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ACCLIMATISATION SOCIETY.

EELS

Life-history of the Two Species of New Zealand Fresh-water Eel

by
D. CAIRNS,
Department of Scientific and Industrial Research,
New Zealand.

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Foreword

by

L. O. H. TRIPP, ESQ., O.B.E.,

Chairman, 1906-1917. *President,* 1918-1944,

Chairman N.Z. Acclimatisation Societies.

I have read with much interest the able report by Mr. Cairns in "The Life History of the Two Species of New Zealand Fresh-water Eel."

I think the Council of the Wellington Acclimatisation Society is to be congratulated in having the report reprinted so that as many fishermen as possible can study it.

I have also perused the letter addressed to the Society by Mr. Cairns in which he outlines a plan for the trapping of eels from the Wainui Stream and subsequent Scientific Studies to determine the effect on the Trout Population.

I hope at a later date it will be possible for the Society to carry out the plan suggested by Mr. Cairns and that if carried out it will prove successful so that the fishing will be improved.

Everyone interested in the improving of the trout fishing in the Dominion will I feel sure be grateful to the Society if the experiment suggested by Mr. Cairns can be given effect to.

LEONARD O. H. TRIPP,

President.

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EELS

Life-history of the Two Species of New Zealand Fresh-water Eel.

by

D. CAIRNS.

LIFE-HISTORY OF THE TWO SPECIES OF NEW ZEALAND FRESH-WATER EEL.

PART I.—TAXONOMY, AGE AND GROWTH, MIGRATION, AND DISTRIBUTION.

By D. CAIRNS, Department of Scientific and Industrial Research, formerly Fisheries Biologist to the Marine Department, New Zealand.

Summary.

The taxonomy of the two species of fresh-water eel in New Zealand is discussed. Statistical evidence is presented on which is based an accurate method of separating the two species.

The age and growth of New Zealand fresh-water eels has been studied. Scales and otoliths were used to determine the age. The growth of eels from the time of arrival in fresh-water until the return migration to the sea is given.

The migrations and distribution of the two species of eel in fresh water have been recorded, and are discussed.

INTRODUCTION.

VARIOUS aspects of the biology of the fresh-water eels of the world have received the attention of fisheries experts for many years. The most intensive studies have been carried out in countries where the eel is of economic importance.

In New Zealand, studies of the eel have been neither intensive nor extensive. The Maori knowledge of the eel was principally confined to the time of movements and migrations, methods of capturing, and utilization as food. Much mythology and legend has been woven round the subject by the Maoris. This has been adequately treated by such writers as Mair(12), Best(2), Hamilton(8), and Downes(4, 5). The writer has not dealt with this subject. Literature in connection with the taxonomy of the fresh-water eels in New Zealand is fairly complete. The subject has received the attention of Phillips(13), Schmidt(14), and Griffin(7). Apart from these studies little has been written on the biology of New Zealand fresh-water eels. Notes on various aspects have been published by Canavan(3), Sherrin(15), Duigan(6), Knox(10), Hector(9), and Archey(1).

The main objects of this investigation were (i) to study the migrations, distribution, age, growth, food, and sexual development of the two fresh-water eels in New Zealand; (ii) to study the eel-trout inter-relationship, and in particular the competition for food and existence.

TAXONOMY.

Schmidt(14) discussed the characters of five eels which had been described for the New Zealand area. He decided that only two species could be upheld, and these he called *Anguilla aucklandii* Rich. and *Anguilla australis* Rich var. *orientalis*. Griffin(7) has recently revised this nomenclature and named the eels *Anguilla dieffenbachii* Gray. and *Anguilla australis schmidtii* Phillips. The writer accepts this nomenclature.

As the differences between the two eels are not generally known Table I has been prepared to enable identification to be made.

TABLE I.

