NEW ZEALAND.

MARINE DEPARTMENT.

FISHERIES BULLETIN No. 3.

A FURTHER REPORT ON

CONDITIONS AFFECTING THE WELL-BEING OF TROUT IN NEW ZEALAND.

BY

J. S. PHILLIPS, M.C., M.A. (Oxon), F.R.G.S.,
Victoria University College.

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

WELLINGTON, N.Z.

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

1931.

Price 1s.]

NEW ZEALAND.

MARINE DEPARTMENT.

FISHERIES BULLETIN No. 3.

A FURTHER REPORT ON CONDITIONS AFFECTING THE WELL-BEING OF TROUT IN NEW ZEALAND.

BY

J. S. PHILLIPS, M.C., M.A. (Oxon), F.R.G.S.,
Victoria University College.

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

WELLINGTON, N.Z.

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

1931.

A Bush Stream, Wellington.

[*Frontispiece*.

PREFACE.

THE extent to which any species can survive and flourish depends upon successful propagation from generation to generation, upon the adequate nourishment of the individuals, and upon their escapement from untimely destruction. All the problems of trout-life may thus be included under the two "positive" categories of breeding and feeding, making for numbers and size of fish, and the one "negative" category that includes the agencies which in various ways make for mortality. Each of the three involves a complexity of factors which it is the fishery investigator's job to elucidate. Why should he investigate or we be interested in his investigations? Simply because if we humans are going to interpose in one of the three categories above mentioned—if we aim at being the chief enemy of the trout with our ever-increasing mechanically aided powers of locomotion, our rods and lines and lures of ever-improving efficiency, and our stream-side tactics perfected by study and experience as anglers—then for what we take away as destroyers we must pay back by assistance on the positive side. Before we can competently assist Nature in the breeding and feeding of trout we must know the material she works with and must understand the laws of its being.

The work of Captain Phillips has had to do mainly with the problems of the feeding of trout. The report which follows is a continuation of the studies previously published in Fisheries Bulletin No. 2. It includes further data as to the details of the conditions of life in some of our rivers, but more particularly it deals with general considerations in connection with the problem of improving the stocks of trout in local streams. Its special importance lies in the fact that definite conclusions are arrived at in connection with certain fundamental problems, and definite developmental or remedial measures are recommended with a view to increasing the supply of trout-food in our streams and ensuring the possibility of an increased population of trout. The recommendations call for serious consideration on the part of those in control of the practical management of our fresh-water fisheries. It is obvious that investigations and recommendations have no value except in so far as they are followed by practical measures. It is not to be concluded that this report contains the final solution of our trout problems. The practical measures here recommended relate to only a part of the whole field, but I would urge that this part of the problem is one which calls for immediate attention and a forward move along the path of a scientific and constructive fresh-water fishery policy.

There remain other problems, among which may be mentioned as of outstanding importance the question of trout-propagation. For instance, how far do our rivers provide for the natural reproduction of trout, to what extent must we rely upon artificial means for augmenting natural reproduction, and what are the best practical means of so doing?

The necessity for more scientific investigation should be generally recognized, and equally clear should be the necessity for an organization competent to carry out the work and to apply its results.

There are in the Dominion thousands of anglers interested in maintaining and improving facilities for the fascinating and wholesome recreation of trout-fishing. Such a work as this might fittingly be dedicated to them, in the hope that by adding to their present interest and satisfaction in trout *killed* a more enlightened interest in trout *living*, and in the other less conspicuous but highly important, and, if one takes the trouble to notice them, exceedingly fascinating inhabitants of the fresh waters, the angler's hours of recreation spent on the river may be made still more pleasant and profitable. The aim of fresh-water research is to benefit anglers, and the interest and help of anglers are essential for its expansion and improvement.

A. E. Hefford,
Chief Inspector of Fisheries.

Marine Department, Wellington.

CONTENTS.

A FURTHER REPORT ON

CONDITIONS AFFECTING THE WELL-BEING OF TROUT IN NEW ZEALAND.

By J. S. Phillips, M.C., M.A. (Oxon), F.R.G.S., Victoria University College.

INTRODUCTION.

This report is a continuation of the one submitted last year (3). Together they form a preliminary survey of conditions in some typical New Zealand streams as they affect the trout-fisherman.

That it has been possible to undertake this work is due to the generosity and public spirit of the Wellington Acclimatization Society, who are the pioneers of fresh-water fishery research in this country.

It must be remembered that this is an intensely democratic country, and that before important schemes of public welfare, such as a fresh-water policy, can be pursued, or even formulated in any detail, the public mind must be reached and persuaded of their necessity.

However painstaking the work of an investigator, however sound his conclusions, backed as they may be with masses of data, their usefulness is always rigidly circumscribed if their significance can be grasped by only a few experts.

Hence, I have striven to avoid the error of the over-technical, and hope that the contents of these papers are plainly intelligible to every man that uses a rod.

My object in these two reports has been to present to the average license-holder a clear mental picture of local fresh-water conditions, to show, to some extent, the inevitable inter-play of cause and effect in the streams, to indicate the logical inferences which may fairly be drawn, and to suggest the necessary remedies which should be applied.

ACKNOWLEDGMENTS.

Throughout the period of research, Professor H. B. Kirk, of Victoria University College, and Mr. A. E. Hefford, Chief Inspector of Fisheries, have assisted me very materially in many ways, and I am indebted to them for their kindly help and for reading through this paper with me.

I also owe much to members and officials of the Wellington Acclimatization Society; in particular to Mr. P. Willson, the Chief Ranger, without whose aid I would not have been able to cover so much ground.

The Dominion Analyst, Mr. W. Donovan, was good enough to undertake the examination of a number of our waters for me, and on one occasion supplied me with two chemists for water-investigations *in situ*, at a moment's notice.

Miss W. M. Mather was kind enough to lend me an unpublished work of hers on local algae, which was of the greatest assistance.

Lastly, Mr. F. E. Thornton, the editor of the *New Zealand Fishing and Shooting Gazette*, has on many occasions given me considerable help, much information, and the loan of useful literature.

INVESTIGATION OF FUNDAMENTAL FACTORS.

Work on Aquatic Insects.

In addition to the experimental and statistical work involved in fresh-water studies of this kind, it was recognized that there were opportunities for working out the identities and life-histories of some of our aquatic organisms, and that such investigations would not only materially assist the work in hand but also be of permanent scientific value in extending the knowledge of the New Zealand fauna.

Naturally, those organisms were chosen which were found to predominate in the food of trout, and it was at once apparent that there was a vast field to cover, sufficient for the efforts of a number of workers over a period of several years ; for, so far, little attention has been paid to these organisms, many are unknown to science, and the rest have been very incompletely studied, particularly in the earlier stages of their life-histories.

The insects of two orders seemed to be of particular importance as trout-food—the Trichoptera, or caddis-flies, and the Ephemeroptera, or may-flies. The adults of the former order had been studied by Dr. Tillyard and described by him in a fairly recent paper (5) ; the latter order, however, had been barely touched, and it was decided to concentrate on this, rather than to dissipate effort over the whole extent of trout-food, which might have been of little value, considering the time, material, and assistance available.

Consequently it has been possible to study the Ephemeroptera in some detail, and in particular the rather neglected nymphal stages, which are eaten by trout all the year round, though the winged stages, which are of first importance to the fly-fisherman, for it is upon these that his art is mainly based, have received their share of attention.

The work entailed rearing them from the egg or nymphal stages, through the subimago or dun, to the imago or spinner. Each species had to be reared separately, so that confusion should not arise after the transformation, and so that it would be possible to recognize later, in the field, various adults and to correlate them with their nymphal forms. In order to achieve this a specially partitioned aquarium was built, through which a stream of running water was kept flowing. Moreover, the different nymphs often required different environmental conditions—*e.g.*, composition of stream-bottom and rate of flow of water—and it was not until these conditions were finally ascertained and satisfied that complete success was attained.

Three years' work on this order has resulted in a considerable increase of our knowledge of New Zealand may-flies. The species previously discovered have been completely worked out and revised, as in most cases only the winged stages had been described, and the earlier ones were either unknown or had only been mentioned in short notes. In addition, eight new species and the nymphal forms of two more have been discovered.

The results of this work are too lengthy and detailed to be included in this report, and have therefore been submitted to the New Zealand Institute and have been accepted for publication in their Transactions (4).

But, although our knowledge of this order has been much extended, there remain several other groups all urgently needing investigation. Thus, whilst the adult stages of many of the stone-flies and caddis-flies have been made known to us within the last decade by Dr. Tillyard, the immature stages, which are the most important to us, as they are spent in the streams, and also their life-histories, are still undisclosed, so that a large number of the aquatic organisms we find cannot be named, nor can they be correlated with their known aerial stages. Much work, too, remains to be done on the life-histories of fresh-water molluscs and crustaceans.

The working-out of these matters is not merely academic or of purely scientific interest, but may be of intense practical value. This year has furnished an instance of this, for Captain L. Hayes, M.C., of the Marine Department, who has been working on the life-history of the whitebait (*Galaxias attenuatus*), has found the weak point in its life-cycle, and disclosed the immense damage, hitherto entirely unsuspected, which stock must inflict on them. Only a study of this fish through all its stages could have revealed this, and similar exhaustive investigations on cognate problems will almost certainly show points of equally vital importance, now hidden. Incidentally, the problem of where and when this fish spawned was solved at the first opportunity, in spite of the fact that it must have been witnessed yearly by hundreds of people interested in aquatic life, who failed to realize the significance of what they saw and heard.

This brings out another important point—namely, that in the solution of our fresh-water problems, more important even than an adequate scientific training are habits acquired by a long apprenticeship of nature-study in early life, to wit, intense interest in wildcraft, schooled habits of observation, and the rare power of making swift and accurate deductions from the facts observed. All these were clearly instanced in the case cited.

Organisms as Indicators.

Apart from work on life-histories, it has been found possible to use the may-fly as an indicator, because the nymphs of certain species are always found in certain types of water.

