NEW ZEALAND.

MARINE DEPARTMENT.

FISHERIES BULLETIN No. 2.

A REPORT ON THE FOOD OF TROUT

AND OTHER CONDITIONS AFFECTING THEIR WELL-BEING IN THE WELLINGTON DISTRICT.

BY

J. S. PHILLIPS, B.A., Oxon.,

Victoria University College.

With a Preface by A. E. HEFFORD, M.Sc., Chief Inspector of Fisheries, Marine Department.

WELLINGTON.

BY AUTHORITY: W. A. G. SKINNER, GOVERNMENT PRINTER.

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Price 1s.

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PREFACE.

The following report by Captain J. S. Phillips will be welcomed by all who are interested in the well-being of the Dominion fresh-water fisheries. It does not represent the first word on the subject. One may recall that in 1904 Mr. G. V. Hudson, in his work "New Zealand Neuroptera (with Notes on their Relation to Angling)," drew attention to the importance of certain insect forms found in streams and rivers of Wellington Province as food material for the acclimatized trout. In 1919 Dr. Tillyard was commissioned by the Department of Internal Affairs to inquire into the problem of trout-food in the thermal lakes and their associated streams. In 1924 Mr. W. J. Phillipps, of the Dominion Museum, made investigations and published a paper on the same subject. Reference to their work is made in the report which follows, so that no further comment is called for here, beyond stating that, as recognized by both these investigators, their observations were too limited, both as to time and locality, to admit of any very conclusive result being arrived at. No information of real benefit to the fisheries can ever be obtained by sporadic and temporary investigations.

Captain Phillips's report embodies the results of the first attempt at a comprehensive and sustained attack on the general problem of the food requirements of trout in the Wellington Province. Though the observations are more or less local, the laws and principles involved and the fundamental aspects of the problems, which are lucidly set forth by the author of the report, will be found to apply throughout the Dominion.

The credit for making these investigations possible is due to the Wellington Acclimatization Society. Their President, Mr. L. O. H. Tripp, was the first in the Dominion to recognize the necessity for the scientific elucidation of the trout problem with which his society was confronted; and, backed by an enlightened council, he found the means of carrying his ideas into effect. In 1927 the Council made a grant to the Victoria University College of £400 per annum for three years to be expended in payment of the salary and expenses of a qualified research student. A Research Committee, consisting of Mr. L. O. H. Tripp (chairman) and Dr. G. F. V. Anson, of the Acclimatization Society Council, and Professor H. B. Kirk and Dr. T. D. M. Stout, of the Victoria University College Council, with myself as technical adviser, was appointed to formulate an outline scheme of work, and to exercise a general supervision. Captain J. S. Phillips was the research student appointed.

It should be mentioned that the North Canterbury Acclimatization Society has also formed a Research Committee, and appointed Mr. A. W. Parrott as their investigator, by whom similar observations have been carried on through the past year in connection with the trout-food conditions in certain of the Canterbury rivers and lakes. Mr. Parrott's first report has been published in the annual report of the North Canterbury Acclimatization Society for the year 1928–29.

The study of the trout in its New Zealand surroundings has a special interest and significance both from the biological and the practical point of view. We are dealing with a species which is usually the only exotic form in the association of native organisms among which it has been introduced by human agency. We are acquainted with similar but more complicated associations in connection with terrestrial wild life, and the remarkable results which have ensued are matters of common (though somewhat superficial) knowledge. With regard to our acclimatized trout, these immigrants transported from the Northern Hemisphere have developed to a surprising degree in their antipodean habitat. In many localities they have become piscine prodigies upon which the interest of anglers throughout the world has been directed with envy or incredulity. But they have not fitted into their new environment as they fitted into their native habitat. They have, as it is usually expressed, disturbed "the balance of nature"; and the operations of man have produced still further disturbance. The study of the factors which make up this "balance of nature" is the task to be done before we can understand the trout's conditions of life, and before we can improve the conditions by any practical measures. This work by Captain Phillips is a considerable step, though only a first step in that direction.

A. E. Hefford.

Marine Department, Wellington, 3rd August, 1929.

CONTENTS.

INTRODUCTION.

An investigation of the food of fresh-water fish in general and of trout in particular is a work of unlimited scope. The methods of approach are so numerous and the data which must be collected before any conclusions can be drawn so extensive that it is difficult to decide how and where to begin.

A preliminary period was spent in seeing as many of the fresh waters as possible and becoming acquainted with the aquatic organisms of the province and their environment. Many of these organisms are still unnamed and unknown to science, and the working-out of their life-histories and ecology offers ample opportunities to future workers.

An obvious line of advance was to examine the stomachs of trout to see on what organisms they fed and which were the most important items of their diet. Then the question arose as to where these staple foods flourished best. Examinations of the streams showed that there were definite types of waters, and that the conditions present in these types produced a fairly constant amount and kind of food. The next step will be to see if it is possible by methods of planting and engineering to turn the types of poor food-yield into a higher class, just as it is possible in agriculture to improve the soil and consequently the yield of a plot of land.

Another point becomes more and more evident, and that is the need for as wide a field as possible and an equally wide measure of co-operation. Among the numerous localities visited, a number of widely differing views were found to be held on some fresh-water problems, and these differences were often due to observations having been confined to too narrow a field. An impartial survey of all the facts revealed the matter in its true aspects.

The compilation of as much data as possible from as wide an area as is practicable, and the co-ordination of research along definite well-thought-out lines, are essential to the successful and energetic prosecution of this work.

A REPORT ON THE FOOD OF TROUT

IN THE WELLINGTON PROVINCE.

PART 1.—FRESH WATERS OF THE PROVINCE.

In last year's report (16)* it was pointed out that owing to the hilly nature of the country the waters of the Wellington Province were largely of the fast-flowing type, and a stream—the Waikanae (figs. 8 and 9)—was described in some detail, together with its flora and fauna.

It is not proposed in this report to describe other waters in the province, although it may be mentioned that a list of streams and rivers has been made, with a few notes on each, and the dates when they were examined, but rather to show the bearing which the characters of our waters have on the problems of providing food and shelter for trout and on the limitations which they impose.

In rapid waters the presence or absence of vegetation on the river-banks and on the slopes of the catchment area is the prime factor in determining the quantity of fish-food in a stream.

Take, for example, the Whakatiki, a tributary of the Hutt River. This stream flows through a bush-lined gorge for a great part of its course. The sides of the gorge are very precipitous and are perhaps 200 ft. or 300 ft. deep in places, yet so thick is the vegetation that to descend from the top of the gorge to the bottom, instead of having to lower oneself cautiously downwards, it is necessary to fight one's way slowly down through the bush. Thus matter dislodged by erosion or any other cause is held in a tangled mat before it can roll far, and little is precipitated into the stream itself. Rain falling is held sponge-like by the humus and the undergrowth, and most of it trickles or seeps slowly down to the Whakatiki, instead of running rapidly down the surface in a series of streamlets as is the case in cleared country.

Examination of the stream itself showed an abundance of food of many kinds, mostly insect larvæ—caddis, May-flies, stone-flies, and various Diptera. Similar examinations of streams in hilly country where the banks had been cleared showed a tremendous contrast, for in these cases there was a remarkable paucity of fish-food. The food aspect will be dealt with under a later heading.

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* To the Research Sub-committee of the Wellington Acclimatization Society.

The removal of riverside bush has the following effects :—

(*a*) Lack of cover for the flying stages of aquatic insects, and their consequent easy destruction by birds and other predators :

(*b*) Lack of food and cover for the river-bank insects, which in well-bushed areas form a considerable item in trout-diet :

(*c*) Scouring of algae and water-plants from the stream—*i.e.*, the food and shelter of trout-food :

(*d*) Increase in rate of current and diminution of plankton :

(*e*) Rapid sweeping of water containing deleterious matter into the stream instead of its gradual percolation, probably much filtered :

(*f*) Easier access to fishermen, and therefore more rapid depletion of stock :

(*g*) Mechanical destructive action through flooding on the stream-inhabitants by stones and boulders :

(*h*) Destruction of food organisms through desiccation because of too rapid lowering of the water-level :

(*i*) Lack of cover and shade for the fish themselves :

(*j*) Shifting of the river-bed.

The disastrous effects of removing vegetation from the catchment areas cannot be overestimated not only from the point of view of fish conservation, but from every other. Where such removal has been effected in other countries it has caused considerable damage, and the areas have had to be replanted, a costly and difficult business. In enlightened communities nowadays timber is only removed from such areas under a system of silviculture known as " the selection system."