Anguilla dieffenbachii (Long-finned Eel). Fig 1.	*Anguilla australis schmidtii* (Short-finned Eel). Fig 2.
1. Dorsal fin much longer than ventral fin.	1. Dorsal fin approximately equal in length to ventral.
2. Vomerine teeth in a narrow band.	2. Vomerine teeth in a club-shaped formation.
3. Eye above and forward of angle of jaw.	3. Eye directly above angle of jaw.
4. Lips thick.	4. Lips thin.
5. Head broad.	5. Head narrow.
6. Nasal organs prominent.	6. Nasal organs small.
7. Mouth gape wide and jaws strong.	7. Mouth gape narrow and jaws small.
8. Tail broad, caudal fin well developed.	8. Tail narrow, caudal fin poorly developed.
9. Pectoral fins prominent.	9. Pectoral fins small.
10. Dorsal area of body black; ventral side a yellowish brown.	10. Dorsal part greenish-brown; ventral a dull white.
11. May reach over 180 cm. in length and 18 kg. in weight.	11. Seldom grows over 90 cm. in length and 1.8 kg. in weight.
12. Average length adult female, 85-95 cm. Average length adult male, 55-65 cm.	12. Average length adult female, 75-85 cm. Average length adult male, 35-45 cm.
13. Average weight adult female, 1.8-2.7 kg. Average weight adult male, 0.9-1.1 kg.	13. Average weight adult female, 1.1-1.4 kg. Average weight adult male, 0.25 kg.

Difference of colour are not reliable when used alone. It has been found that the short-finned eel can be recognized fairly readily in the water because of its rapid movements and fairly distinct scale pattern.

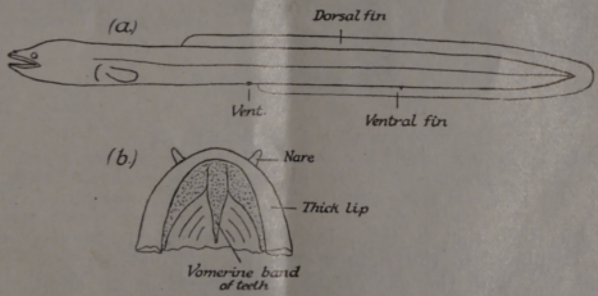

FIG. 1.—*Anguilla dieffenbachii* (long-finned eel).
(*a*) Outline of eel showing position of dorsal fin, thick lips and position of eyes; (*b*) upper jaw. (Note central or vomerine band of teeth.)

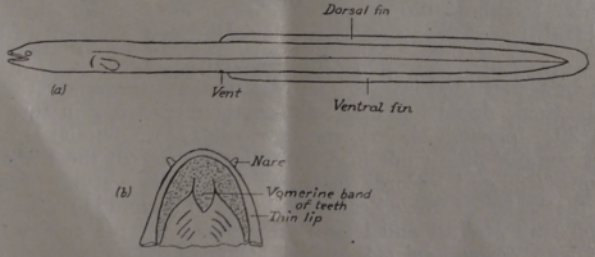

FIG. 2.—*Anguilla australis Schmidtii* (short-finned eel).
(*a*) Outline of eel showing the position of the dorsal fin and eye; (*b*) upper jaw. (Note the central or vomerine band of teeth and the thin lips.

Schmidt(14) has outlined in detail a method for the separation of these two species on the length of the dorsal fins. The method is as follows: The distance between the anterior edge of the dorsal fin and the position of the vent is measured along the body of each specimen (Figs. 1 and 2); this length is then expressed as a percentage of the total length of the body. Since the dorsal fin of the long-finned eel is much longer than the dorsal fin of the short-finned eel the percentage obtained in the calculations effectively separate the two species. Schmidt found that the percentage for the long-finned eel was between 8 and 14, while for the short-finned eel it was between — 1 and + 5. There is thus no overlapping as far as this character is concerned. Schmidt suggested in his paper that the range as given above would be widened when larger samples than he had at his disposal were examined. The range of the writer's material, with full details, are recorded in Table II.

TABLE II.

Percentage Difference.	Number of Eels.	Percentage Difference.	Number of Eels.
Long-finned Females.		*Long-finned Males.*	
6-7	3	8-9	3
7-8	21	9-10	6
8-9	30	10-11	11
9-10	152	11-12	10
10-11	463	12-13	6
11-12	524		
12-13	310	Total ..	36
13-14	96		
14-15	44	*Short-finned Females.*	
15-16	11	—1-0	9
16-17	4	0-1	71
17-18	3	1-2	143
18-19	1	2-3	176
19-20	1	3-4	127
		4-5	50
Total ..	1,663	5-6	7
		Total ..	583

It is thus seen that in these large samples all specimens could, with certainty, be placed in the right species on this one character alone. It was found that with the use of the teeth bands as an additional guide, together with the position of the eye, there was no difficulty in deciding the species. The writer has not recorded any other species of fresh-water eel in New Zealand than those previously recorded. In view of the widely placed sampling stations and the size of the samples taken it would seem doubtful if any other species does exist in New Zealand waters.