The presence, for instance, of *Coloburiscus humeralis* indicates a first-class trout-water, for this nymph is always found in rapid waters with a pebble or boulder bottom, containing a small amount of algal growth, on which it lives. It is far more sensitive to adverse conditions, such as a lowering of the oxygen content of the water, than are trout, for experiments have shown me that this may-fly nymph requires a constant stream of well-aerated water, whereas trout were found to be less exacting.

All may-fly nymphs of the family Siphlonuridae inhabit good trout-waters, and their presence is a favourable sign, while their absence may be taken as meaning that it is poor water for brown trout, but not necessarily for rainbow.

The importance of various organisms as indicators cannot be over-estimated, and their significance should be realized by all interested in fish-culture. A number of them, such as the species mentioned above, are only found in good trout-waters; the great majority are comparatively tolerant and cannot be taken safely as a guide, whilst others are found in waters unsuitable for trout. Other creatures which indicate good trout-waters are the crayfish, the "creeper," and nearly all stone-flies.

To compile a list of organisms which indicate waters unsuitable for trout would be very difficult, because the fauna which live in such waters have a very wide range of toleration, and therefore may also be found in waters suitable for trout. These tolerant organisms include such forms as many diatoms, slime algae, and some molluscs; also the larvae of a few species of Diptera, such as the introduced *Eristalis tenax* (the rat-tailed maggot) and some species of Psychodidae and Tipulidae (moth-midges and daddy-long-legs). The point to note about these creatures is that they will be relatively far more numerous in unsuitable trout-waters than in places where they have to compete with a large number of less-tolerant forms of life, so their preponderance will probably indicate water unfit for trout.

Aquatic Flora.

In the final analysis the quantity of trout that any body of water can support is dependent almost entirely on its aquatic flora. It is true that during certain months of the year an appreciable amount of food comes from sources outside the river—for instance, the green beetle (*Pyronota festiva*) which is carried by the wind or falls from vegetation near by; but the amount of such extraneously provided food forms a negligible proportion of the gross amount.

Caddis, may-flies, gasteropods, "creeper," water-boatmen and small fish comprise, almost exclusively, the food of trout in our waters, and these creatures in turn prey either on other aquatic organisms or directly on the aquatic flora. This latter, then, is the lowest link in the chain of life, and a paucity of it will necessarily mean a scarcity of its devourers, and therefore insufficient trout-food, and finally, therefore, fewer trout.

The converse is true up to a point, but, unfortunately, waters which are most suitable for aquatic vegetation are generally unsuitable for trout; that is why backwaters are so essential: and the swift, clear waters which provide optimum conditions for trout are only suited to a comparatively small number of aquatic floral species; this is one of the reasons why the banks of such water-reaches should be well bushed.

It is necessary, then, to encourage the growth of suitable aquatic flora and to protect it from the destructive action of sudden fluctuations in the stream-level and from the mechanical action by flood-carried boulders.

Certain species are harmful in the slower waters. For example, the roots of willows and the submerged exotic *Elodea canadensis* (Canadian water-weed), though excellent fodder for the fauna, are apt to choke up the slower waters, unless checked. Such checking would be impossibly costly in this country. Many floating species—*e.g.*, *Lemna minor* (duckweed) and *Azolla rubra*—will quickly cover a pool or almost stagnant creek. Particularly in summer, when the water is low for long periods, such organisms may be detrimental to the fishing. Another kind of deleterious plant is the slime alga. The nymphs of may-flies may be often found entrapped in such matter; and, further, in certain conditions, it appears to give off noxious and miasmic by-products, which are definitely harmful to many of the trout-food organisms. On the other hand, when the water is not too low, these slime algae are mostly beneficial and provide both food and shelter for some of the more minute water-creatures. There are at least three caddis larvae (two species of *Oxyethira* and one undescribed species) which are common in this habitat, and *Potamopyrgus*, the main molluscan trout-food, a creature of very catholic taste, is also often found in this environment.

The great importance of the lower forms of aquatic plant-life lies in the fact that many of them are found in places where Phanerogams (water-weed, &c.) cannot exist. In the local streams pure associations are not usually found, but nearly always there is a mixture of species.

Such factors as the rate of flow of the water, the amount of light present, the nature of the substratum, and probably the pH value (*i.e.*, acidity or alkalinity) of the water limit the distribution of the different species.

Bush-clad streams are, on the whole, unfavourable to an abundant growth of the more readily observable algae, though on the dark spray-dashed surfaces of rocks in the rapids Cyanophyceae (blue-green algae) may often be noticed.

In moderately rapid waters tufts of the Chlorophyceae (green algae) are not uncommon; thus, in the Hutt River tributaries (*e.g.*, the Korokoro and Moonshine Streams) *Cladophora* is frequently encountered, and in its tangled masses lie sheltered a host of lodgers, notably case-making caddis larvae, the larvae of chironomids (midges), and an abundance of micro-organisms.

These algae are important then, not only as providing food, but also in that they produce altered conditions in the original habitat—*i.e.*, they make small oases of shade and shelter in the exposed deserts of rapid water.

In this district the common Cyanophyceae (blue-green algae) belong to the genera *Anoboena*, *Nostoc*, *Oscillaria*, and *Lyngbya*; and the Chlorophyceae (green algae) most frequently found are *Spirogyra*, *Zygnema*, *Vaucheria*, *Ulothrix*, *Oedogonium*, *Cladophora*, and *Draparnalda*.

The presence or absence of algal species in a stream is affected not only by seasonal changes, but also by the facility with which they become re-established after severe freshets.

Miss W. M. Mather, M.A., who has made a study of local algae (7), finds that "Of the replacement plants, *Vaucheria* is one of the first to appear in a stream, and *Spirogyra* and *Zygnema* in a ditch." Her distinctions would appear to differentiate between running and stagnant water, and actually the word "ditch" could be replaced by the phrase "a stagnant area of a stream."

The commonest alga was found to be *Vaucheria sessilis*; the desmid which occurred most frequently was *Cosmarium botrytis*; and the following diatoms seem the most ubiquitous: *Navicula viridis*, *Synedra pulchella*, *S. ulna*, and *S. radians*, *Frustularia rhomboides*, *Cocconeis pediculus*, and *Melosira varians*.

It is difficult to realize how universally the diatoms are distributed. Every water-sample collected in the field this season, either for analysis or accompanying specimens of the various flora and fauna collected, contained some of these microscopic organisms. Invisible save in mass, they seem to permeate every inch of watercourse, and the alimentary tracts of most of the aquatic herbivores—especially the insects—are crammed with them. The silt in the stream-beds is full of these organisms, and many are found among the algae, which cover stones and boulders.

The desmids are found in the slower waters, often attached to some larger vegetable organism. In addition to *Cosmarium botrytis*, mentioned above, *Closterium moniliferum* is very abundant. The fact that they have a narrower limit of tolerance makes them of less importance as a basic food than diatoms or algae. A small number of autopsies were made this year on the immature stages of aquatic insects. The contents of the alimentary tracts revealed traces of filimentous algae and of diatoms, but not of desmids: this may have been due to the extreme delicacy, and therefore swift digestion, of the last-named organisms.

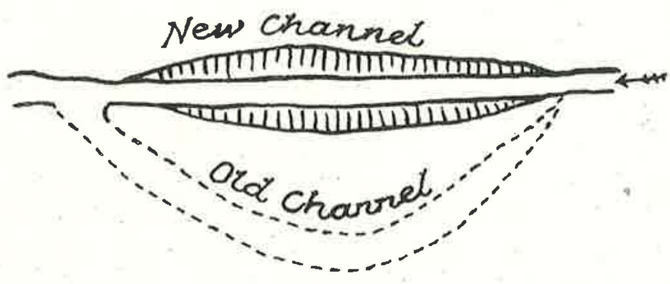
With regard to the role played by the larger aquatic plants this is more complex.

The rooted phanerogams (water-weeds) are useful in a number of ways. They have a binding action on the loose bottom, making it stable and amassing fruitful silt, productive of a greater number and variety of organisms than was originally the case. The stems and leaves provide food and shelter for the fauna and also for smaller species of flora, for they are generally covered with algae, desmids, and diatoms. In slow waters, where aeration is naturally poor, the plants take up the work and render considerable areas of water fit for fish-life which without vegetation would be unfit.

Furthermore, some of the mineral contents of the waters are absorbed and utilized by the plants and thus made available indirectly to the fauna. Pond (1) has shown how the mineral contents of waters are absorbed by the root-hairs in species of *Vallisneria* (eel-grass), *Ranunculus* (water-buttercup), *Elodea* (Canadian water-weed), *Myriophyllum*, and *Potamogeton*, *when rooted in a soil substratum*, and that they are "important contributors to the plankton food-supply, because when living they organize matter that may be used as food, and in death they yield important salts and organic substances to the water."

When deprived of the soil substratum, Pond found that these plants could not survive a single season. Here, then, is another disadvantage of too rapid waters: not only have they a mechanically destructive effect on the flora, but they inhibit the formation of the necessary substratum without which these aquatics cannot live. When such plants are found in apparently swift waters—as they sometimes are—it is invariably because the current at the bottom is very much slower.

On the other hand, a retardation of the water-flow will at once encourage the growth of these aquatics, as was aptly illustrated by a recent occurrence at Karori, Wellington. In this locality is a small, moderately rapid stream, the South Karori (fig. 1), winding erratically through a steep valley towards the sea. There are many bends in this stream and one of them has been recently straightened thus—



and the upper end of the old channel blocked up, the lower end being left open, leaving in effect a backwater. (See also fig. 2.)

The new channel has soon assumed the character of the rest of the stream, which has a shingle and boulder bottom, with grass banks running down to the edge (though the new channel has, of course, necessitated a steep cutting).