Riverside bush is still being cleared—*e.g.*, in the north Wairarapa. The acclimatization societies should make strong and immediate representations to the authorities concerned to stop this ruinous policy, and to replant wherever and whenever possible.

Geology.

As mentioned in a previous report (16), the geological formation of the province is largely greywacke and argillite (Triassic). In the north-east corner there is a small limestone area, of which the Makuri may be cited as a river type. This water is reported to give excellent fishing, and was found by the writer to contain a few types of food not noted by him in the streams of the main greywacke area.

The rivers of the extreme north of the province rise in the volcanic area of the National Park. It is reported that such waters are unsuited to trout and other aquatic life, and that one in particular, the Wangaehu, cannot be stocked with trout for this reason. This district has not been investigated as yet, and the writer is not in possession of any evidence for or against.

Analyses.

No analyses have been made other than those mentioned in an earlier report (16)—*i.e.*, of the Waikanae, Ohariu, and Manawatu Rivers, and the Masterton Hatchery springs. In the swift waters of this province the oxygen content is always ample, and contamination is not a serious factor, for its dispersal is rapid.

Temperatures.

This is a factor which should have both a direct and an indirect effect on trout. In the former case it may be either above or below the limits within which trout-life is possible. Such temperatures as have been taken at various times tend to show that the waters of this province do not exceed these limits in either direction.

The highest temperature noted was 77° F. (River Ohariu, 2 p.m., 19th January, 1928). Several trout were noticed here on this date and did not appear to be inconvenienced by this temperature. In a paper by Embody (3) it is mentioned that both brown and rainbow trout can stand a temperature of 81·5° F., and after a number of experiments he found the limiting temperatures to be 83° F. for brown and 85° F. for rainbow. In August, September, and October temperatures as low as 46° and 47° F. have been taken on the Waikanae and tributaries of the Hutt River. These are well above the low limit of temperature for trout-life.

The indirect effects influence the fish through the variation in number and kind of food organisms present in the water at different temperatures—in effect, at different seasons.

Here, too, the climate of this province is so equable that seasonal differences are not very great. The chief foods—caddis larvae, *Potamopyrgus*, and May-fly larvæ—may be found in abundance throughout the year, differing, it is true, in size at different seasons, but always plentiful. The life-cycles seem to overlap to some extent, for often very small specimens and full-grown specimens of the same larvae—*e.g.*, *Olinga feredayi*—may be found together. Throughout the year, too, the flying stages of caddis, May-flies, and Diptera are to be found, though, as might be expected, they are far more abundant from December to March than in the winter months. These play a significant part in bringing the fish into good condition for the spawning period.

The general opinion is that the fish do not feed during this latter period, or do so only to a very limited extent, and it is, perhaps, fortunate that it coincides with a time of food minimum. Hope (6) has found that trout feed very little or not at all during the winter months. After spawning, however, the fish, thin and exhausted, require a diet which will restore them to condition as soon as possible. It is, maybe, the weak point in our seasonal chain, for at this time — early spring — the majority of food organisms are in their smallest stages. This, surely, is a strong argument for the restriction of whitebait-netting, for it is at this very season that the whitebait and elvers, if allowed to do so, move up stream and river in their thousands and supply an abundance of sizeable food when it is most needed.

Summary.

The hilly nature of the province gives rise to a type of stream which is dependent on riverine and catchment-area vegetation for both its stability and productivity. Non-recognition of this has led to deplorable results.

The equable climatic conditions make for a minimum of seasonal changes in the aquatic fauna.

PART 2.—FOOD OF TROUT.

Caddis-flies (Trichoptera).

Caddis larvae form the predominating item of trout-food in the Wellington Province, and probably in swift-flowing streams and rivers throughout New Zealand. About 80 per cent. by number of the stomach-contents examined was made up of these insects, and though this is probably unduly high, owing to the persistence of such indigestible matter as the caddis - cases compared with the more easily digestible organisms, there is no doubt that they constitute the principal food.

The number of species of Trichoptera in this country is considerable. The two species which predominate both in the streams and in the contents of trout-stomachs are *Olinga feredayi* (fig. 14, *b*) and *Pycnocentria evecta* (fig. 14, *a*). Both of these inhabit elongated cylindrical cases. Unidentified caddis with similar cases of fine sand and rock-fragments are also abundant in the rapid streams of this province, and it seems evident that there is some connection between the shape and material of the species and the strength of the current.

In pools and slow-flowing weedy streams, the caddis found have cases of a different nature, as instanced by *Pseudonema obsoleta* (fig. 13), which lives in hollowed twigs and sometimes in fragments of vegetable matter—though this may possibly be another species of a similar appearance—and *Oxyethira albiceps*, which lives in a flask-shaped horny case and inhabits submerged algae.

Another important, though extremely small, caddis is *Helicopsyche zealandica* (fig. 12). The case of this caddis is composed of fine sand-grains, and looks exactly like a small spiral shell. It is found, often in colonies, on stones in both fast- and slow-flowing waters. A considerable number of specimens have been found in trout-stomachs.

The only other caddis which occurs commonly in stomach-contents is *Hydropsyche colonica*. This insect lives in swift waters, and is generally found caseless—always so in stomachs.

Some caddis-fly larvae are herbivorous; others are carnivorous. The pupae are sometimes taken by trout, the imagines (or flying stage) rarely.

The work done on Trichoptera in Europe and America is very considerable. In this country practically nothing is known about the larvae, though Tillyard and others have described a number of adults; and, as these larvae constitute such an overwhelming percentage of trout-diet, they would well repay study, and more especially their life-history in connection with their environment.

May-flies (Ephemeroptera).

This important group of insects provided about 10 per cent. by number of the stomach-contents examined. In swift waters they form a very large proportion of the aquatic fauna; in slow streams and lakes they are not nearly so abundant.

Apart from their numerical value, their significance to fishermen lies in the fact that in the winged stages they induce the fish to rise to the fly, and in some waters fly fishing will be only moderately successful unless there is a "hatch" of ephemerids taking place, and in any water the chances of taking with the fly (more especially with the dry fly) are enormously increased when a "hatch" is taking place. Moreover, observers in other countries have paid tribute to the wonderful condition of fish which have been feeding on the winged stages of these insects. Why this is so is not clear, though experiments on this point have been and are being made. The writer suggests that it may be because the fly (at least, the female) is practically little else but an egg-sac — food in its most concentrated form. Captain Hayes, of the Marine Department, states that trout will take the female, but often reject the male fly.

A considerable amount of work has been done on this group, the results of which, it is hoped, will appear in appropriate technical journals.

The morphological adaptations of May-fly nymphs are extremely interesting, and show very clearly how they have been modified to exist under different conditions. The primary determining condition seems to be the strength of the current; the main modifications are the shape of body, the gills, and the legs. Local specimens show extraordinary and perhaps unique adaptations in this respect. Such points may appear academic, but they have in reality a very practical importance, determining the presence or absence of such-and-such a fish-food in a certain type of stream, and for this reason alone they would repay study.

In very swift waters the predominating May-fly is *Coloburiscus humeralis*. In the type of stream characterized by a chain of slow-flowing water containing algal-covered boulders and connected by small rapids *Ameletus ornatus* is generally a common species in the pools. Submerged sand or silt will often contain the burrows of *Ichthybotus hudsoni*, a species very local in its distribution. On the under-surfaces of stones and in among the gravel are a number of species of the family Leptophlebiidae, and in pools the bottoms of which are covered with mud, debris, and decaying vegetation exists mainly the species *Atalophlebia versicolor*.

The great majority of our May-flies are small insects, and the few large species are never found in the vast numbers which often appear in and on English and American waters. The introduction of a few such species from these countries, provided they were herbivorous and introduced under suitable control, so that they were free of parasites, is, in the opinion of the writer, a desirable measure. Tillyard (20) recommended the introduction of the English "green drake" (*Ephemera danica*).

Stone-flies (Plecoptera).

The nymphs of these insects live among the stones and boulders in swift streams. The adults are sluggish, and are seldom seen in flight. The one most generally found in stomachs is *Stenoperla prasina* (fig. 10), the large green stone-fly, which Tillyard (20) considers one of the best of trout-foods. On the other hand, the nymph of this fly is predaceous, feeding on May-fly nymphs and other small insects. Most of the other species are small insects. Stone-flies are found more often in the swift boulder-strewn tributaries than in the main rivers themselves. They are now rather local in distribution, giving some colour to the belief that they have been largely eaten out by the trout in places. Muttkowski (21) found that stone-flies were the most conspicuous trout-food item (90 per cent.) in Yellowstone streams; next come May-flies, and thirdly, caddis. This was in rapid mountain streams.