AGE AND GROWTH

Scales were first used by Gemsoe(19) for the determination of the age of the eel. Some doubt has been cast on their efficiency in this direction by Gilson(20), Johnson(24, 25), and Hornyold(23). The latter concluded that scales were of little value in determining the age of the British eel.

Johnson (*loc. cit.*) records instances of greatly varying numbers of zones on the scales of New Zealand eels. McFarlane(11) used scales in conjunction with otoliths and length frequencies for the determination of the age of New Zealand eels. He records: "The least variation in the number of the annuli and the highest number of annuli occur in the scales along the lateral line, in the posterior third of the body." This is the position in which the scales first form.

The writer has used both scales and otoliths for the determination of the age of the eel. The scales commence development near to the lateral line and close to the vent. Each scale is lodged in a pocket in the skin just below the superficial layer of the epidermis. They are flat disk-shaped objects with zones of platelets indicating periods of growth (Fig. 3). The otoliths (Fig. 3) are commonly termed ear bones and are contained in small capsules on either side of the brain.

The scales are removed with a sharp knife and mounted in water for examination. To remove the otoliths a knife is inserted between the angle of the lower and upper jaw-bone and the joint broken. A cut is made through the gill-arches and the whole of the roof of the mouth exposed by turning the lower jaw downwards. A transverse incision is made on the lower side of the cranium at a point where the otic or auditory capsules are situated and the cranium broken open at the incision to expose the brain

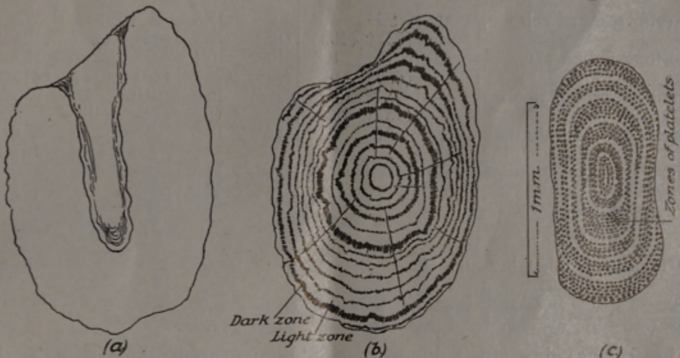

FIG. 3.—Otolith and scale of eel.
(*a*) Otolith, unground; (*b*) otolith, ground and mounted in aniline oil. Note dark and light zones, indicating thirteen years of growth (the cracks shown are the result of grinding); (*c*) scale. Note zones of platelets and clear areas representing six growth stages. Scale refers to (*c*) only.

and the auditory labyrinth. The otoliths are lodged in the auditory capsules and are paired. The grinding is carried out in the following way: Fine emery jeweller's paste is mixed with a little water on a sheet of thick glass. The otolith is fitted around the end of the forefinger with the convex side outermost. It is then ground against the glass surface with the emery powder as a grinding base. The otolith is examined from time to time under the binocular microscope to determine the stage of the grinding and the thickness. When grinding is complete the otolith is mounted in aniline oil and the dark and light zones counted. It was found advantageous at times to place the otolith in very dilute hydrochloric acid for a short period. This treatment had the effect of showing up the zones more clearly.

By a study of the otoliths of the young eels from the time they enter fresh water it was found that the scales of the New Zealand eels form regularly in the seventh year of life. McFarlane (11) also found this to be true. Thus, the scales as well as the otoliths, are of value in determining the age of eels in New Zealand.

The above conclusion was based on the assumption that the "Seewasserringe" of Hornyold (*loc. cit.*) or the nucleus of the otolith was complete when the elver reached fresh-water; that it represents a larval period of two years (there are two dark inner rings on the majority of the otoliths); and that the dark (or winter) rings and the light (or summer) zones represent complete years of growth. This latter point has been proved by McFarlane(11) and also overseas.

Table III gives the age and growth of New Zealand eels from one to nine years. Comparative figures are given for eels of similar ages in Germany (Ehrenbaum and Murakawa(17) and Holland (Tesch(29)). McFarlane's(11) figures for New Zealand are also given, his reliance on length frequencies probably accounts for some of the discrepancies noted between his figures and the writer's.

TABLE III.—AGE AND GROWTH OF EELS UP TO 10 YEARS.