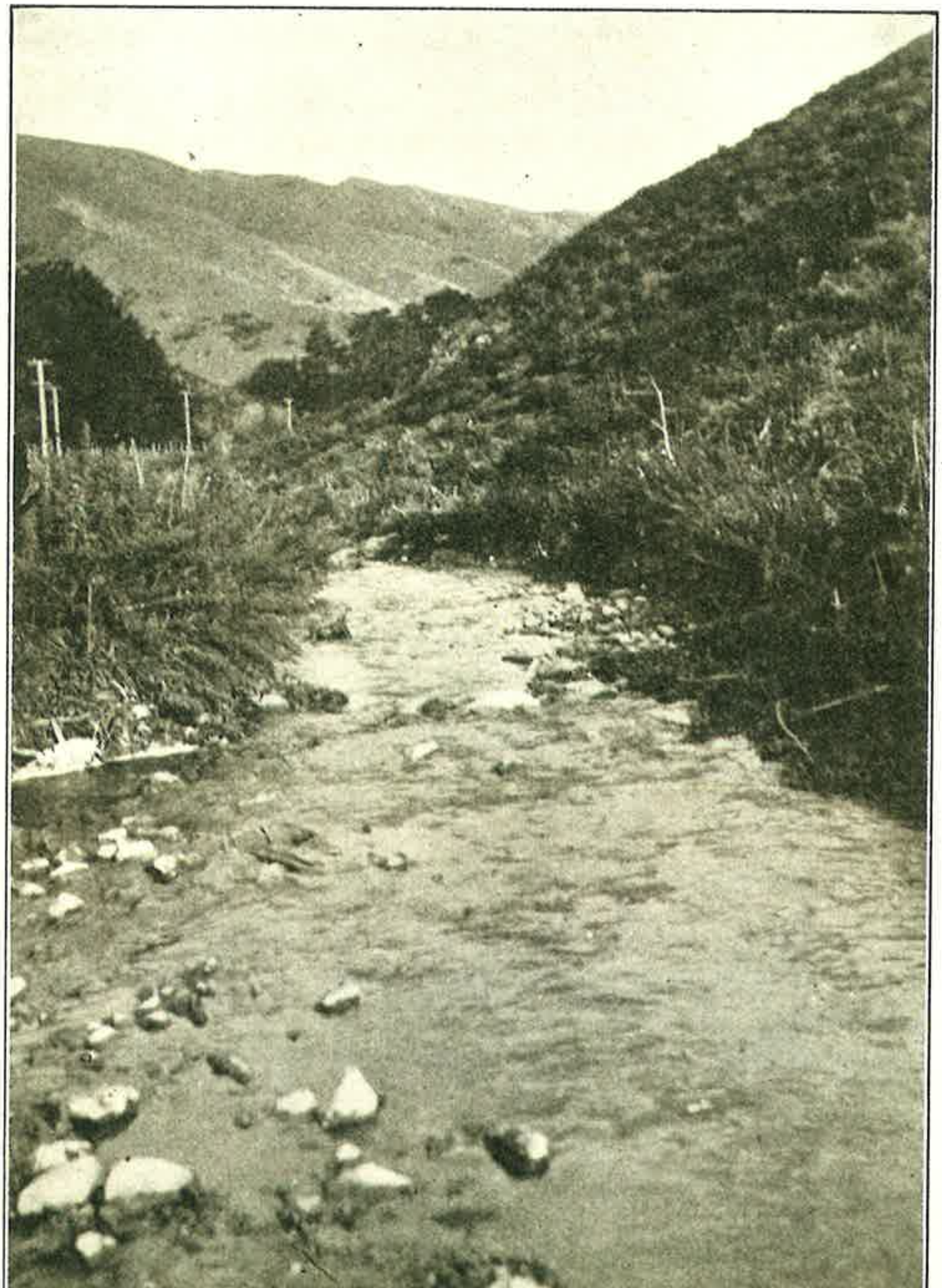


FIG. 1.—South Karori Stream.

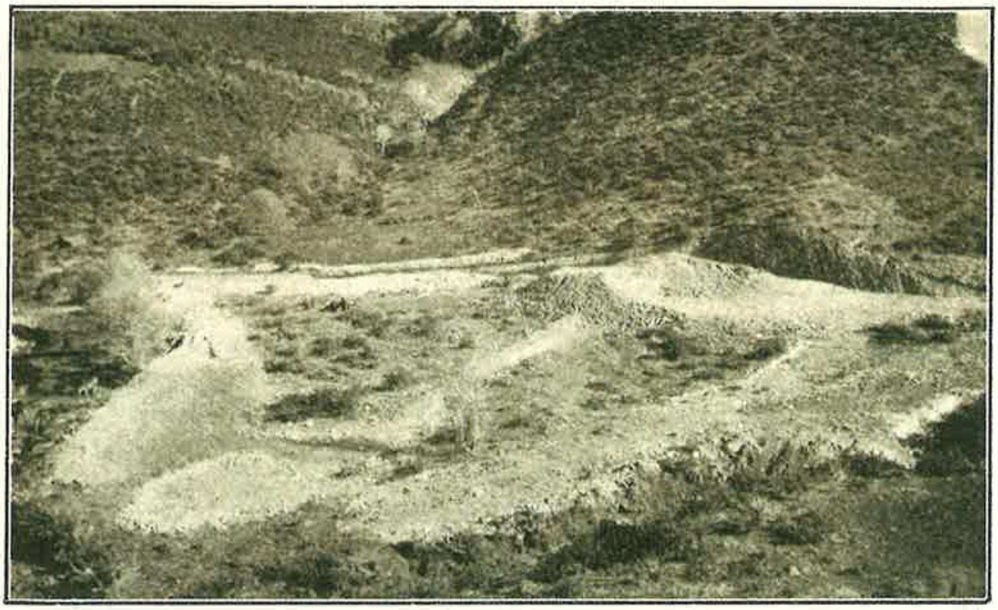


Fig. 2.—South Karori Stream: Old and new channels.

Fig. 3.—South Karori Stream: Old channel, now a backwater.

The fauna is not very abundant, mostly caddis larvae, may-fly nymphs, and "creeper"; and sometimes near the banks, where the current is slower, there is an occasional growth of watercress with colonies of the mollusc *Potamopyrgus*.

The old course, though still full of water, except towards the upper end, has entirely changed its character in a few short months (fig. 3.) The confluence at the lower end is choked with masses of starwort (*Callitriche verna*), the bottom is inches deep in silt and small stones, and the watercress has ramified exuberantly. Higher up, there is an abundant algal growth, more watercress, clumps of *Ranunculus sceleratus* and *Potamogeton polygonifolium*.

The fauna, too, has changed and is far richer quantitatively. All the phanerogams are covered with the small mollusc *Potamopyrgus* and also with the gammarid *Paracalliope fluviatilis*; on the muddy bottom there are large numbers of the water-boatmen (*Arctocorisa arguta*). Even at the top end, where there is a host of mosquito larvae, the water is still sweet.

A comparison of a square foot of the old bed with a similar area of the present stream-bed lower down showed the following differences:—

Old Bed.		Normal Part of Stream.	
Water-boatmen	73	May-fly nymphs	31
Potamopyrgus	212	Caddis larvae	17
Gammarids (many probably missed, hidden among vegetation)	184	"Creeper"	5
Dipterous larvae	57	Dipterous larvae	11
Caddis larvae	27	Oligocaetes	3

The contrast is very marked.

After a freshet much of the food-supply of this backwater will be swept past the confluence and will augment the normal supply of the stream. It is easy to envisage the great difference a number of such backwaters would make to the trout-supporting capacity of a given stretch of stream.

It was hoped to discover which were the most valuable aquatic plants, so that they might be encouraged in suitable places. With this in mind, sample areas, 1 ft. square, of *Potamogeton* spp., *Callitriche verna*, *Ranunculus* spp., *Elodea canadensis*, *Lemna minor*, *Azolla rubra*, *Myriophyllum* spp., and a few algae were taken from various streams and rivers throughout the provincial district, and the numbers and kinds of organisms on each sample ascertained.

The results were so conflicting as to be quite valueless, and so they are not reproduced here. Samples of the same plant from different rivers, or even from the same river, would disclose such varying numbers and kinds of organisms that it proved impossible to find the relative value of the different plant species. Doubtless there are a number of factors which determine the fauna-bearing capacity of a unit area of any species. All that can be said is that *Lemna minor* (duckweed) and *Azolla rubra* are of little value as foraging-grounds (except for micro-organisms such as rotifers, Entomostraca, &c.), and the algae far less useful than the rooted phanerogams. Concerning these latter plants, it did not appear that each was a host to some special faunal organism, but that all of them furnished subsistence for a faunal group consisting of such organisms as *Potamopyrgus* spp., gammarids, fresh-water prawns (*Xiphocaris curvirostris*), a few may-fly species of the family Leptophlebiidae, the water-boatman (*Arctocorisa* *arguta*), some aquatic beetles of the families Dytiscidae and Hydrophilidae, and a few caddis and diptera.

Investigations have been made in America as to the comparative value of different forms of aquatic vegetation as regards their yield of fish-food fauna. Needham (9) in two seasons' work found the following results, which, however, he expressly states must not be taken as averages, as only one unit area study was made in each type :—

Vegetation.	Weight in Grammes of Fish-food per Square Foot.
Stonewort (*Chara*)	37·0
Watercress (*Nasturtium aquaticus*)	12·8
Potamogeton crispus	5·85
Willow-root bed	4·88
Alga and moss, mixed (*Cladophera* and *Fontinalis*)	4·15
Water-buttercup (*Ranunculus aquatilis*)	3·51
Moss (*Fontinalis* sp.)	3·4
The average for stream-bottoms—	
Of plant-beds was	7·88
Of bare stream-beds was	1·05
Of bare pool-beds was	0·21

On examining the fish-foods of plant-beds he found the numerical percentages to be as follows :—

	Per Cent.		Per Cent.
Crustacea	42·16	Mollusca	2·73
Diptera	22·17	Plecoptera	0·91
Caddis	8·88	Neuroptera	0·12
Hemiptera	7·82	Odonata	0·04
Coleoptera	6·36	Miscellaneous	3·15
Ephemeroptera	5·66		

It is probable that fairly similar figures would be obtained here, except that the Mollusca would most likely be second on the list and the Plecoptera would be nil.

Apart from increasing the food-supply, the effect of vegetation is to increase the proportion of molluscs and crustaceans at the expense of may-flies and caddis. This would tend to produce a more delicately flavoured fish, but possibly one which would not rise to the fly so readily.

Chemical Character of Trout-waters and Pollution.

The question of pollution does not appear to be a very serious one at present. Nevertheless, it is one which will grow increasingly important with the spread of population and industry throughout the country, and therefore it will require very careful and constant watching.