The "black creeper" (*Archicauliodes dubitatus*), the sole representative, as far as is known, of the order Megaloptera in this country, though not a stone-fly, may be considered with the stone-flies. It is abundant in parts, and comparatively scarce in others, where, according to report, it used to be very numerous. This larva is an excellent trout-food, and is often found in stomachs, but it, too, is predaceous, feeding on other larvae. It is found under stones in rapid portions of the stream, but when about to pupate it goes to the edge of the bank and metamorphoses under a large stone or boulder.

Tillyard has described a number of adult stone-flies, but practically no work has been done on the nymphs of this order. We do not even know whether their role as trout-food is or is not counterbalanced by that of competitor for other trout-food : this matter is worth investigation.

Beetles (Coleoptera).

The beetles found in streams may be classed under three headings—(*a*) Completely aquatic in all stages ; (*b*) with aquatic larvae, the adults generally living on the water's edge ; (*c*) land-beetles which live on the vegetation near streams and which may fall into the water.

Class (*a*) : Aquatic beetles are probably of more harm than benefit to trout. Many of them are extremely voracious both in the larval and adult stages and have been known to attack young fry in other countries, and they take a heavy toll of caddis and May-fly larvae and other trout-food. Fortunately, they occur mostly in lakes and the slower parts of streams, though our largest dytiscid (*Colymbetes rufimanus*) has been found in the Whakatiki, and a smaller and common one (*Rhantus pulverosus*) has been collected by the writer in many streams—*e.g.*, the Waipoua, the Ruamahanga, and some of the tributaries of the Hutt.

Berosus mergus, a hydroptilid was collected in December in the Waipoua, the Ruamahanga, and the Mangaterere, and in January in a lake near Marton. This beetle occurs in very large quantities ; unfortunately it was not possible to secure a trout-stomach from these localities at the time, though an effort was made to do so. Another beetle (*Antiporus strigulosus*) was taken at the same time in the Ruamahanga. This is not so common as the last species.

Of class (*b*) there is one species in particular, one of the Parnidae, whose larva is very common and which is often taken by trout. A number of adult *Parnidae*, probably the same species, were found from time to time last year in trout-stomachs. It is a small black beetle, very common among pebbles on the banks of streams. This beetle is believed to be *Hydora picea*.

Class (*c*) : Strangely enough, this class appears to be of some value, but for a short season only in early summer and midsummer, and this is due solely to two beetles, *Pyronota festiva* (the green chafer or manuka-beetle) and *Odontria zealandica* (the brown chafer), which drop from the riverside vegetation in considerable numbers and are eaten by the trout.

The evidence, so far, is that beetles as a whole are not a very important factor in trout-food.

Diptera.

The order Diptera includes a number of families which contain species with aquatic larvae, the most important of which are the mosquitoes (Culicidae), the crane-flies (Tipulidae), the so-called " sand-flies " (Simuliidae), and the gnats (Chironimidae).

Individual species of other families occur in some quantity ; for instance, the writer has found on many of the streams numbers of an adult of an unnamed fly of the family Dolichopodidae, and there are a number of Anthomyids, which prey on May-flies. In fact, there are few dipterous families unrepresented in some form or other either in or around the streams; but it is the four families mentioned above which are most usually taken in trout-stomachs.

There can be no doubt that the proportion of Diptera eaten is underestimated : they are small, delicate, easily-digested organisms, and probably only a small percentage of those present are recognized. Diptera form a much larger proportion of the insect food present in lakes and slow waters than in rapid ones.

Chironomids are by far the most important family of this order in our rivers, as elsewhere. Johannson (8), writing of the genus *Chiromonus*, quotes Garnon as saying, " Probably no other one genus of insect constitutes as important an item in the food of as large a number of fishes " ; and Needham (13) found that brook-trout live almost entirely on blood-worms (Chironomid larvae) at certain seasons at least. Kendall and Dence (9) found that chironomids were the main item of trout-diet in Allegany State Park.

An examination of six fingerling trout by the writer in December and January showed the food to be over 80 per cent. culicid and chironomid or allied larvae. In seven bullies from the Belmont Stream (22nd January) 142 chironomid larvae were found, and they were also present in eels caught in a ditch connected with the Waiwetu. These larvae live in sand and mud, and feed on fragments of decaying vegetation.

Mosquito larvae are only found in slow-flowing or still waters, but the sand-fly is an inhabitant of swift waters. It hangs on to stones by means of a silk-like secretion and posteriorly - placed hooks, straining the water for plankton by means of a pair of fans placed on either side of the mouth.

Diptera can be summed up as a small but useful food-producing order. It needs no encouragement or protection, for most species are very prolific, and there are plenty of species in this order which can exist under each of the various conditions extant in our waters.

Dragon-flies (Odonata).

The nymphs of this order are met with in ponds, lakes, and sluggish waters. They are plentiful in the backwaters of our rivers. Two small species, *Austrolestes colensonis* and *Xanthocnemis zealandicum*, are common in backwaters of the Hutt, the Waikanae, and, in fact, most of the sluggish and stagnant waters of the province, and a vast number of nymphs of a large dragon-fly was found in the backwaters of the Tukituki. No nymphs or adults were found in the stomachs examined, except in one taken from a pond close to the Hutt River, near Trentham.

Parrott (15) states that dragon-fly adults are eaten in North Canterbury during February and March. Tillyard (20), in November, 1919, found the larvae of five species in the Taupo-Rotorua region,and states that in certain parts of New Zealand he found dragon-fly larvae to be the principal food of trout. However, he does not say which parts.

In the waters of our province their importance as a trout-food is slight. In lakes, ponds, and slow waters they form quite an appreciable item of trout-food ; on the other hand, in both the nymphal and imaginal stages they are voracious consumers of insect-life, competing with the trout. As adults, however, they are probably beneficial to the fishermen, destroying enormous numbers of mosquitos, midges, and sand-flies.

Hempitera.

Few insects of this order are aquatic, and the only one of any importance as a trout-food is the water-boatman, *Arctocorisa arguta* (family Corixidae).

These insects abound in slow running water, lakes, and the margins of streams and rivers. They occur in parts of the Hutt, the Manawatu, the Ruamahanga, the Maingatainoka, the Waipoua, &c. Perhaps the greatest number seen was in the lower Selwyn in March, 1929, when countless hordes were noticed among the water-weed, and a fish of about 3 lb. was found to contain three or four hundred in its stomach, and nothing else. Parrott (15) found they were eaten by bullies of over 6 cm., as well as by trout, in the North Canterbury district.

Backwaters of rivers are also a favourite resort for this insect. The insects are predaceous, and, according to Furneaux (4), attack other insects by plunging their beak-like proboscis into them and sucking their juices.

During the summer cicadas often fall into streams and are sometimes found in trout-stomachs.

Crustacea.

Crustaceans are considered by many authorities to be the finest food for trout, particularly as they appear to give its flesh a pinkish tint and a delicious flavour. Dahl (2) considers crustacea and mollusca the best trout-food.

Our most important crustacean is the koura, or native fresh-water crayfish. This animal has been reported as almost "eaten out" by the trout in many districts. However this may be, there can be no doubt that it is plentiful in many of our streams, especially the smaller ones and in the higher reaches. It is generally found either among vegetation or beneath a boulder. In such streams as the one at Khandallah it is very common, and the Papawai (Greytown), the Katerawa (Manawatu), and the Makuri may be mentioned as waters where crayfish abound.

No crayfish have been found in the stomachs examined ; nevertheless numerous reports from different quarters show that it is a trout-food, and, indeed, an important one. On the other hand, a fisherman from Pahiatua saw a large crayfish attack and kill a passing trout.

The only other crustacean of prime importance is the fresh-water prawn (*Xiphocaris curvirostris*). This organism lives on aquatic plants which grow in slow-flowing waters, and it is therefore not abundant in our streams, though it has been found in several—*e.g.*, the Waikanae and the Manawatu ; nevertheless, if cover were provided, it could be cultivated in our pools, backwaters, and the more sluggish rivers. It is a most valuable food and of a good size, the female when full-grown being about 2 in. long. It is not harmful to other food organisms, as it lives on vegetation and decaying matter. The slow-flowing Canterbury streams, such as the Cam and the Styx, are full of prawns, and in consequence the trout there are twice the size of ours, and have beautiful, delicately flavoured, pink flesh.

There is a host of small crustaceans, most of them confined to slow-moving waters, and the greater number microscopic. They are important mainly as the food of fry and of the creatures on which larger trout feed.