Age in Years — — —	1-2.	3.	4.	5.	6.	7.	8.	9.	10.
Writer (short-finned eels) ..	At sea	5.7* (53)†	7.8 (105)	9.5 (85)	17.5 (23)	24.5 (32)	31.2 (28)	39.5 (18)	47.8 (19)
Writer (long-finned eels) ..	"	5.8* (45)†	8.7 (33)	10.8 (51)	16.1 (27)	20.4 (28)	25.2 (17)	31.5 (21)	39.0 (25)
McFarlane (long-finned eels)	"	6.0* (13)†	8.5 (12)	11.0 (13)	16.0 (8)	19.0 (14)	24.0 (10)	.. ..	.. ..
Ehrenbaum and Murakawa .	"	7.0 ..	8.2 ..	11.8 ..	14.5 (84)†	19.3 (141)	25.0 (114)	33.8 (75)	39.3 (21)
Tesch (river eels)	"	.. ..	.. ..	.. ..	17.6* (19)†	21.5 (20)	25.6 (8)	31.7 (7)	.. ..
Tesch (coastal eels)	"	.. ..	.. ..	.. ..	.. ..	22.1* (70)	24.7 (325)	31.7 (23)	34.1 (23)

* The average length in centimetres of each year group. † The number in the sample.

Sex organs had not become differentiated in any of the eels included in the samples shown by the writer in Table III.

The figures given in Table III are shown graphically in Fig. 4.

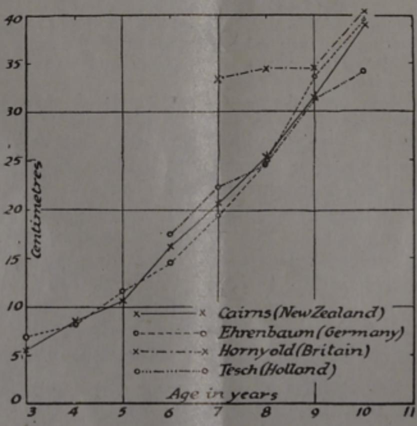

FIG. 4.

The growth of eels in Germany and Holland as recorded by Ehrenbaum and Murakawa(17) and Tesch(29) is shown to be very similar to that of the New Zealand eels. This similarity does not persist very much beyond the ninth year of life.

The comparison in growth between long-finned and short-finned eels is shown in Fig. 5. The short-finned eel grows more rapidly in length than the long-finned, but both male and female short-finned eels mature at a smaller size than the long-finned eel.

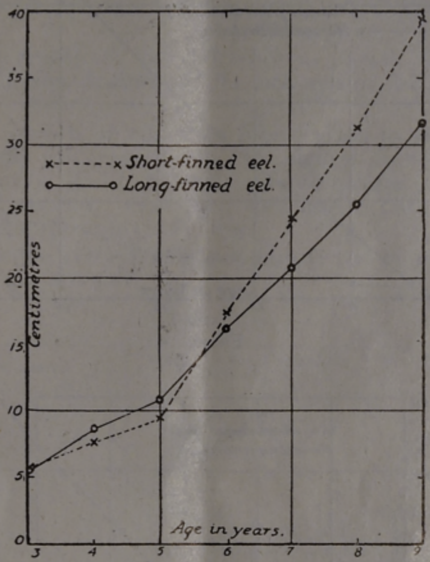

FIG. 5.

The age and growth of New Zealand eels from the tenth to the fifteenth year of life is given in Table IV, and a comparison with the age and growth of British eels is given in Fig. 6.

TABLE IV.—AGE AND GROWTH OF NEW ZEALAND EELS FROM THE TENTH TO THE FIFTEENTH YEAR OF LIFE.

Age in Years — —	10.	11.	12.	13.	14.	15.
—	Length, in Centimetres.					
Long-finned eel (females)	32.5-45.3 (52)	42.3-52.5 (64)	47.5-60.0 (44)	58.2-67.3 (75)	65.6-80.3 (38)	75.1-88.9 (4)
Short-finned eel (females)	42.5-58.3 (27)	52.4-61.0 (33)	57.5-70.6 (42)	66.3-80.2 (7)	75.0-92.5 (3)	.. ..
Long-finned eel (males)	38.9-45.2 (12)	50.2-57.8 (15)	53.5-62.0 (9)	62.4-65.3 (3)	.. ..	.. ..

