·34
Stone-flies—*Stenoperla*	1	0·1
Caddis-flies—		
Hydropsyche	4	0·43
Polycentropus	8	0·87
Hydrobiosis	14	1·52
Pseudonema	1	0·11
Oxyethira	17	1·84
Beetles—Parnidae	8	0·87
Midges and flies—		
Chironomidae	666	72·4
Limnobiidae	24	2·6
Other dipterous larvæ	4	0·43
Aquatic worms—		
Stylodrilus	1	0·1
Nais	122	13·22
Chaetogaster	10	1·1
Eiseniella (1 cocoon).		
Crustacea—*Gammarus*	2	0·22
	922	

2,070 per square foot.

Upper Selwyn River at mouth of Hororata River, 3rd June, 1931. Straight smooth flow, no ripples, 9 in. deep, mixed gravel, ⅛ in. to 4 in.; luxuriant diatomaceous growth with much *Ulothrix*. Sample, 4 square decimetres (= 4/9 square foot).

——	Number.	Percentage of Total.
May-flies—*Deleatidium*	191	51·8
Caddis-flies—		
Pycnocentria	145	39·0
Hydropsyche	2	0·5
Oxyethira	3	0·8
Beetles—Parnidae	4	1·8
Midges—Chironomidae	23	6·2
Aquaric worms—*Eiseniella*	2	0·5
	370	

830 per square foot.

Hydra viridis present on stones.

Hutt River, 2nd September, 1930, at Moonshine Bridge, fourteen miles above mouth. Shingle containing flat stones 6 in. by 3 in., among fine material down to ⅛ in. Very little diatomaceous cover; stones well worn. Sample, 4 square decimetres (= 4/9 square foot).

——	Number.	Percentage of Total.
May-flies—		
Deleatidium	57	42·0
Coloburiscus	2	1·5
Ameletus	3	2·2
Caddis-flies—		
Hydropsyche	2	1·5
Hydrobiosis	3	2·2
Pycnocentria	2	1·5
Beetles—Parnidae	40	29·4
Midges—		
Chironomidae	20	14·7
Limnobiidae	4	2·9
Snails—*Potamopyrgus*	1	0·7
Aquatic worms—*Eiseniella*	2	1·5
	136	

306 per square foot.

Ohariu River, 2nd September, 1930. Hard stable bed, small stones up to 2 in. diameter; pool about 18 in. deep. Sample, 4 square decimetres (= ⅜ square foot).

—	Number.	Percentage of Total.
May-flies—*Deleatidium*	7	2·6
Stone-flies—*Zelandobius*	1	0·37
Caddis-flies—		
Helicopsyche	8	3·0
Oxyethira	1	0·37
Pycnocentria	10	3·75
Pseudonema	2	0·75
Olinga	2	0·75
Midges—Chironomidae	7	2·6
Beetles—Parnidae	167	62·5
Snails—*Potamopyrgus*	44	16·6
Crustacea—*Ostracoda*	1	0·37
Aquatic worms—		
Eiseniella	2	0·75
Tubifex	15	5·65
	267	

600 per square foot.

Ohariu River, 2nd September, 1930. Sand by edge of pool. Sample, 4 square decimetres (= ⅜ square foot).

—	Number.	Percentage of Total.
Caddis-flies—		
Pseudonema	1	..
Oxyethira	1	..
Pycnocentria	21	1·5
Beetles—Parnidae	38	2·7
Midges—Chironomidae	51	3·65
Crustacea—		
Paracalliope	7	0·5
Ostracoda	64	4·6
Snails—*Potamopyrgus*	876	62·5
Aquatic worms—		
Eiseniella	38	2·7
Tubifex	303	21·5
	1,400	

3,150 per square foot.

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