In the Wellington district, not only are there many miles of fishing-waters unlikely to be contaminated for years to come, but also those which are exposed to contamination are usually so swiftly-flowing that the ill effects are fortunately dissipated in a short time. An example of this occurred recently, when a small creek on the outskirts of Wellington, the South Karori Stream, was reported to be seriously contaminated by sewage. At the reported place the water was rendered filthy by sewage matter, and the effluvia was extremely nauseating; yet when the water a few yards below the outlet was tested on the spot by chemists from the Department of the Dominion Analyst it was found to be innocuous to trout. A copy of the analysis is appended. There can be no doubt that in rapid waters, pollution of this nature must be considerable before it can become *directly* injurious to fish.

Pollution may be of such a nature as sawdust, but usually it is of a chemical character and will materially alter certain basic factors of the water. Thus the water may become too acid or too alkaline; or there may be an increase in the carbon-dioxide content or a decrease in the oxygen content.

Carbon dioxide is usually generated by the decomposition of animal or vegetable matter, and, as it forms, it uses up oxygen, so that an excess of carbon dioxide usually means a deficiency of oxygen in the water.

Fresh-water life can exist only within certain limits of tolerance, the limits varying for each species. Thus, if the water is too acid or too alkaline, or if it contains too much or too little oxygen or carbon dioxide for a particular organism, that organism will die. Trout are particularly sensitive, and can only exist between rather narrow limits. The limits in all cases are somewhat affected by the temperature of the water: the colder the water, the higher can the acidity be without injurious effects.

What is the practical application of all this?

It is as follows: As pollution generally affects water in the ways outlined above, we can test any suspected water for pollution by finding out whether it is within the limits of toleration (for these factors) for trout or not. Thus, allowing for temperature, we can test the oxygen content, the carbon-dioxide content, and the relative acidity or alkalinity of a particular water.

As testing all these things takes some time and requires a certain amount of apparatus, and as a serious pollution very often affects all the factors, it is quicker and easier, when doing field-work, to test for one of them; then, if the result is unfavourable, a larger sample can be taken back to the laboratory for analysis.

The method of testing the relative acidity or alkalinity by determining its pH value or hydrogen-ion concentration is the quickest and simplest. Where a water has been seriously polluted, its hydrogen-ion concentration will usually alter materially, and so testing this is often a good indication as to whether pollution is or is not occurring. For this reason a portable pH determinator for work in the field was purchased and used throughout the last year of research. Incidentally, this will also be of use in ecological studies, and, further, in the determination of the best media for the development of aquatic organisms.

The instrument used was Hellige's comparator. The method is a colorometric one, and the pH value is found in this way: A fixed amount of water to be tested is tinted with a certain small quantity of indicator fluid and the resultant colour is compared with a series of colour-fields marked on a rotating disk. Against each colour-field appears a number, its corresponding pH value. The disk is rotated in its housing until the colour-field which most nearly matches the indicator-tinted water is brought into juxtaposition with it, and the pH value is read and noted. The test is made three times, and the mean of the three is taken.

Three different indicators, with their disks, have been used, the first giving pH values between 5·2 and 6·6, the second between 6·0 and 7·6, and the third between 6·8 and 8·4. The neutral point is 7·0, and, as the majority of waters tested were very slightly alkaline (*i.e.*, above 7·0), the first solution was seldom used and the third only as a check on the second one.

The tap-water at Victoria College, Wellington, has a pH value of 7·1. Certain of our waters gave results as follows :—

6/11/29.	Khandallah Stream	7·1
17/11/29.	Mungaroa (below the flax-growing area)	6·0
23/11/29.	George's Creek	6·9
23/11/29.	Wainuiomata	6·9
26/11/29.	South Karori Stream (100 yards below sewage effluent)	6·3
26/11/29.	South Karori Stream (400 yards below sewage effluent)	6·3
3/12/29.	River Hutt (Melling)	6·9
3/12/29.	River Hutt (Lower Hutt)	6·9
15/12/29.	River Hutt (Belmont)	7·1
15/12/29.	Belmont Stream	7·1
7/1/30.	Waikanae	7·2
26/12/29.	Ruamahanga (Masterton)	6·9
27/12/29.	Waipoua (Masterton)	7·1
23/1/30.	Gowan River (Lake Rotorua)	7·2
11/2/30.	River Akatarawa	6·9
13/2/30.	George's Creek	6·9
20/2/30.	River Hutt (Moonshine)	7·1
20/2/30.	Moonshine Stream	7·1
3/3/30.	River Wairua (near Hikurangi)	6·4
4/3/30.	Jordan Stream (near Hikurangi)	6·8
–/3/30.	River Manawatu (Palmerston North)	7·0
–/3/30.	River Tiritia (Palmerston North)	7·1
–/3/30.	Papawai Stream (Greytown)	6·8
–/3/30.	River Waiohine (Greytown)	7·1
–/3/30.	River Maungatarere (Greytown)	7·1
5/4/30.	Korokoro Stream (Petone)	6·9
–/3/30.	River Tauherenikau (Featherston)	6·9
–/3/30.	River Otaki (Otaki)	6·9
–/3/30.	River Ohau (Levin)	6·9
6/4/30.	Porirua Stream..	7·1
13/4/30.	Little Akatarawea	7·1
13/4/30.	River Akatarawea	7·1
18/4/30.	Makara Stream..	7·1
18/4/30.	South Karori	6·9
24/4/30.	Kaiwarra Stream (Wilton's Bush)	7·1
24/4/30.	Tributary of same	7·1
–/4/30.	Waikanae River	7·2
–/4/40.	Maungekatukutuku Stream	7·2
–/5/30.	Korokoro Stream	6·9
–/5/30.	Belmont Stream	7·1
–/5/30.	River Hutt (Belmont)	7·1

These samplings would seem to indicate that the pH value is liable to slight fluctuations, as exemplified in the case of George's Creek, which gave a value of 6·9 in November and 7·1 in February, and that of the Akatarawea Stream, which was 6·9 in February and 7·1 in April. In both cases water was taken from the same part of the stream. These small differences may have been due to variation of water-level and therefore of water-flow, or perhaps the effect of algae, present at one season and not at the other. In all cases, the pH value shown was well within the limits of trout-tolerance.

The Wangaehu, which has always been said to be unfit for fish-life because of contamination by sulphur and similar injurious matter from the volcanic area in which it rises, as, indeed, may be the case in the upper reaches, was visited on 4th and 5th October, 1929, about ten miles from its mouth. Many inanga were seen in its waters, as well as aquatic insects and an abundance of water-vegetation. A water-sample was brought back and sent to the Dominion Analyst, who was good enough to analyse it for us. The result is shown in the second of the reports on water-analyses which follow.

Dominion Laboratory
(Department of Scientific and Industrial Research),
Wellington, N.Z., 7th February, 1930.

W.D.
P.J.C. 8·86.
H.J.W. 6·48.
Report on specimens No. V. 73 (1–2).
Forwarded by Captain Phillips, Victoria University College, Wellington.
Particulars :—

Effluents.

(1) South Karori Stream : Outlet pipe.
(2) South Karori Stream : 30 ft. below outlet of septic tank.

ANALYSES.

(Results expressed in parts per 100,000.)

	(1.)	(2.)
Smell when heated to 100° F.	Strong	Earthy.
Chlorine in chlorides	5·68	4·44
Nitrogen in nitrates	Nil	Nil.
Nitrogen in nitrites	Nil	0·002
Ammoniacal nitrogen from free and saline ammonia	2·0784	0·0482
Albuminoid nitrogen	0·3674	0·0152
Oxygen absorbed in four hours at 80° F.	2·118	0·279
Solids—		
(*a*) In suspension	11·0	2·0
(*b*) In solution	28·0	15·0
Oxygen dissolved (cubic centimetres per litre)	0·67	7·39

On standing, (1) gave a very large deposit. Swarms of Protozoa were detected. (2) gave a moderately large deposit; several Protozoa and diatoms were detected.

(1) The oxygen absorbed and solids in suspension are somewhat high. Cleaning of the tank is recommended.

(2) Figures for No. 2 sample, taken 30 ft. below outlet, indicate that oxidation proceeds rapidly, and nothing was disclosed which would be injurious to fish-life.

J. S. McLaurin, D.Sc., F.I.C., Dominion Analyst.

Dominion Laboratory
(Department of Scientific and Industrial Research),
Wellington, N.Z., 25th October, 1929.

L.R.D.
H.J.W. 6·22.
Report on Specimen No. U.2176.
Forwarded by Captain Phillips, Victoria University College, Wellington.

Water from Wangaehu Stream (for fishery purposes).

ANALYSIS.

(Results expressed in parts per 100,000.)

Silica (SiO_2)	2·18
Oxides of iron and aluminium (Al_2O_3 and Fe_2O_3)	0·28
Calcium ion (Ca^{++})	1·78
Magnesium ion (Mg^{++})	0·38
Potassium ion (K^+)	0·24
Sodium ion (Na^+)	1·78
Sulphate ion ($SO_4^{=}$)	2·69
Chloride ion (C_1-)	2·52
Bicarbonate ion (HCO_3^-)	6·10
Total dissolved mineral solids	17·95

The analysis discloses nothing that would be injurious to fish-life. Oxygen absorbed was not done, owing to insufficiency of sample. If this is required, a larger sample should be sent, express delivery. Dissolved oxygen is best done on the spot.

W. DONOVAN, M.Sc., F.I.C., Acting Dominion Analyst.

HABITAT-ANALYSES.

Investigations of this nature, which were initiated last year, were continued throughout the current period. Here, perhaps more than elsewhere, progress was hindered by the lack of assistance and material, and I do not consider that work of this kind can be done effectively single-handed. Furthermore, a satisfactory sampling-apparatus must be of some bulk, and would necessarily involve a car for transporting it and two men for working it. However, with the rough methods previously described (3), various areas were examined. The areas examined in April, 1929, near Belmont, were re-examined in February, 1930. Results on both dates are given below for comparison, and show the yield of stream-bottom per square foot.