The figures in parentheses give the number in each group examined.

Male and female eels have been recorded separately for the purposes of comparison in Table IV.

The more rapid growth of the New Zealand eels is obvious from Fig. 6. Hornyold's(22) sample may not be fully representative of the eels of Great Britain whereas the New Zealand material has been collected from all parts of the country.

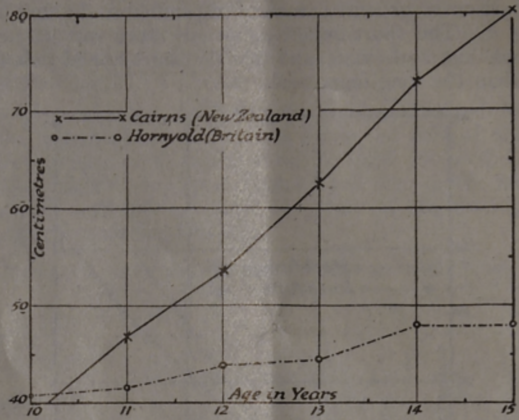

FIG. 6.

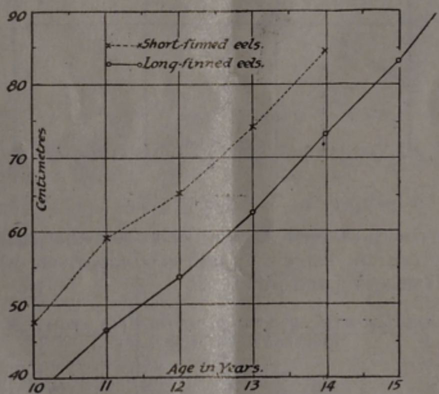

FIG. 7.

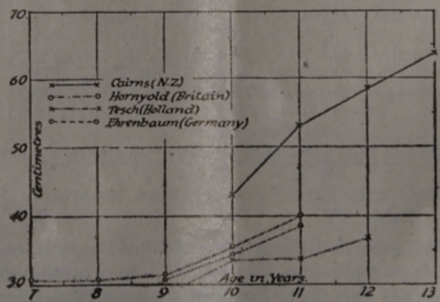

FIG. 8.

A comparison of the growth of the long and short-finned eels is given in Fig. 7. This graph indicates that the growth in length of the short-finned eel exceeds that of the long-finned eel at each age. It must be noted that the short-finned eel reaches maturity earlier in life and that it has not been recorded in the writer's samples longer than 92.5 cm. This latter was exceptional.

Fig. 8 shows graphically the difference in growth between the male long-finned eels of New Zealand and the male eels of Britain, Holland, and Germany.

The age and growth of eels from fifteen years to seventeen years is represented by only a few specimens. The figures are as follows: fifteen years (five specimens), 75.1 to 88.9 cm.; seventeen years (three specimens), 95.0 to 107 cm.; eighteen years (two specimens), 120.6 and 134.8 cm.; nineteen years (one specimen), 145.5 cm.

Table V gives the average weight of female eels of the two species at lengths from 45 cm. upwards.

TABLE V.†

Length, in Centimetres.	Weight of Short-finned Eel (Females).	Weight of Long-finned Eel (Females).
*45 (18 in.)	185 gm. (5½ oz.)	224 gm. (8 oz.)
50.0	252 gm.	350 gm.
60.0 (24 in.)	473 gm.	668 gm.
70.0 (28 in.)	835 gm. (1lb. 14oz.)	1,036 gm. (2 lb. 5 oz.)
80.0 (32 in.)	1,279 gm.	1,475 g.m.
90.0 (36 in.)	1,587 gm. .. .. (Limit of length and size in samples taken.)	2,169 gm.
100.0 (40 in.)	..	3,560 gm.

* One hundred eels were measured for each size and the average weight recorded.
† The complete range of figures is given on the last page of this paper.

The table above indicates clearly that the long-finned female eel increases in weight much more rapidly that the short-finned female, although the latter, at each age-group, is greater in length.

MIGRATIONS FROM SEA TO RIVERS.

Schmidt(28) suggested, after a study of the ocean currents, ocean depths, and salinity measurements, that a great deep off the coast of the Great Barrier Reef, Australia, and near to the equator was the most likely place for the breeding-ground of the New Zealand eel. Schmidt based his statement on the fact that the two groups of eels which he had already studied spawned in areas which were very deep and in which the temperature and salinity were approximately the same as in the area mentioned above. No data have been collected regarding the sea-life of the New Zealand eel, but some facts given later lend some support to Schmidt's hypothesis, as does also the distribution of eels in Australia (Schmidt(28)).