They are found chiefly among aquatic vegetation. The commonest and most important is the gammarid *Paracalliope fluviatilis*, which is very minute. But there is a larger species, found occasionally among watercress; it is about $\frac{1}{2}$ in. long, and might be worth cultivation. This crustacean has been collected in the upper reaches of the stream at Khandallah, in the Makuri, in the stream flowing through the park at Masterton, and in the Tukituki; it was also noted in a Canterbury stream.

Mollusca.

Molluscs seldom inhabit fast-flowing streams, consequently they are poorly represented in the waters of the Wellington Province. The only one of any importance as a trout-food here is the small gastropod *Potamopyrgus*. Both *P. antipodum zealandiae* (fig. 12*a*), and *P. corolla Salleana* (fig. 12*b*), appear in enormous quantities, particularly the former. They prefer the slow parts of streams, but are by no means confined to them, and they may be found on pebbles and boulders and among algae and vegetation of all kinds; they also occur buried among sand and silt.

These organisms form over 10 per cent. of the stomach-contents examined, and in some cases almost the whole of the contents. Often the bed of the stream may be seen covered with these molluscs for several yards. The shell of these water-snails is less than $\frac{1}{4}$ in. long, and consequently a large number of them must be required to provide a square meal for a good-sized trout, and it is unfortunate that we have no larger snails.

In some of the South Island rivers an English snail of the genus *Limnoea* has been liberated. This species is three or four times as large as *Potamopyrgus*, but its habitat is slow waters, and consequently its use in our streams would be very limited. However, a few were sent to Masterton last year, so that they might multiply in one of the races at the hatchery. Unfortunately, they were attacked and eaten by crayfish. Mottram (10) states that crayfish eat snails, and that crayfish and shrimps feed on snails' food; he is nevertheless a great believer in the chalk-stream as opposed to the mud-stream inhabiting varieties of snails. Dahl (2), too, has pointed out the value of mollusca as trout-food.

A bivalve, *Corneocyclas*, is reported by Parrott (3) to be present in the Canterbury waters, but this also would not flourish in swift streams.

A snail of nearly twice the size of *Potamopyrgus* was found by the writer in considerable quantities in the Tukituki and in lesser quantities in the Makuri. Both these rivers flow through limestone country, and whether this species would flourish in a non-limestone stream is open to doubt, but might be worth investigating. Another gastropod found in both these rivers was a species of *Planorbis*. This mollusc, unfortunately, is even smaller than *Potamopyrgus antipodum zealandiae*.

A small fresh-water limpet about $\frac{1}{3}$ in. long, *Latia neritoides*, belonging to the family Ancylidae, is sometimes found on the under-surface of stones in some streams—*e.g.*, the Makara. It has not been found by the writer in any trout-stomachs, but was identified by W. J. Phillipps (17) in two stomachs examined in 1925.

This writer also mentions the kakahi, or fresh-water mussell, as not uncommon in several of the rivers round Masterton, and a small yellowish bivalve, *Sphaerium novae-zealandiae*, as occurring in the Kaiwarra Stream, but no reports have been received of either of these having been found in trout taken in the Wellington Province.

Fish.

Of the fresh-water fish, only three are of any real importance to trout in this province: they are the bully, the eel, and the inanga (including, of course, its juvenile form of whitebait).

Smelt (*Retropinna retropinna*) are eaten fairly extensively by the trout in many parts of the South Island. Phillipps (17) states that it was formerly very common in the Hutt River. It does not appear to be so now.

The bully (*Gobiomorphus gobioides*) is advocated by many as the solution of the problem of supplying food of suitable size for large trout. There can be no doubt that the trout in Lake Taupo, Lake Ellesmere, the lower Selwyn, and other districts grow to a very much larger size than ours do, and an examination of their stomachs will show a large proportion of bully. Trout from Taupo, the River Selwyn, and Otago have been examined by the writer and found to be full of bully, and Parrott (15) gives tables of the proportion of bully eaten by trout in North Canterbury. More bully have been introduced lately into Lake Taupo to avert any possible shortage of trout-food.

It has been stated that this fish used to swarm in our waters and that now there are few left. This is by no means the case: in almost any of our streams, particularly in the less rapid portions, bully may be found in considerable numbers, generally on the bottom and rather difficult to see. Nevertheless, in over a hundred trout-stomachs examined from our waters only a single bully was found. Moreover, as is shown in another place, the bully is a competitor with the trout for its food. In large sluggish waters, and particularly near the entrance to lakes, where bullies often migrate at certain times in shoals, they are no doubt an easy prey to the trout, but in our narrower, faster waters, where there is an abundance of shelter in the nooks and crannies of the stream-bed for such a bottom-living fish as the bully, its capture by the trout is by no means so easy. It is doubtful whether the amount eaten compensates for the loss of other foodstuffs which they take. Bullies have been reported as sometimes attacking young fry, just after being put out.

Whitebait (*Galaxias attenuatus*), as has been shown in an earlier part of this report, arrive in large quantities at a time when trout can best utilize them and when there is a minimum of other nourishing foods. They do not skulk about the bottom, and are therefore much easier for trout to catch. Hamilton (5), writing over twenty-five years ago, considered that the great size of New Zealand trout was due mainly to feeding on whitebait. Hope (6) states that whitebait formed the staple food of *Salmo fario* in the South Island for the greater part of the year when the trout were first introduced, and that "with the decline of the inanga there has been a corresponding decline of the trout; the latter have deserted the up-stream waters and are now only found near the mouth of our large rivers." It must be admitted that in the Wellington Province, too, the largest fish are found either at the mouths of rivers or in the well-bushed country in the less-settled parts—where such still exists. Also, the inanga is not found very far up our rivers, where formerly it was reported as common.

How far the inanga competes with the trout for its food-supply has not been investigated as yet, but Phillipps (19) reports that he found *Potamopyrgus* in the stomach of a female, and (18) copepods and other crustacea in the stomach-contents of adult museum specimens of inanga.

The landlocked variety of inanga, *Galaxius brevipinnis*, sometimes called the gudgeon, so common at Taupo, was found in a lake near Marton, and is eaten by the rainbow trout which inhabit the lake.

Eels are exceedingly numerous in all our streams. Their role as competitors and predators will be discussed in other parts of this report. They prefer the slow and still waters, but are by no means confined to them. They reach enormous sizes. The stomach of a 35 lb. eel was forwarded to the writer from Pahiatua this summer, and there have been several reports of eels caught of even greater size. In the early spring, when the elvers ascend the rivers, they serve as trout-food, and reports have been received of trout having been caught containing young eels. These fish are very tenacious of life, and tolerate almost any environment. They live in places difficult of access. As a last resource they can move overland. They either fast for considerable periods or they can live on minute organisms, for it is by no means uncommon to find an eel with an empty stomach. All these factors assist the eel to thrive under conditions which would kill the trout, and if it is found necessary to eradicate this fish it will be by no means an easy task.

A Habitat-analysis of Fish-food in Different Stream Types.

As investigations proceeded it soon became evident, as mentioned in an earlier part of this report, that a certain type of stream-bed and a certain strength of current could be correlated with definite species, and also roughly with a certain quantity of fish-food. In order to get some idea of these relations, sample areas of 1 square foot were marked off with skewers at a uniform distance (3 ft.) from the bank. A net was placed just below the skewers to catch the organisms. The bottom of the plot was vigorously disturbed so that the force of the current carried the contents into the net. Any stones and boulders within the area were washed and brushed free of their inhabitants into the net. Four areas of each kind were taken, and the contents placed in a large bottle and examined later in the laboratory. The results were divided by four to give an average value for each type examined. The areas were as follows :—

No. 1—River Hutt, 200 yards above its junction with the Belmont Stream : Pebble and boulder bottom ; banks bare ; temperature, 15½° C. ; current, approximately 1 to 3 m.p.h. (Fig. 1).

No. 2—A connecting ditch between the Belmont Stream and the Hutt ; 100 yards from area 1 : Muddy bottom ; under willows ; temperature, 14° C. ; very slow current.

No. 3—Belmont Stream, about 200 yards from mouth : Temperature, 15° C. ; nearly stagnant ; boulder and pebble bottom, covered with algae ; willows on one bank. (Fig. 3.)

No. 4—Belmont Stream, about one mile from mouth : Temperature, 12½° C. ; pool ; current not greater than 1 m.p.h. ; gravel and boulder bottom ; heavily bushed banks. (Fig. 4.)

No. 5—Belmont Stream, same situation as No. 4, but rapid current : Temperature, 12½° C. (Fig. 5.)

Photographs of these sample areas, except No. 2, are shown. Area No. 2 was rather like fig. 2, which is of a backwater of the Mangatainoka, near Pahiatua.

Quantitative Analysis of Stream Types.

April, 1929.

Sample Area 1.