These figures show that the inhabitants of similar areas or even of the same area at different times, are by no means constant. On the whole, they confirm last year's conclusions on the important effect of the presence or absence of bush on the banks, notably when the current is rapid. They would seem to indicate that there is more food in February than in April, but it is quite possible that in the later period this apparent deficiency is balanced by a larger number of very young organisms, possibly overlooked by reason of the crude methods I had to employ.

Further work on these lines was done in other parts of the Wellington Provincial District, and as far as possible the conditions in the areas chosen were such as to correspond with those of the original sample areas. As before, three samples were taken in each place and the mean of the results (to the nearest integer) was taken to represent each area. It was difficult to find four areas similar to sample No. 2—in fact, the similarity of conditions in this case was only very approximate.

Furthermore, it should be noted that the samples were not all taken during the same month, but spread over a period of three months. Limitations of time and help made this inevitable. It is, however, unlikely that the extended time was a very serious drawback or that it affected the results very considerably.

Probably the only organism affected is the terrestrial beetle, which is found in large numbers in the water during the earlier part of this period, but only occasionally later on.

The tables given below are cast in a slightly different form from the preceding ones. Only the most important species are given individually; the others are included in their families in the case of may-flies, in their orders in other cases.

The figures, as before, represent the number of organisms per square foot of stream-bottom.

The final table is a comparison of the different types, and the figures show the average number of organisms found in each type of area.

The tables do not represent correctly the numbers of fish, crayfish, and other mobile creatures, which vanished before the samples could be taken; they do not include micro-organisms.

Table A.

Organisms.	Sample Area No. 1: River Hutt, 200 yards above its Junction with Belmont Stream. Pebble and boulder bottom; banks bare; current, 1 to 3 m.p.h.		Sample Area No. 2: A connecting ditch between the Belmont Stream and River Hutt, 100 yards from Area No. 1. Muddy bottom; under willows; very slow current.		Sample Area No. 3: Belmont Stream, about 200 yards from mouth. Nearly stagnant; boulder and pebble bottom, covered with algae; no bush.		Sample Area No. 4: Belmont Stream, about 1 mile from mouth. Banks heavily bushed; gravel and boulder bottom; pool.		Sample Area No 5 As Area No. 4. Rapids.	
	April, 1929.	Feb., 1930.	April, 1929.	Feb., 1930.	April, 1929.	Feb., 1930.	April, 1929.	Feb., 1930.	April, 1929.	Feb., 1930.
Larvae of *Hydropsyche*	..	..	..	..	..	..	7	5	27	31
Pupae of *Hydropsyche*	3	..	..	..	..	..	2	8	15	23
Larvae of *Olinga feredayi*	1	7	31	68	14	53	5	12	57	69
Larvae of *Pycnocentris* spp.	..	..	..	..	2	17	3	12	25	43
Larvae of *Pseudonema* spp.	..	..	1	..	..	11	..	..	..	..
Larvae of *Helicopsyche*	..	..	..	3	..	..	6	23	..	..
Larvae of other caddis	6	2	34	36	11	..	13	7	17	5
Nymphs of *Deleatidium*	5	11	..	..	..	..	45	38	71	142
Nymphs of *Coloburiscus*	..	..	..	..	..	..	14	27	43	84
Nymphs of *Atalophlebia*	1	3	..	..	..	..	..	18	2	5
Nymphs of *D. myzobranchia*	..	..	..	..	..	..	..	..	9	5
Nymphs of *Ichthybotus*	..	..	1	..	..	..	1	..	1	..
Nymphs of *Stenoperla*	..	..	..	..	..	..	..	..	17	8
Nymphs of other stone-flies	..	..	..	..	..	..	..	..	23	17
"Creeper"	..	..	1	..	..	..	1	..	15	18
Earthworms	..	..	1	..	..	..	..	..	..	..
Oligochaetes	..	3	11	5	..	5	2	7	..	1
Diptera	2	12	12	7	11	41	..	..	..	..
Beetles	..	..	..	2	..	..	..	..	..	..
Potamopyrgus	..	..	138	57	11	27	..	..	..	..
Hydracarinae	..	..	..	..	ca. 300	..	..	..	..	..
Planarians	..	..	..	..	..	..	..	..	..	17
Crayfish	..	..	..	..	..	..	..	..	..	3
	18	38	230	178	49	144	89	162	322	511

TABLE B.—AREAS WITH PEBBLE AND BOULDER BOTTOM; BANKS BARE; LITTLE OR NO VISIBLE AQUATIC FLORA; CURRENT, 1 TO 3 M.P.H.

Organisms.	River Hutt at Melling: January, 1930.	River Ruamahanga, at Masterton: January, 1930.	River Otaki, at Otaki: March, 1930.	River Waiohine, at Greytown: March, 1930.
May-flies—				
Ephemeridae ..	..	..	3	..
Siphlonuridae ..	..	..	..	1
Leptophlebiidae ..	14	11	5	9
Stenoperla prasina ..	..	..	..	..
Other stone-flies ..	..	..	..	..
Caddis—				
Olinga feredayi ..	6	24	..	7
Pycnocentria spp.	..	..	..	..
Pseudonema spp. ..	..	1	..	..
Other caddis ..	3	7	1	6
"Creeper" ..	..	..	..	..
Water-boatmen ..	..	6	..	..
Diptera	7	2	13	4
Aquatic beetles ..	..	52	6	16
Land beetles ..	3	7	..	..
Oligochaetes ..	..	1	2	..
Hydracarinae ..	..	..	..	..
Gammarids ..	..	..	..	..
Fresh-water prawns ..	..	..	..	..
Fresh-water crayfish	..	..	..	..
Mollusc *Potamopyrgus*	..	..	..	27
Other molluscs ..	..	..	..	..
Bullies	2	..	..	..
Inanga, or whitebait	..	..	..	..
Other organisms ..	..	..	..	..

TABLE C.—AREAS WITH MUDDY BOTTOM AND VERY SLOW CURRENTS; A LITTLE ADJACENT VEGETATION.

Organisms.	Waimea Stream, Waikanae: March, 1930.	Papawai Stream, Greytown: March, 1930.	Small Stream crossing Road between Otaki and Otaki Beach: March, 1930.	Small Stream at Featherston, a Tributary of the Tauherenikau: January, 1930.
May-flies—				
Ephemeridae ..	..	..	..	..
Siphlonuridae ..	..	..	..	..
Leptophlebiidae ..	7	13	2	5
Stenoperla prasina ..	..	..	..	..
Other stone-flies ..	..	..	..	..
Caddis—				
Olinga feredayi ..	98	14	57	..
Pycnocentria spp. ..	..	..	..	..
Pseudonema spp. ..	5	31	..	..
Other caddis ..	23	17	11	14
"Creeper" ..	..	..	..	..
Water-boatmen ..	..	15	11	..
Diptera	41	73	6	15
Aquatic beetles ..	7	11	3	..
Land beetles ..	..	..	..	4
Oligochaetes ..	17	6	9	19
Hydracarinae ..	..	..	11	..
Gammarids ..	132	112	41	..
Fresh-water prawns ..	3	1	..	..
Fresh-water crayfish	..	..	..	..
Mollusc *Potamopyrgus*	97	83	31	51
Other molluscs ..	5	..	..	..
Bullies	3	1	..	..
Inanga, or whitebait	5	..	4	..
Other organisms* ..	4	2	..	..

* Dragon-fly nymphs.

TABLE D.—NEARLY STAGNANT AREAS WITH BOULDER AND PEBBLE BOTTOM, COVERED WITH ALGAE; NO BUSH.

Organisms.	River Hutt, at Melling: January, 1930.	River Ruamahanga, at Masterton: January, 1930.	River Otaki, at Otaki: March, 1930.	River Waiohine, at Greytown: March, 1930.
May-flies—				
Ephemeridae ..	..	..	..	..
Siphlonuridae ..	..	..	..	..
Leptophlebiidae ..	17	23	5	14
Stenoperla prasina ..	..	..	..	..
Other stone-flies ..	..	..	..	5
Caddis—				
Olinga feredayi ..	7	..	21	14
Pycnocentria spp. ..	3	..	1	..
Pseudonema spp. ..	5	4	..	14
Other caddis ..	17	23	15	27
"Creeper"	..	..	2	..
Water-boatmen ..	5	43	..	115
Diptera	41	37	17	62
Aquatic beetles ..	3	141	7	39
Land beetles ..	5	7	..	1
Oligochaetes ..	8	14	1	..
Hydracarinae ..	..	7	..	137
Gammarids ..	..	..	..	43
Fresh-water prawns ..	..	..	..	..
Fresh-water crayfish	..	..	..	..
Mollusc *Potamopyrgus*	57	9	..	83
Other molluscs ..	..	..	..	..
Bullies	..	3	1	..
Inanga, or whitebait	..	..	2	..
Other organisms* ..	1	..	..	..

* Eel.

TABLE E.—AREAS WITH GRAVEL AND BOULDER BOTTOM; HEAVILY BUSHED BANKS; POOLS.

Organisms.	River Whakatiki, about 1 Mile from Confluence with River Hutt: February, 1930.	River Waikanae, above Railway-bridge: March, 1930.	River Waipoua, just above Masterton: January, 1930.	Kaiwarra Stream, Wilton's Bush: February, 1930.
May-flies—				
Ephemeridae ..	..	4	..	..
Siphlonuridae ..	25	18	7	14
Leptophlebiidae ..	43	21	31	51
Stenoperla prasina ..	3	4	2	..
Other stone-flies ..	5	6	3	3
Caddis—				
Olinga feredayi ..	11	17	14	7
Pycnocentria spp. ..	6	13	7	..
Pseudonema spp. ..	..	2	..	4
Other caddis ..	14	23	27	9
"Creeper" ..	3	1	1	..
Water-boatmen ..	9	..	..	..
Diptera	11	34	17	15
Aquatic beetles ..	5	7	143	1
Land beetles ..	17	2	5	..
Oligochaetes ..	3	1	3	7
Hydrocarinae ..	..	..	..	..
Gammarids ..	..	..	..	83
Fresh-water prawns ..	2	4	..	..
Fresh-water crayfish	3	1	..	..
Mollusc *Potamopyrgus*	..	..	..	..
Other molluscs ..	..	..	..	..
Bullies	..	4	..	2
Inanga, or whitebait	..	3	..	..
Other organisms ..	..	..	..	..