The ocean currents which would bring larvae to our coasts from such a breeding-ground sweep down the east coast of Australia and into the Tasman Sea. Here there is a convergence with a cold sub-antarctic current. The main sweep of water then passes up the west coast of New Zealand, while a minor branch passes to the south of the South Island and exerts some influence on the climate of the Chatham Islands. If the New Zealand eels breed in the region mentioned by Schmidt, then the first elvers to arrive in New Zealand rivers would come up the West Coast rivers. Records of the elver migrations are not very complete, but those which have been obtained show that the first "run" of elvers each year comes to the Waikato River, on the west coast of the North Island. Although the evidence is not conclusive, it would appear that the elvers are arriving off the New Zealand coast from the westerly direction.

New Zealand eel larvæ metamorphose close to the coast and begin an active swimming existence. The changes during metamorphisis are admirably described by Grassi and Calandruccio(21), Schmidt(27) and Ford (18). The body becomes thin and needle-shaped, the dorsal and ventral fins develop, and the first rudiments of the teeth begin to appear. The larvæ are then known as elvers (Fig. 9). Contact with the fresh water rapidly induces pigmentation, and the young eels swarm up our rivers in countless thousands. As soon as pigmentation commenced the elvers were found to take cover during the day and travel up the rivers at night.

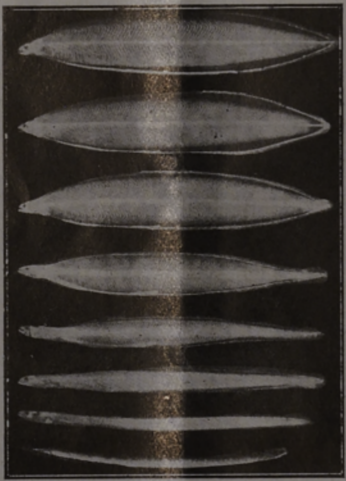

FIG. 9.

Metamorphisis of the eel larva to an elver. (After Schmidt.)

In the Waikato River, however, elvers have been observed running freely during the daytime. Elvers have been found to travel freely during times of flood or freshes in rivers. Thus, in many places, it was discovered by netting that they travel upstream during spring floods without being observed. The writer observed one "run" of elvers ascending the Waikato River, in daylight during a slight fresh, passing a point in the river for over eight hours; this shoal was over 15 ft. wide and 8 ft. to 10 ft. in depth. The elvers were packed closely within the shoal.

The elvers were between 5.7 cm. and 6.9 cm. when they entered fresh water. At this stage the gut was surrounded and embedded in a jelly-like material, and the diverticulum had only commenced formation. The teeth were rudimentary and a supplementary heart was present on the dorsal aorta, situated about three-quarters of the length of the fish from the head. Pigmentation commenced first near the lateral line and rapidly extended over the dorsal surface and along the tail. Scales were absent. The elvers sought cover in the lower reaches of the rivers lying buried in thousands, in the sand, under logs, under boulders and in the mud (Fig. 10). Young eels were found buried deep in stony banks often far from the running water, but always below the water-table. There was some evidence that they had access to certain waters by this subterranean path, but this will be studied later. The eels do not move freely from these habitats when feeding.

As the eels approach 10 cm. to 12 cm. in length large numbers leave the lower reaches of the rivers and migrate to the upper waters. The young eels are then heavily pigmented, the diverticulum is well developed, and the teeth are complete. The movement of these young eels up-stream in January and February may be correlated with the movement into fresh water of the elvers from the sea in October, November and December. These elvers swarm into the river mouths and, after a short period, com-

FIG. 10.

Typical habitat of young eels in estuarine waters. Hundreds of eels between 6 cm. and 15 cm. were removed from the rocks and lumps of earth shown.

mence feeding. The slightly older age-groups then travel up-stream. It is interesting to record that these upwardly-migrating young eels replenish the upstream population of eels, which is depleted in the autumn by the down-stream migration of mature eels. Thus a perfect ecological balance seems to be effected and food supplies are utilized to the best advantage of each size group.