Pupae of *Hydropsyche*	3
Larva of *Olinga feredayi*	1
Larvae of *Deleatidium*	5
Larvae of unknown caddis	6
Larva of *Atalophlebia*	1
Larvae of Diptera	2

Sample Area 2.

Potamopyrgus	138
Larvae of Diptera	12
Larvae of *Olinga feredayi*	31
Larvae of unknown caddis	15
Larvae of other species	19
Larva of Sialid	1
Larva of *Ichthybotus*	1
Larva of *Pseudonema obsoleta*	1
Earthworm	1
Aquatic oligochaetes	11

Sample Area 3.

Larvae of *Olinga feredayi*	14
Larvae of *Pycnocentria*	2
Larvae of unknown caddis	11
Larvae of Diptera	3
Oligochaetes	8
Potamopyrgus	11
Hydracarinae	*circ.* 300

Sample Area 4.

Larvae of *Coloburiscus*	14
Larva of *Ichthybotus*	1
Larvae of *Deleatidium*	45
Larvae of *Olinga feredayi*	5
Larvae of *Hydropsyche*	7
Pupa of *Hydropsyche*	2
Larvae of unknown caddis	13
Larvae of *Helicopsyche*	6
Larvae of *Pycnocentria*	3
Oligochaetes	2
Archicauliodes dubitatus	1

Sample Area 5.

Larvae of *Archicauliodes dubitatus*	15
Larvae of *Hydropsyche*	27
Larvae of *Pycnocentria*	25
Larvae of *Olinga feredayi*	57
Larvae of unknown caddis	17
Larvae of *Coloburiscus humeralis*	43
Larvae of *Atalophlebia cruentata*	2
Larvae of *Deleatidium*	71
Larvae of *Myzobranchia*	9
Larva of *Ichthybotus hudsoni*	1
Pupae of caddis	15
Larvae of *Stenoperla prasina*	17
Larvae of unknown stone-flies	23

Quantitative Analysis of Stream Types—*continued.*

Organism.	Area 1.	Area 2.	Area 3.	Area 4.	Area 5.
Caddis—					
Olinga feredayi	1	31	14	5	57
Pycnocentria	0	0	2	3	25
Hydropsyche	3	0	0	9	27
Pseudonema	0	2	0	0	0
Other caddis	9	34	11	19	32
May-flies—					
Deleatidium	5	0	0	45	71
Atalophlebia	1	0	0	0	2
Myzobranchia	0	0	0	0	9
Coloburiscus	0	0	0	14	43
Ichthybotus	0	1	0	1	0
Stone-flies—					
Stenoperla	0	0	0	0	17
Others	0	0	0	0	23
Diptera	2	12	3	0	0
"Creeper"	0	0	0	1	15
Worms	0	12	8	2	0
Potamopyrgus	0	138	11	0	0
Fish	0	0	2	0	0
Other organisms	0	1	*circ.* 300	0	0

These results are considered by the writer to be highly significant, for not only do they show the ecology of the different kinds of trout-food, but they also demonstrate unmistakably that where the vegetation has been cleared the food vanishes in all except the slowest streams. Compare sample area 1 with areas 4 and 5, and this becomes evident. However, where the current is slow (samples 2 and 3), the absence of bank-vegetation does not matter so much, for algae and water-weed will establish themselves in the stream. A comparison of sample areas 4 and 5 show that where the stream is well bushed a rapid portion is as well supplied with food organisms as is a still one. These fundamental facts have been found by the writer to apply throughout the province and in other parts of the country.

In North Canterbury the rivers were poorly provided with riparian vegetation, but those seen were mainly slow-flowing, and therefore full of aquatic vegetation and well provided with food organisms. (Fig. 7.) In such country deforestation would have little effect on the waters and their inhabitants, but in our hilly province its importance is vital.

A visit to Hawke's Bay brought out another important point. Here the waters are more rapid than those of North Canterbury, but not so swift as the Wellington ones. The rivers are not well bushed, and yet the Tukituki, for instance, is noted for its fine fishing, though this year it has been somewhat disappointing. An examination of this river and its neighbouring ones showed, on the whole, a poor yield of fish-food in the river-bed itself. What, then, was the reason that many good fish could be found there? The answer is—backwaters. Although the beds of the main rivers are comparatively barren, there are a large number of backwaters which teem with organisms, some of them of considerable size—in fact, the backwaters of the Tukituki are richer in food organisms than any other fresh-water area visited by the writer. These pass from time to time into the main river in increased amounts with each freshet, and it must be these which support the trout-life in the main rivers.

There are backwaters on the Hutt, but they do not compare in size or depth with those of the Tukituki, nor have they the wealth of aquatic vegetation found in those of the latter. There are probably areas where it would be possible to establish such vegetation and improve the backwaters generally at comparatively low cost, for, short of an ambitious and extensive programme of afforestation and engineering, it is the only way we can improve the food-carrying capacities of our denuded rivers.

The sample-area method is a valuable test of the productivity of different types of stream. Improved methods of this kind will be employed next year; meanwhile the results, though, of course, only approximations, are of value, as the whole idea was to make a comparative test of the different types, and not of their actual yields. Probably the results obtained in the rapid areas were placed rather high compared with the slow areas, for in the former case all organisms were swept into the net; in the latter case many, no doubt, escaped.

A point which will be studied later is the relative quantities of fish-food provided in those parts of the river where different species of aquatic vegetation exist. This would show us which species are the best to plant and encourage. Experiments of this kind have been made in America (17), which show the superiority of stonewort and watercress in this respect.

Summary.

A habitat-analysis of different types of waters showed that in hilly country a good yield of fish-food is dependent on abundant riparian vegeta-

tion ; in flat country it is not so dependent. In slow waters the size of fish-food organisms is greatest where there is abundant aquatic vegetation. Where the main river is poor in fish-food yield, the deficiency may be supplied by backwaters.

Methods of habitat-analysis may and should be applied to attack many of the preliminary problems whose solution must precede the formation of a comprehensive policy for fresh-water conservation.

STOMACH-CONTENTS.

An examination of the stomach-contents of trout this year confirms the results of last year, and shows that the diet of this fish is identical with that of thirty years ago. Such minor differences as exist are unimportant, and would probably disappear had ten times as many stomachs been examined in each case. It is evident that 90 per cent. (by number) of the food of trout in this province consists of insects, and 10 per cent. of a small mollusc or water-snail. Of the insect food, the main item is caddis larvae, and two species furnish an overwhelming proportion of the Trichoptera consumed. The rest of this proportion of insects consists very largely of May-flies, whose importance as a food, as explained earlier, is of greater value than its numbers would suggest. The remainder of the food appears to be of little importance, but it must be borne in mind that the figures represent numbers of organisms, and *not* volume. Thus the 1 per cent. " creeper " cannot fairly be compared with 77 per cent. caddis, as a " creeper " is a much larger organism. Again, the 1¼ per cent. Diptera, as pointed out later, is a questionable figure, as it comprises a number of minute, delicate, and easily-digested organisms, a great proportion of which were probably not recognizable. Other stomachs, not included in the statistics, examined in the north of the province showed similar results.

An examination of six small trout, ranging from 3 in. to 5 in., and caught in the tributaries of the Hutt River in December and January, contained mostly chironomid and culicid larvae and pupae, and a small number of May-fly and caddis larvae. It would seem that very small trout feed on similar items of diet to large ones, but in different proportions, the Diptera predominating.

Very different, however, are the results obtained in other parts of New Zealand. Stomachs from Taupo were found to contain bully and gudgeon. The trout average four times the size of ours.

A number of stomachs were received from the South Island, from North Canterbury, and also from Otago, and contained mainly bully. These fish averaged two or three times the weight of ours. To illustrate the food found, it may be mentioned that a 4½ lb. fish contained seventeen and a 5 lb. fish nineteen bullies. The majority of these fish came from the lower Selwyn, and it is curious that when a visit was paid to this locality by the writer in March a fish of about 3 lb. when opened was found to contain three or four hundred water-boatmen only. In other waters of this district the fresh-water prawn forms an abundant fish-food.

The results obtained by Parrott (15) working in this district are of great interest. He considers that the size of the fish largely determines the diet on which it feeds, a theory which does not seem to hold in this province, except in the case of fingerlings and very small fish. He also considers that the diet varies according to the time of year and the habitat. Here, again, results in the Wellington Province do not bear this out, or only to a very limited extent—*e.g.*, May-fly imagines, which occur mainly during the summer—probably because the seasons are far more equable and the waters not so varied in type. In such rivers, however, as resemble ours the results he obtained were very similar.

A brief visit to Hawke's Bay showed their conditions were similar to ours.