TABLE F.—AREAS WITH GRAVEL AND BOULDER BOTTOM; HEAVILY BUSHED BANKS; RAPIDS.

Organisms.	River Whakatiki, about 1 Mile from Confluence with River Hutt: February, 1930.	River Waikanae, above Railway-bridge: March, 1930.	River Waipoua, just above Masterton: January, 1930.	Kaiwarra Stream, Wilton's Bush: February, 1930.
May-flies—				
Ephemeridae ..	..	1	..	..
Siphlonuridae ..	43	59	17	15
Leptophlebiidae ..	37	57	41	62
Stenoperla prasina ..	15	11	9	5
Other stone-flies ..	12	15	5	7
Caddis—				
Olinga feredayi ..	31	43	17	9
Pycnocentria spp. ..	35	51	9	5
Pseudonema spp. ..	..	..	..	..
Other caddis ..	12	33	25	17
"Creeper" ..	16	15	5	11
Water-boatmen ..	..	..	..	..
Diptera	7	3	..	1
Aquatic beetles ..	3	5	4	..
Land beetles ..	..	..	6	1
Oligochaetes ..	3	5	1	..
Hydracarinae ..	..	..	..	..
Gammarids ..	..	..	..	..
Fresh-water prawns ..	..	..	..	..
Fresh-water crayfish	2	3	2	1
Mollusc *Potamopyrgus*	..	..	..	..
Other molluscs* ..	5	3	..	..
Bullies	..	..	..	..
Inanga, or whitebait	..	..	..	..
Other organisms† ..	1	..	..	..

* *Latia neritoides.* † One small brown trout.

TABLE G.—SUMMARY OF AREAS.

Organisms.	Sample Area No. 1 and Table B. Pebble and boulder bottom; bare banks; moderate current.	Sample Area No. 2 and Table C. Muddy bottom; a little vegetation; very slow current.	Sample Area No. 3 and Table D. Pebble and boulder bottom covered with algae; no bush; nearly stagnant.	Sample Area No. 4 and Table E. Gravel and boulder bottom; bushed banks; pools.	Sample Area No. 5 and Table F. Gravel and boulder bottom; bushed banks; rapids.
May-flies—					
Ephemeridae ..	1	..	..	1	..
Siphlonuridae ..	..	..	..	16	44
Leptophlebiidae ..	10	5	10	41	72
Stenoperla prasina ..	..	..	..	2	11
Other stone-flies ..	..	..	1	3	13
Caddis—					
Olinga feredayi ..	8	45	18	11	38
Pycnocentria spp. ..	..	..	4	4	28
Pseudonema spp. ..	..	6	6	..	..
Other caddis ..	4	23	16	20	18
"Creeper"	..	..	..	1	13
Water-boatmen ..	2	7	41	2	..
Diptera	7	26	34	13	2
Aquatic beetles ..	12	4	32	26	2
Land beetles ..	2	..	2	4	1
Oligochaetes ..	1	11	5	4	2
Hydracarinae ..	..	2	74	..	..
Gammarids	..	71	11	21	..
Fresh-water prawns ..	..	1	..	1	..
Fresh-water crayfish ..	..	..	..	1	2
Mollusc *Potamopyrgus*	5	76	33	..	..
Other molluscs ..	..	1	..	..	..
Bullies	1	1	1	1	..
Inanga, or whitebait ..	..	2	..	1	..

What do these figures signify ? It seems to me pretty evident that certain broad issues are plainly manifest—to wit, 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.

Sample areas 4 and 5 and Tables E and F represent, to some degree, streams in virgin bush, and may be held to typify our waters before they were spoilt, though, of course, the fauna is much reduced through the ravages of certain birds.

Sample area 1 and Table B may be considered as representing what happens when the aforementioned areas have been cleared of bush. There is no longer a succession of pools and rapids ; the bottom becomes covered with layers of round pebbles and boulders ; aquatic vegetation is represented, if at all, only by a few hardier species of algae. As regards the fauna, the stone-flies are exterminated, most of the may-flies vanish except a few crevice-inhabiting or stone-hugging species of Leptophlebiidae, caddis diminish very appreciably, the " creeper " cannot exist, crayfish disappear ; only organisms of minor importance in the population, such as beetles and oligochaetes and diptera seem to hold their own, and sometimes mollusca in small numbers become established. Not until backwaters and deviations with slow water are formed, with the consequent growth of aquatic vegetation, do forms of life begin to appear in the water again.

Sample areas 2 and 3 and Tables C and D may be said to represent deviations. It will be noticed that the crayfish, " creeper," may-fly, and stone-fly do not reappear, but the caddis does, though here it should be stated that this is due rather to an influx of new species than to a return of all the original ones. Diptera, beetles, oligochaetes, and molluscs seem to make good progress in these conditions, and there is a great invasion of minute gammarids and the useless (from a trout point of view) water-mites.

But even if the new food were as valuable and abundant as the old—and it is not—it must be remembered that these sheltered places form only a small proportion of the new stream type, whereas the conditions exemplified in Tables E and F were prevalent almost throughout the entire length of the old stream type.

The tables, then, show with some emphasis and unanimity the deterioration of the stream-bed under modern conditions.

But when different examples of the same types of stream are compared one cannot help but be impressed with a minor lack of uniformity in the population, due perhaps to all sorts of different factors.

It would, therefore, be quite unjustifiable for me to take certain types of stream-bottom—*e.g.* (*a*) with large boulders, (*b*) with small gravel of a certain size, (*c*) with moss-covered stones, &c.—and calculate the percentage of certain organisms to so many places of decimals. However, the fact that types of stream-bed cannot be assessed as having a precise yield is, for our purpose, quite immaterial. The trout is a fairly omnivorous feeder and will, other conditions being constant, favour the best foraging ground. What we wish to know is which types of stream-bed are the most favourable food-producers and which less so. The analyses outlined above show us this, and the next step is to transform the less productive areas into more productive ones.

PROBLEMS OF STREAM REGENERATION.

Provision for Trout-reproduction.

In my last report (3) I emphasized that the root cause of the deterioration of our fisheries is the removal of bush from the stream-banks and catchment areas. I omitted to mention what must be regarded as one of the most harmful results of this removal—that is, the destruction of the spawning-grounds, owing to the greatly altered conditions of the streams. The area of natural spawning-grounds at present available must have been reduced very considerably during the last fifty years.

Consider the millions of trout put out by our hatcheries every year: the natural increase of one year's output alone—were there sufficient shelter, food, and suitable spawning-grounds—would be enough to provide abundant supplies of fish in every stream in the country. Yet, in spite of the millions added every year and their potential progeny, there does not appear to be a vast annual increase. Hewitt (2) believes the loss in America to be probably 95 to 98 per cent. of fry and fingerlings put out.

It is unreasonable to suppose, as some suggest, that this is due to over-fishing. The entire annual catch must be a negligible fraction of what is put into the river from the hatcheries, quite apart from the natural increase.

Natural reproduction could be considerably increased were the spawning-grounds extended and protected from destruction by ameliorative measures. At present we would seem to be almost entirely dependent on the hatcheries for our yearly supply of fish—an expensive and, perhaps, somewhat unsatisfactory state of affairs—and it might well prove advantageous were we to endeavour, by improving the streams wherever possible, to increase the number of fish reared naturally and thus to relieve some of the burden now placed on our hatcheries.

We are in the position of a rich and lazy man who spends much money on doctors, spas, and expensive treatments, when he could have kept in good health by the expenditure of a little common-sense and boot-leather.

There is no doubt that our entire system of treatment of the trout in its early stages requires extensive overhauling, because although we can produce a far higher percentage of hatched ova than would occur under natural conditions, yet possibly all the advantages we gain are more than counterbalanced when the artificially reared fry are plunged suddenly into their stern and unforgiving natural environment.

One of the weakest points of our production system is the time when fish leave the hatchery and are put into the stream. It is interesting to refer to a method adopted by the Massachusetts Commission in 1920 and quoted by Kendall (6). Here the eyed ova, one to two weeks old, were planted in suitable stretches of stream—shallow, spring-fed ones are suggested—in wire baskets or trays, of a heavy wire mesh, of such a size as to prevent the eggs slipping through. They are spread evenly in the baskets, in numbers varying from five hundred to one thousand to the square foot. The tray is placed in the stream, set on small wooden uprights forced into the bottom of the stream, and held about 2 in. above the bottom, so that the water entirely covers the container and its contents. The flow should be such as to give complete circulation in every part of the tray. After the basket is placed in position it is protected and concealed by covering it with brush or evergreen boughs in the form of a lean-to over the stream. As the eggs hatch, the fry drop through the mesh of the basket and lie quietly on the bottom until they begin to feed. When the time comes they rise and scatter far up and down the stream in search of possible feeding-grounds. This simulates closely the natural method of propagation.

Such a method could be easily tried at our Masterton hatchery, where a spring-fed creek runs through the grounds, and the experiment might prove well worth while.

The paper (6) by Dr. Kendall, quoted above, contains a considerable amount of useful information and suggestions. Amongst other ideas, he quotes Bean's suggestions for the protection of fry put out in headwaters and small tributaries, by making a number of miniature dams in these rivulets, thus increasing the area of food-supply, insuring a good water-supply for the young fish in dry seasons, and keeping them from being swept away by spring freshets; it also keeps them away from the large fish, generally found further downstream.

Attention is also directed to the chapter on inland water culture in Needham and Lloyd's classic (8). This is admirably lucid and full of ideas.

Provision for Habitat-improvement.

As stressed under the preceding heading, the lack of spawning-grounds restricts the annual increase; incidentally, it may be a reason why fish have been found to leave certain rivers.

But even supposing that the trout could spawn successfully in present conditions, their myriad progeny would be menaced by a further consequence of the shifting stream-beds—namely, lack of sufficient food and shelter.

From whichever angle the problem of fishery deterioration is tackled, it invariably leads back to the fundamental cause, the destruction of the bush—which, incidentally, is still allowed to continue.

Conversely, a reversal of this disastrous policy would improve not one aspect of the trouble alone, but each and all; further, the improvement of the individual factors would react favourably to their mutual benefit.