This secondary movement was a well-defined migration, as it was observed at several different points in New Zealand. It was often accompanied by some elvers and a number of larger eels up to 45 cm. in length. At the power-house at Hora Hora, on the Waikato, the migration is observed each year. Migrations have also been observed regularly on the Waihou at Okoroire, at the Ohura Falls on a tributary of the Wanganui River (Mair(12), and at the Kaimata Dam in Westland (personal communication from Mr. Hobbs, Fresh-water Fisheries Biologist). The date of arrival at the power-house on the Waikato is very regular as the following figures show: 20th January, 1936; 18th January, 1937; 19th

January, 1938: 22nd January, 1939. These eels swarm up the inspection tunnels at the Arapuni power-house, often making the walls seem black because of their numbers. Access to the tunnels can only be by the minutest cracks, but the eels seem to be capable of moving along these provided the rock is damp. The problem of eel access to certain waters has exercised the minds of many people. During this migration eels are capable of climbing vertical walls provided the surface is damp. The eels go up the highest and steepest waterfalls in the country by travelling up the damp sides out of the main rush of water. During migrations they will travel across land in heavy rains, or if the grass is wet with dew. Thus they have found their way into almost all areas of permanent water. There are, however, certain waters in New Zealand to which eels cannot get (Hector(10)), and the reason appears to be that eels will not travel against a fast current rushing over bare rock for a considerable distance, or up waterfalls if the sides are not damp. The first of these places of interest is on the Waiau River in North Canterbury and was first observed by Travers(16). He concluded that a line of rapids some thirty miles below the source of the river acted as a physical barrier to the passage of eels. This rapid was not of the usual type and has been described by Travers (*loc cit.*).

No eels are found above this section of the river, and there is certainly no obvious difference in the water above the rapids. A similar section of water exists in the Waihou River at Okoroire, in the Waikato basin. Here the river passes almost underground in a narrow rocky channel only a few feet in width. The river is very fast and turbulent, and the rock walls smooth. Many days of intensive searching failed to yield any evidence that the eels go above the rapids. The absence of eels in the upper waters of the Waihou River is of great importance from the trout population point of view, and will be dealt with later in the paper.

On the Oraka Stream near Tirau there is a barrier similar to that described on the Waihou River at Okoroire. Eels congregate in large numbers below this barrier until a flood occurs. The water then rises and spreads out over the sides of the barrier, and the eels can travel upstream. This is an excellent example of delayed access.

Before the Arapuni Dam was built in the Waikato River eels could pass up the river as far as a section somewhat similar to the one just described in the Waiau (probably referred to by Hector(10) as Maungatautari Falls), situated about a mile above the present dam. Arapuni Lake has obliterated this region of fast water flowing between smooth rock walls which previously kept back the eels, and it is probable that they can proceed as far as the Huka Falls, once past Arapuni. Since Arapuni has been erected the power-house has been closed for one or two periods and eels have gained access to the waters above the dam. There are no eels in Lake Taupo above the Huka Falls. The number of eels in the river above Arapuni is very small compared with the numbers in the lower part of the river.

There are no eels in Lakes Rotorua and Rotoiti (Hector (*loc. cit.*)). The eels can proceed as far as the Okere Falls on the Kaituna River, but the smooth, dry rock walls of the fall are so shaped as to provide no surface on which the eels can grip. Attempts have been made by both Maori and white man to establish eels in these lakes, but without success.

A further case where eels are prevented from entering a portion of a water system because of a natural barrier occurs in the Waimarino Acclimatization Society's district. On the Wangaehu River sulphur springs enter the river near its source, and the influence of the pollution is evident for some considerable distance down-stream. Eels will travel up the river to a point (near Totangi) at which the pollution becomes too strong for them to live. The tributaries coming into the main river above this point are free from pollution and eels, and have been stocked with trout. On occasions when the sulphur pollution has become more concentrated than usual, and consequently travelled further down-stream, large numbers of eels have been killed in the lower part of the Wangaehu River.

Where access up the rivers is unobstructed samples taken at certain temporary hindrances have revealed the size of the young eels on this migration. In a sample taken on the Waikato River at Hora Hora, consisting of some thousands of young eels, the average length of one thousand picked out at random was 9.8 cm., the range being from 8.9 cm. to 12.0 cm. The run was mixed in species, there being 70 per cent. short-finned and 30 per cent. long-finned. There was a difference in the average length of a sample of either species; 150 short-finned eels averaged 9.5 cm., 150 long-finned eels averaged 10.6 cm.