It is unfortunate that no really large trout were available for examination from the waters of Wellington Province, for it is most important that we should find out whether their diet is the same as that of the fish of average size or not. That large fish will feed on insects, however, is shown by the example of the trout-stomachs from Lake Coleridge given later.

Conclusions drawn.

The diet of trout in this province is almost entirely composed of insects, and mainly of two species of caddis larvae, with May-flies as the next most important component. Apart from insects, the only other important food is a small mollusc.

The diet of trout in other parts of New Zealand differs, but only when the type of streams differs also. In favourable conditions fish average from two to four times the size of those in the Wellington District, and their diet contains a greater proportion of fish and crustacea, and a smaller proportion of insects.

Summary of Trout-stomach Contents, October, 1928, to End of April, 1929, Wellington Province.

Number of stomachs	42
Identified as male	11
Identified as female	15
Average weight	1 lb. 8¾ oz.
Average length	16 in.

Description of Contents.	Number.	Percentage.
Trichoptera (Caddis)—		
Olinga feredayi	2,319	26
Pycnocentria	4,007	45
Other caddis	521	6
	6,847	77
Ephemeroptera (May-flies)	832	9
Plecoptera (stone-flies)	27	
Sialoidea ("creeper")	69	1
Diptera (gnats, sand-flies, mosquitos, &c.)	111	1¼
Coleoptera (beetles)	23	
Hemiptera (water-boatmen, &c.)	11	
Hymenoptera	3	
Lepidoptera	0	
Orthoptera	2	
Arachnida (spiders)	7	
Crustacea (crayfish, prawns, shrimps)	43	½
Mollusca—Potamopyrgus (water-snails)	921	10
Oligochaetes (worms)	15	
Total	8,911	

Note.—These stomachs are from rod-caught trout. It has been observed that such fish frequently void a portion of their stomach-contents, particularly the food most recently taken. This accounts for the remarkably few ephemerid and dipterous adults found in the stomachs of fish caught during the evening rise, when they have been feeding almost exclusively on such diet. The percentage of May-flies and gnats has therefore been greatly underestimated.

Summary of Trout-stomachs.

—	1927–28.	1928–29.	Mr. G. V. Hudson (1899–1902), for comparison.
Number of stomachs	48	42	60
Identified as female	9	11	Not given.
Identified as male	14	15	Not given.
Average weight	1 lb. 9½ oz.	1 lb. 8¾ oz.	Not given.*
Average length	15½ in.	16 in.	Not given.

* Hamilton (5), writing about this time, gives the average weight of trout, taken in New Zealand as a whole, as about 2 lb., and that of estuarine ones (or those taken near the mouths of rivers) as about 5 lb.

Stomach-contents.

—	1927–28.	1928–29.	1899–1902.
Trichoptera—			
Olinga feredayi	2,775	2,319	923
Pycnocentria	3,075	4,007	2,959
Other caddis	367	521	359
	6,217	6,847	4,804
Ephemeroptera	661	832	529
Plecoptera	21	27	16
Sialoidea—*Archicauliodes diversus*	58	69	18
Diptera	65	111	42
Coleoptera	54	23	590*
Hemiptera	16	11	23
Hymenoptera	4	3	4
Lepidoptera	1	0	0
Orthoptera	0	2	3
Arachnida	1	7	4
Crustacea	4	43	1
Mollusca—*Potamopyrgus*	740	921	21
Oligochaetes	2	15	0

* Due to one special case of 500 *Hydora*.

An interesting demonstration of the great range in taste shown by trout is exemplified by a sample of nine trout-stomachs sent here for examination from Lake Coleridge. Nos. 1, 2, 3, and 5 were brown, the rest rainbow trout. No. 1 was taken at the end of November; Nos. 2 and 3 at the beginning, and Nos. 4 and 5 towards the end of December; Nos. 6, 7, and 8 the second week in January; and No. 9 on the 6th February.

No. 1 (12½ lb.).—Small fragments of digested and unrecognizable matter.

No. 2 (3 lb.).—Water-boatmen, 4; Orthoptera leg, 1.

No. 3 (3 lb.).—Water-boatmen, 237; Hymenoptera, 3; Coleoptera, 9; earwig, 1; pieces of wood, 2.

No. 4 (6½ lb.).—Carabid beetle (1½ in.), 1; worm (Nematode), (14 in.), 1; manuka-beetles, 4; water-boatmen, 6; Hymenoptera, 3; plant hopper, 1; stems of grass.

No. 5 (4 lb.).—Water-boatmen, 2; Orthoptera legs, 4.

No. 6 ($4\frac{1}{4}$ lb.).—Water-boatmen, 212; Hymenoptera, 2; aquatic beetles, 2; vegetable matter.

No. 7 ($4\frac{1}{4}$ lb.).—Water-boatmen, 25; dragon-fly larva, 1; small molluscs, 2.

No. 8 (4 lb.).—Bullies, 3; manuka-beetles, 3; bluebottle, 1.

No. 9 (4 lb.).—Caddis larvae (? *Pseudonema*), *circ. 800.*

N.B.—It is possible that fish No. 1 voided its stomach-contents when it was hooked, as may have been the case with others—*e.g.*, Nos. 2 and 5.

PART 3.—ENEMIES AND COMPETITORS OF TROUT.

Enemies of Trout.

Predators.

The important trout-predators are the shag and the eel. A spasmodic war has been waged on the shag in various districts from time to time, but little is known of their actual relations with regard to trout. In places they are plentiful, a vast number being seen by the writer at Taupo in August, 1928, and a few at various times on most of our rivers. But shags, too, have been reported to keep down eels. They have been accused of being harmful to trout in that they are the secondary host of a thread-worm which parasitizes trout. Evidence is wanting on all counts, and before systematic measures are taken against this bird we should know approximately how harmful it really is, by examining a number of stomachs and ascertaining in some detail its habits and life-history.

The eel is considered by many anglers as the most deadly enemy the trout has. When trout fry are first placed out they are very liable to attack by eels, and a curator stated that after he had put out some fry he came back an hour or two later and was just in time to see an eel disappear. He killed it and found it full of trout fry. Reports have also been received of eels being seen to attack and kill passing trout, and it is not uncommon to catch a fish whose tail or fins have been partly bitten off by eels. Examination of stomach-contents of eels sometimes show trout-remains, but more often not. It will be necessary to examine more eel-stomachs before a definite opinion can be formed as to the amount of harm the eel does to trout. On the other hand, the eel may be doing us a service in keeping down the weaker and diseased, and therefore the more easily caught, trout.

It should not be forgotten—as discussed under another heading—that they form an important trout-food when they come up-stream as elvers. However, the balance of their utility to trout is almost certainly against them. A campaign has been waged against them in this province, but, though their numbers can be lessened, they cannot be exterminated by the present methods. It would seem far more efficacious and easy to destroy them when they are most vulnerable—that is, at the annual migrations to and from the sea. If this were done for nine years systematically there would be few eels indeed in the rivers where trapping operations had been in progress. In Europe the river life of an eel is from six to eight years; in New Zealand the period is unknown. The suggestion of nine years' trapping assumes a similar period in this country. It is true that they often ascend from the mouths of rivers with whitebait and other fish, but it should not be difficult to devise some means of separating out the elvers

A question which seems important, and one which has not been investigated, is how far the ova and alevins produced by natural spawning are affected by predators. Perhaps observation in some such stream as the Waipoua (fig. 6) might offer some light on this question.

Parasites.

There is no evidence that parasites of any kind are a serious danger to trout, and, in fact, where fish are healthy and have abundance of room and food, parasites are usually unimportant. Where there is insufficient nourishment, or where the fish are crowded, they become "slabs," and parasites may be expected to become a dangerous menace. Such conditions were present some years ago in the Thermal District—Tillyard (20)—and an outbreak of *Ichthyopthirius multifiliis* among the bully and gudgeon in Taupo last year may have been due to a similar cause.

Only one of the fish examined in our district was found to contain threadworm. However, the trout were not specially examined for parasites, and it is quite likely that many trout have them and under normal conditions they do little harm.

Parrott (15) reports that many of the trout and trout-foods in North Canterbury are infested with parasitic worms. Kendall and Dence (22) found 484 nematode parasites in 113 trout examined, eighty-two of which were parasitized. There was no apparent evidence of harmful effects in the general appearance of the trout.

A May-fly of the genus *Deleatidium* from a stream near Wellington was noticed to be badly attacked by a sporozoan.

Summary.

There is insufficient evidence both for and against the shag. The eel is detrimental, but how far so we do not yet know. It could be fought by more efficient methods than those now used.

Parasites, on the whole, do not appear to be a danger at present.