Yet, although this is undeniable, are there any signs of a disposition on our part to tackle the necessary ameliorative measures?

A certain species of solitary bee forms its nest of a cell of mud; in this cell it deposits a number of loads of food for the future grub, lays an egg on top, and seals up the cell. If during the process of filling the commissariat the bottom of the cell is cut away, the bee will still carry out her normal programme, happily oblivious of the fact that every load she puts into the cell falls out through the bottom. Our annual stocking of the streams may not be so very dissimilar. The bee, however, does not possess the power of reasoning, man's proudest attribute.

Such measures as we are taking at the present time are concerned solely with the collection of existing data, on which to base a future policy. It is true that too much data cannot be gathered; every possible fact that is established will be of help in the future; but at best this is a passive line, and side by side with research of this kind should march experiments of a constructive nature

There is no real reason why experiments in rebushing and stream-engineering should not be made. Extra expenditure need not be involved. For instance, a hatchery might be closed down (as a hatchery) for one year and its personnel and resources used to restore a particular area.

The money usually expended for hatchery purposes—*e.g.*, the purchase of ova—would instead be used for seedlings and so forth. No doubt, voluntary help from license-holders might be forthcoming if the scheme were properly organized and fully explained to them ; and here also would be a great opportunity for the critic to employ his energies constructively.

Before restoring the area, it should be examined as fully as possible by the biologist, the fauna and flora being sampled in a large number of places per unit area both quantitatively and qualitatively, and particulars of the stream taken—*e.g.*, depth of water, rate of flow, nature of the bottom, &c. This examination should cover a whole year, so that conditions all the year round may be known.

After the area has been restored, the biologist should resurvey the area bi-monthly or quarterly for the next five years. A similar area in the neighbourhood, left unrestored, should be surveyed at the same time as a check.

The experimental area need not be very large, but it should be of sufficient size to give the factors of the locality a fair chance to make their influence felt—say, at least 400 yards of stream. It should include backwaters or places where backwaters could be made, for these are the food-reservoirs of any stream ; they swarm with food, yet, because of their sluggishness, are little frequented by trout.

The experiment should not be confined to one factor, but should be extended to as many as possible, consistent with not making the areas of experiments so small as to be valueless.

The area should be subdivided into smaller areas, each of the same size. In one area a certain growth should be encouraged, in a second another, in a third yet another, whilst in a fourth a mixed growth could be used. Elsewhere the interaction of various ecological factors might be deliberately fostered and the results noted.

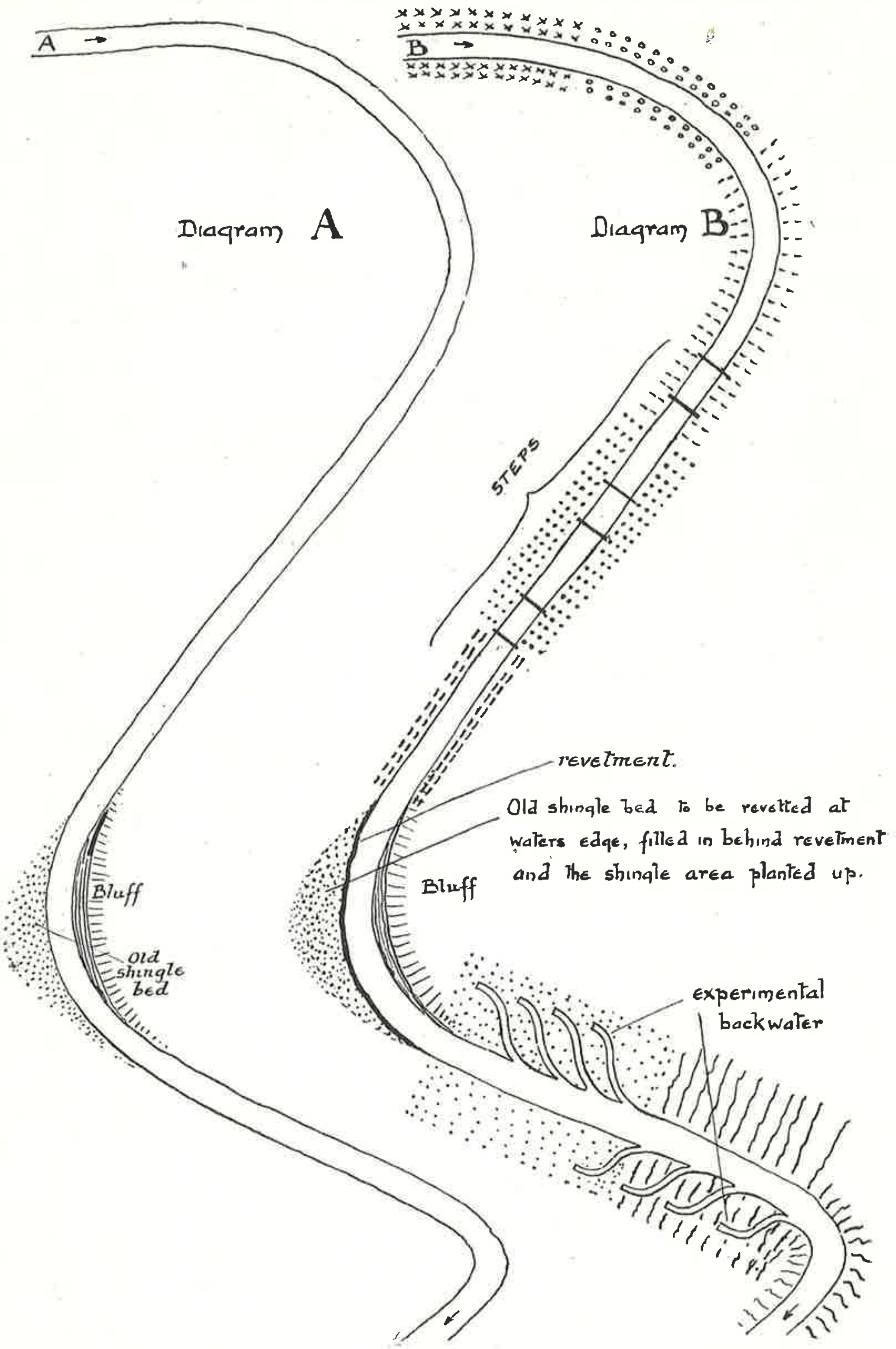
The backwaters would be specially utilized for the growth of different kinds of aquatic and subaquatic vegetation. Here, to my mind, is the greatest and quickest field for finding how to improve the food-supply, for the knowledge gained here in half a dozen years could be at once utilized on a large scale quickly and inexpensively. Elsewhere, the efficacy of different methods of harnessing the stream might be tested. In short, such an area offers unlimited scope for intensive and constructive experiment.

Diagrams A and B illustrate a hypothetical experimental area before and after regeneration.

The area is of a typical piece of stream in the shape of an inverted " S." It is in a gently sloping valley, where the bush has been cleared. Below the first bend there is a straight stretch, where the water is very fast after a freshet ; consequently this stretch is lined with loose shingle, and a bed of it has been deposited at the next bend, stretching well outside the normal bed, as the water renews its incursions at its outer edge, and freshet-borne material is also deposited there. The conditions of this imaginary site could be found, reproduced in reality, in hundreds of places in this district.

To regenerate this area it is proposed to plant up the banks with a variety of vegetation, represented by different markings on the diagram : thus one marking might represent manuka, another a mixture of fuchsia and wineberry, a third kowhai and lacebark, &c.

Next, the straight stretch of stream, which at present has a bed in the form of a moving mass of menace after each heavy rainfall, is to be harnessed to a life of peaceful fruitfulness by " stepping " it, so that it will form a series of pools and rapids.


A →
Diagram A
Bluff
Old shingle bed
B →
Diagram B
STEPS
revetment.
Old shingle bed to be revetted at waters edge, filled in behind revetment and the shingle area planted up.
Bluff
experimental backwater

The old shingle-bed is to be covered with a layer of soil and planted up, and protected from future floods by revetting the normal edge of the stream to a sufficient height.

Farther down-stream will be a series of experimental backwaters, of somewhat sinuous outline and joining the river at a narrow angle. Each backwater should be primarily devoted to a specialized flora, so that in one *Myriophyllum* should predominate; in another, *Potamogeton;* in a third, watercress; and so forth. Secondary species will, of course, spring up naturally in association with the primary water-weed. Finally, one backwater should be left unplanted, and allowed to reproduce naturally whatever the factors of the habitat decide. A census of the fauna should be taken at intervals.

There is no doubt that at present much of fresh-water mileage is hardly worth fishing, besides being an eyesore and a danger to adjacent areas. All this could be altered and the greater part of these water-stretches so improved as to be a valuable asset to the fisherman as well as a great gain from the aesthetic and social point of view.

Hewitt (2), in his investigations in America, found large areas of stream that were unsuited to hold trout continually: he said that the fish were unable to stay in water travelling at more than 200 ft. per minute—*i.e.*, about $2\frac{1}{3}$ m.p.h.—and were more frequent in water below 50 ft. per minute (1,000 yards per hour). That whereas when the bottom was composed of small stones the velocity of the stream there was much the same as on the surface, it was very much less with a bottom of large stones, and with boulders practically nil. That in the rock pools, though there was little food, they were preferred by trout because of the protection there from rounded stones, which were a danger to them in the gravelly rapids during freshets. There is no evidence of this danger here, and local fishermen question the possibility of damage from this source. He concluded that slower water was necessary, with good hiding-places, security from freshets, and abundant food, and remarked, "If these conditions could be attained, the stocking problem would solve itself. The fish would do their own stocking." He then goes on to suggest stepping the stream by a series of slow dams, and describes and illustrates how this could be done at a very small expenditure.

ADDENDUM.

Conditions in some North Auckland Streams.

Report on a Trip to North Auckland.

This journey was undertaken at the end of February, 1930, and terminated at the end of the first week in March.

The district of the North Auckland territory which I covered, mainly the locality south-east of a line drawn from Riponui to Hukerunui (a few miles north-west of Whangarei), consists of undulating swampy land, drained by a number of sluggish creeks and by the main river, the Wairua.