Competitors of Trout.

The competitors of trout are numerous and varied, for many of the organisms on which trout feed eat each other, few being exclusively herbivorous.

Birds of many kinds feed on the imagines of aquatic insects, and on all stages of riparian ones. A few, such as the shag and the kingfisher, take their food from the water itself.

Other competitors share the waters with the trout, and of these we shall consider the eel and the bully, which seem the most important.

Eels are omnivorous. A large number of them have been caught in this province for some time past. The writer has made many and repeated attempts to get eel-catchers to send him the stomach of eels they catch, but without success, for only one stomach was received: this was from Pahiatua, where the stomach of a 35 lb. eel was found to contain three vertebrae of a trout, and nothing else. Other eels examined contained mainly dipterous larvae, but these were from ditches or slow-flowing creeks. Phillipps (17) states that they eat shrimps, crayfish, bullies, and small trout. More evidence is badly needed from all quarters as to the food of eels.

During January and February, 1929, the alimentary tracts of twenty-six bullies were examined; the results were as follows: May-flies—Larvae of *Coloburiscus humeralis*, 9; larvae of leptophlebids, 18. Diptera—Larvae of chironomids, 356; larvae of culicids, 36. Caddis larvae, 27. Flat-worms (planarians), 22.

The specimens were from the Belmont Stream and the Moonshine Creek (tributaries of the Hutt), the Hutt River itself, and the South Karori Stream. The evidence afforded by the data is slender, but even so it is very significant. Except *Coloburiscus humeralis*, the organisms live in slow-flowing water and on or in the river-bed. Chironomids, the preponderating item, are generally found buried in sand or mud in slow streams, and planarians are found clinging to the surfaces of stones. Although the fish were taken at a time when the hatching of flies was at its maximum, not one fly was found: the bully is evidently a bottom feeder.

Parrott (15) has been able to investigate the food of the bully in greater detail, and his results are of great interest. They differ from those obtained by the writer, but the difference in the type of stream in North Canterbury and in the Wellington Province must be borne in mind. He found that the diet varies according to the size of bully, and up to 4½ cm. long it fed exclusively on amphipods; larger ones fed on caddis and May-fly larvae and water-snails (presumably *Potamopyrgus*). Between 6½ cm. and 9½ cm. they consumed dragon-fly larvae, water-snails, and water-boatmen, and above 10 cm. on the fresh-water shrimp (? prawn).

The specimens taken in our district varied in size, but their diet did not appear to vary with the size of fish.

The competition of the bully does not seem to be sufficient to be a serious factor in types of stream where the food-supply is normal, but where such supply is subnormal it may well be so.

To sum up, bullies compete with the trout for bottom food. The significance of such competition requires further investigation.

PART 4.—RESULTS.

The foregoing pages form a brief survey of the factors affecting trout in this district.

We have now to consider the general conclusions which may fairly be drawn from this survey, and, finally, to make recommendations for the conservation and improvement of our fresh waters.

General Conclusions.

That, owing to various causes, the fauna of our waters has been seriously depleted in many parts of the province, and that if no steps are taken to combat it the situation will worsen progressively.

That deforestation has been the main factor in creating this deficiency, for it is most marked where the stream-banks—and also, as a further consequence, the river-beds—have been denuded of vegetation, and that this applies mainly to fast-flowing waters.

That where adequate shelter exists, the food-supply is ample to maintain a considerable number of trout of medium size, but that large trout require certain foods, which in turn require certain conditions.

That such conditions now exist mainly in lakes, near the mouths of rivers, and probably in pools in well-bushed country difficult of access.

That the diet of trout in the Wellington area does not differ appreciably from that of thirty years ago.

That aquatic insects form at least nine-tenths of the food of trout in this province, and, where bait food is taken, they form most of the food of such bait.

That diminished whitebait supplies have led to the absence of an important food factor at a time when it is most needed.

That where there is a deficiency of food in the main rivers it may be compensated by copious supplies in the backwaters.

That more information is necessary before pronouncing an opinion on the importance of the enemies and competitors of trout. The eel appears to be a harmful factor.

That there are insufficient data to formulate comprehensive recommendations, and that such data are urgently needed and could best be obtained by a well co-ordinated scheme of research pursued over as wide an area as possible.

Recommendations.

It is necessary to take immediate steps to check the depletion of our best fish-foods, and to conserve and encourage their increase wherever possible. The introduction of food organisms in places where they have been decimated must be preceded by measures which shall first ensure them adequate food and shelter; otherwise time and money will be wasted.

The strongest and most urgent representations should be made to the Government by the associated acclimatization societies to stop the unnecessary cutting-down of all vegetation on the river-banks and in the headwater catchment areas; and steps should be taken to replant areas already denuded wherever and whenever possible.

The species of trees recommended for planting will depend largely on the factors of the locality. In catchment areas they must be such as will either provide a good bed of rain-holding humus or tolerate a heavy undergrowth. Along river-banks such indigenous trees as kowhai, fuschia, lacebark, and wineberry, and the exotic alder would be suitable.

In any case, it would be possible to plant up a small stretch (say, 200 yards) of the banks of a denuded stream and compare it from time to time with an equivalent neighbouring (up-stream) unplanted portion.

Private owners should be encouraged and, perhaps, assisted to replant their riparian property.

In all places where it is practicable a scheme of aquatic engineering should be drawn up and executed as opportunity may arise, so that by dams, weirs, diversions, and other expedients the rivers may become a series of pools and rapids, instead of sprawling their capricious and changeful course over a wide and sterile pebble-strewn area. In many places, by a small expenditure of time, money, and energy, a portion of the waters of a stream could be diverted over a somewhat longer but more gently flowing course, as often occurs naturally—*e.g.*, the Tanaki Stream, near the Dannevirke–Woodville Road. Here the diversion swarms with food and brown yearlings, while the main stream is comparatively barren.

Backwaters of main rivers should be improved by deepening and extending, planting up shelter-trees to prevent them drying up, and planting *Potamogeton*, starwort, and millfoil in the water itself.

This vegetation should also be encouraged in the rivers themselves, near the banks, and in their tributary creeks. If planted in too slow waters it will choke them in course of time, but there are few waters in this province to which this would apply.

When these plants are once established, measures may be taken to introduce such special foods as are of a particularly nourishing nature; but it must be pointed out that, with the establishment of aquatic vegetation, food organisms will appear without human intervention and flourish in abundance.

The foods which are recommended for introduction into such waters are—

(*a*) *Xiphocaris curvirostris*, the fresh-water prawn, a number of which might be procured from the Cam or the Styx.

(*b*) The species of gastropod found in Hawke's Bay, if experiment shows it will flourish here.

(*c*) A number of the larger herbivorous May-flies, such as occur in swarms on rivers at Home. Species suitable to our conditions could be procured from such institutes as the Department of Ecology and Limnology, Cornell University; and Dr. Needham of this department, with whom the writer has been in communication, estimates the cost of gathering, packing, and delivering a supply of eggs to be from 25 to 50 dollars. The Bureau of Entomology in England might also be able to assist us in this way.

(*d*) Increase of whitebait, by restricting the netting of them to definite times. It is believed that action of this kind is pending.

The destruction of eels should be encouraged, and the stomachs of eels destroyed should be examined. If the results show that eels eat a large proportion of trout, more drastic steps for their extermination should be undertaken.

In order to determine which waters are the more urgent cases for treatment, methods of habitat-analysis such as those outlined should be carried out in as many streams as possible. Waters might be classified in groups, according to the number of organisms per unit area.

When pollution is suspected, a chemical analysis of the water should be made, and rangers should report all new sources of possible pollution to the secretary as soon as they are aware of them.

Attempts should be made to ascertain the general movements of trout in our rivers.

Such experiments as it is recommended should be made locally in the near future include the following items: Tests to determine what happens to trout in the first six months after they have been put out, the percentage which survive, and, if possible, the causes of death in the remainder; the grouping of some of our local waters by methods of habitat-analysis, as outlined previously; researches into the value of various types of aquatic vegetation as shelter and as food-breeding grounds.

In order to determine when and where they might best be introduced or encouraged, the life-history of important food organisms should be worked out, and the ecological conditions in different types of streams studied in some detail.

Further investigations should be made into the feeding-habits of the more important trout enemies and competitors, and their role as such ascertained with more precision.

Several of the desideranda above noted can be followed up by the writer; others he can follow up with such ready assistance and co-operation as he has always had from the society's officers. But for such of the remedial measures as may be approved action by responsible governing authorities will be necessary.

In order to concert adequate measures for conserving and improving our fresh waters in the most efficient and economical way, duplication and overlapping of work must be avoided, and a well-thought-out and co-ordinated scheme of research should be adopted for the whole of New Zealand.

To this end, it is suggested that—

(1) The acclimatization societies of New Zealand co-operate for research on their fresh-water problems.

(2) A New Zealand Research Committee be formed, which shall meet annually (or at such intervals as shall be deemed advisable) in order to review progress and make recommendations for future work: the personnel to consist of one member from each society, with co-opted technical members.

(3) Each society have a research sub-committee, which shall assist the work as far as possible and furnish the research workers with information about their districts and put forward any local problems.

(4) Research workers to be under some centralized control. The workers to specialize along certain aspects of research as far as possible, and not to be attached permanently to any one particular district.

(5) A research laboratory be established in the most suitable position.

Acknowledgments.

The writer is very greatly indebted to Professor H. B. Kirk, of Victoria University College, Wellington, and to Mr. A. E. Hefford, Chief Inspector of Fisheries, for their never-failing help and kindly criticism throughout the period of research.

Invaluable assistance was given to the writer by members and officials of the Wellington, North Canterbury, and Hawke's Bay Acclimatization Societies.

Captain L. Hayes, of the Marine Department, has given valuable help to the writer in many ways.

For the photos illustrated as Figs. 10 to 14 (inclusive) he is indebted to Mr. Harvey Drake.

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Fig. 1.—The Hutt River, near Belmont.

Fig. 2.—A backwater of the Mangatainoka, near Pahiatua.

Fig. 3.—Belmont Stream, near confluence with Hutt River.

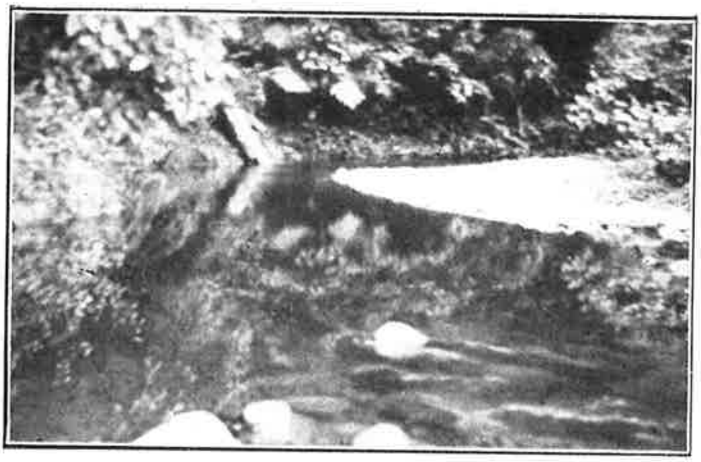

Fig. 4.—Belmont Stream, about one mile above mouth. Pool.

Fig. 5.—Belmont Stream, about one mile above mouth. Rapids.

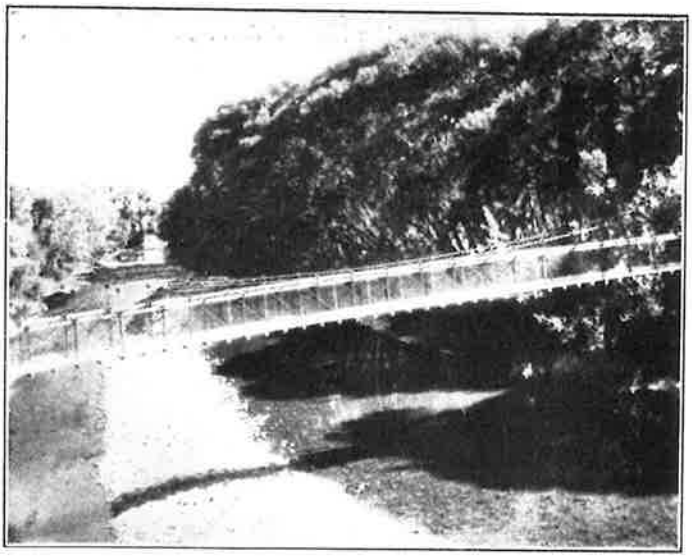

Fig. 6.—Waipoua River, near Masterton.

FIG. 7.—River Styx, North Canterbury.

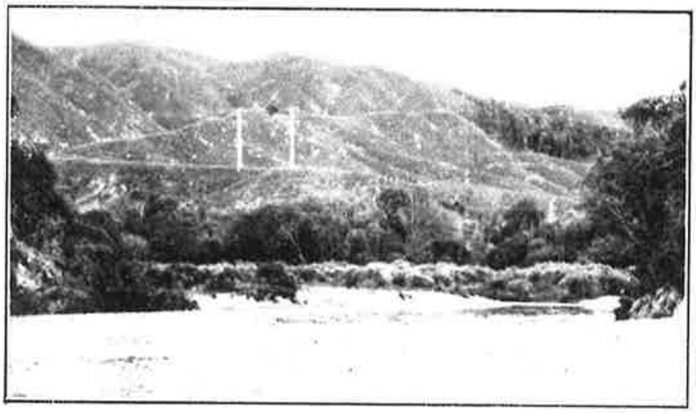

FIG. 8.—River Waikanae, by railway-bridge.

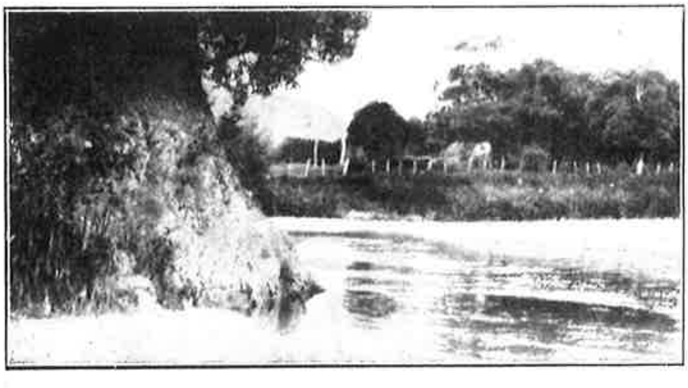

FIG. 9.—River Waikanae, by railway-bridge.

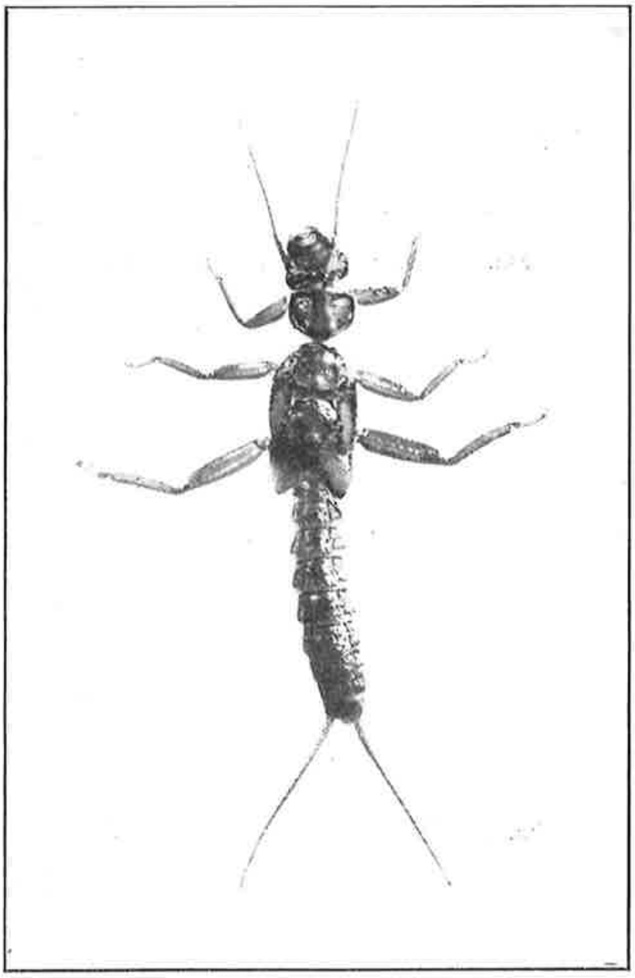

FIG. 10.—Stone-fly nymph (*Stenoperla prasina*).
Twice natural size.

FIG. 11.—Caddis larva (*Helicopsyche zealandica*). Twice natural size.

FIG. 12.—(*a*) *Potamopyrgus antipodum zealandiae*; (*b*) *P. corolla Salleana*. About four times natural size.

FIG. 13.—Caddis larva (*Pseudonema obsoleta*). About twice natural size.

FIG. 14.—Caddis larva—(*a*) *Pycnocentria evecta*; (*b*) *Olinga feredayi*. About twice natural size.