No trout were seen, and, though I understood before I visited the district that this was due to the water-temperatures being too high, investigation of actual temperatures on the spot and observation of the aquatic fauna led me to the conclusion that other features than temperature are responsible for the lack of trout.

The water-temperatures at midday averaged 17·5 degrees C. (63·5° F.) —mean of twelve observations—by no means high for this time of year, nor even appreciably higher than those found in sluggish waters in the Wellington District.

At night, the humid conditions gave rise to a ground-mist and this blanket keeps the temperature fairly equable, though in the early morning it is distinctly chilly.

The fauna of the creeks is similar in most respects to that of those farther south, crayfish being abundant in the faster streams.

Those species of aquatic insects which are found in the slower streams of the Wellington District are common here; those of the rapids, as might be expected, were very sparsely represented, but "creeper" was found in places.

Thus, using the may-fly as an indicator, *Atalophlebia versicolor* was the predominant species, *A. cruentata* was also common and the Leptophlebiidae, in general, were far more heavily represented here than farther south.

No Ephemeridae were found, but this is probably due to my not encountering a favourable position for their burrows.

The Siphlonuridae were represented by only one species of the genus *Ameletus*, probably a new species very closely resembling *A. flavitinctus*, but, as only half-grown nymphs were found, it is possible that they were a variety of *A. flavitinctus* differing slightly from the central New Zealand type.

The nymphs of two species of *Atalophlebia* were also found.

The fauna of the slower creeks and of the Wairua River was of a different type. Ephemeroptera were not in evidence, there were a few caddis, but the two orders mainly found were Diptera and Odonata. Members of this latter order were extraordinarily abundant: there were countless individuals, and from one spot I noticed five different species pass me within a minute—viz.: *Xanthocnemis zelandica*, *Austrolestes colensonis*, *Aeschna brevistyla*, *Uropetala carovei*, and a species of the family Corduliidae.

But the main thing that strikes the eye and ear is that throughout the whole district the Orthoptera predominate. In the high grasses, which grow luxuriantly, there is a wealth of crickets (Gryllidae) and long-horned grasshoppers (Tettigoniidae), and the manuka is full of stick insects (Phasmatidae). In addition, the whirr of the large locust or short-horned grasshopper (Acridiidae) is common, and I also found mole-crickets (Gryllotalpidae).

In the trees tree-crickets and cicadas are much in evidence.

A small bluish butterfly (*Zizina labradus*) was very abundant.

The waters were very slightly acid, averaging a pH of 6·8. This acidity is not sufficient to be injurious to trout, and I am inclined to the opinion that the general muddiness of the waters is probably the most inimical factor: it would, in any case, preclude the successful reproduction of either brown or rainbow trout.

There is plenty of trout-food in these waters. On two of the days excursions were made westwards and northwards, and the local waters explored. The results did not differ appreciably from those obtained at the main base.

On the return journey a stop was made at Taumarunui, and the Wanganu and one of its smaller tributaries reconnoitred.

These waters resemble the hilly ones of the Wellington District, the pH being slightly alkaline (7·1), the fauna being practically identical with that of such rivers as the Waikanae (listed in a previous report). A few trout were noticed at various places in this river and there were also bully. No inanga were observed, but this, of course, must not be taken to mean that there are none, for the observations were limited to a few hours and to an extent of a few hundred yards in a number of different parts.

REFERENCES.

(1) Pond, R. H. The Biological Relation of Aquatic Plants to the Substratum. U.S. Commission of Fish and Fisheries. Washington, 1905.

(2) Hewitt, E. R. Telling on the Trout. Charles Scribner's Sons. London, 1930.

(3) Phillips, J. S. A Report on the Food of Trout. New Zealand Marine Department. Fisheries Bulletin No. 2. Wellington, 1929.

(4) Phillips, J. S. A Revision of New Zealand Ephemeroptera. Trans. N.Z. Inst., Vol. 61. pp. 271–390, 1930.

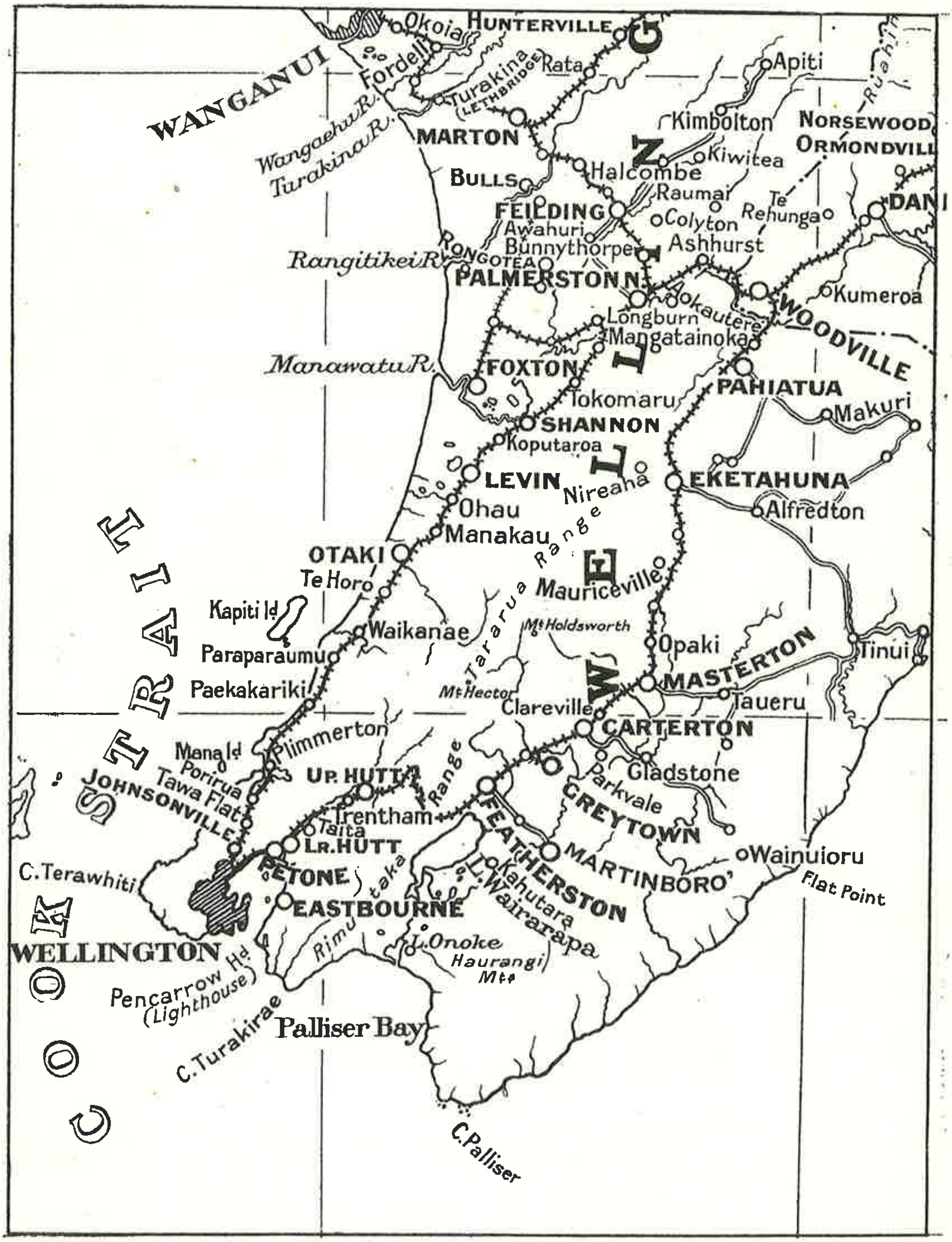
(5) Tillyard, R. J. Studies of New Zealand Trichoptera. Trans. N.Z. Inst., Vol. 53, 1921, and Vol. 56. 1924.

(6) Kendall, W. C. The Status of Fish Culture in our Inland Public Waters, and the Role of Investigation in the Maintenance of Fish Resources. Roosevelt Wild Life Bulletin, Vol. 2, No. 3. 1924.

(7) Mather, W. M. Fresh-water Algae of the Hutt Valley. Unpublished thesis. Wellington, 1927.

(8) Needham, J. G., and Lloyd, J. T. The Life of Inland Waters. The Comstock Publishing Co., Ithaca, New York. 1916.

(9) Needham, P. R. Quantitative Studies of the Fish Food Supply in Selected Areas: A Biological Survey of the Erie-Niagara System. State of N.Y. Conservation Dept., Albany, N.Y., 1928.



WANGANUI
HUNTERVILLE
Okoia
Fordell
Turakina
(LETHBRIDGE)
Rata
Apiti
Wangaehu R.
Turakina R.
MARTON
Kimbolton
NORSEWOOD
ORMONDVILL
Kiwitea
BULLS
Halcombe
Raumai
Te Rehunga
DAN
FEILDING
Awahuri
Colyton
Bunnythorpe
Ashhurst
Rangitikei R.
RONGOTEA
PALMERSTON N.
Aokautere
Kumeroa
Longburn
Mangatainoka
WOODVILLE
Manawatu R.
FOXTON
PAHIATUA
Tokomaru
Makuri
SHANNON
Koputaroa
LEVIN
Nireaha
EKETAHUNA
Ohau
Alfredton
Manakau
OTAKI
Tararua Range
Te Horo
Mauriceville
Kapiti Id.
Waikanae
Mt Holdsworth
Paraparaumu
Opaki
Tinui
Paekakariki
MASTERTON
Mt Hector
Taueru
Clareville
CARTERTON
Plimmerton
Mana Id.
Gladstone
Porirua
UP. HUTT
Rimutaka Range
Parkvale
Tawa Flat
GREYTOWN
JOHNSONVILLE
Trentham
Taita
LR. HUTT
MARTINBORO'
Wainuioru
PETONE
FEATHERSTON
Flat Point
C. Terawhiti
EASTBOURNE
Kahutara
L. Wairarapa
WELLINGTON
L. Onoke
Haurangi Mts
Pencarrow Hd. (Lighthouse)
C. Turakirae
Palliser Bay
C. Palliser
COOK STRAIT
WELLINGTON

By Authority: W. A. G. SKINNER, Government Printer, Wellington.—1931.
[1,000/2/31—13122