On arrival up-stream the eels bury themselves in the mud under boulders and logs once more. The writer has dug out eels in great numbers from drains entering streams and rivers, one notable instance being on the Waihou, some distance below Okoroire. Here the eels were so thick in the side drains that every shovel full of mud revealed up to six individuals. These young eels had not long migrated up the Waihou River.

DISTRIBUTION

Professor Johs. Schmidt, during his visit to New Zealand, and subsequent to his examination of the material which had been forwarded to him from the Dominion, came to the conclusion that New Zealand eels were distributed, in general, on a geographical basis. This is shown by reference to his map (Schmidt(14, p. 387)). Schmidt concluded from his material "that *Anguilla aucklandii* (long-finned eel) belongs mainly to the south and west, *Anguilla australis* (short-finned eel) chiefly to the north and east." In order to conduct a re-examination of the data on which Schmidt made this statement the Fisheries Branch of the Marine Department obtained in detail from the Copenhagen Laboratories the location of the collecting stations and the nature and the size of all the samples which Schmidt had at his disposal. This data was made available to the writer. Of the 1,400 eels which comprised Schmidt's total sample, 558 were elvers, and over 100 were small eels. As these eels have been shown to be migratory it does not seem to be correct to base any distribution data on their position when captured. This material must be eliminated, and it reduces Schmidt's sample considerably, although it would seem that he used all the material as a basis for his distribution map. The rest of the material consists of adults, but the collecting stations were so scattered and the samples from some of them so meagre that it is surprising that Schmidt attempted any generalizations from it. In a study of the distribution of eels in New Zealand waters the writer took samples from over one hundred collecting stations. Some of the principal collecting stations, and the number, species, and sexes of the eels obtained, are recorded in the appendix to this Part. Approximately 25,000 eels were examined, none of which were migratory. The distribution recorded by the writer is not in agreement with that recorded by Schmidt (see above). The following examples will give some indication of the distribution based on the data from the above collecting stations. Eleven thousand eels were taken from the Hedgehope River and its tributaries in Southland. These were all long-finned females. The Hedgehope River is a tributary of the Oreti (or New) River. In the estuarine waters of the Oreti the short-finned female eel was taken along with the long-finned female eel. At a collecting station situated where the tidal influence ceases to affect the river-flow, 98 eels were taken. Of these, 97 were long-finned female eels and 1 a short-finned eel. Above this point all samples consisted of long-finned female eels. This was also true for the Waimatuku Creek, the Aparima River, and the Waiau River. The Waituna Lagoon contained both long and short-finned male and female eels.

In the Kakanui River in Otago the short-finned female eel was taken only as far as the tidal influence affects the flow of the river. This was also true of the Waimakiriri River and the Rakaia River in Canterbury. Lakes Ellesmere and Forsyth, however, contained both sexes of both species and in these lakes the short-finned female was in the majority.

In the North Island the rivers of the Wellington Province were extensively trapped. The Hutt River, Otaki River, Waikanae River, Ruamahanga River, Tauherenikau River and many others of the fast-flowing, shingle-bottomed rivers have the short-finned eel only in the lower reaches, which are, as a rule, deep and slow-flowing. In the Wanganui and the Manawatu Rivers the writer found that the short-finned eel penetrated well inland. In the Wanganui River it is not found very far above Pipiriki, and in the Manawatu River not far above Palmerston North. The lake-controlled Waikato River has short-finned eels inhabiting the same water as long-finned eels. Only the females of the two species, however, travel up-stream. In the Waipa River, which is deep and sluggish for a considerable distance up-stream (above its confluence with the Waikato River at Ngaruawahia), there is a big population of short-finned female eels. This river receives the waters of a number of small lakes. An interesting fact was noted during sampling of this river. A small tributary, the Kaniwhanawhana Stream, joins the main Waipa at Karamu. This stream comes from steeper country to the west, and about half a mile from the main river no short-finned female eels were obtained, although these eels were obtained many miles farther up the Waipa River. This change in population seemed to be correlated with the change in type of the stream to a fast-flowing boulder-strewn mountain water. The population of eels in this habitat was entirely long-finned. In the Waihou River the short-finned female eels are to be found some distance above Te Aroha, but up-stream from here the population is almost entirely long-finned females. Long-finned female eels are also found in the Kaueranga and Waitewhata tributaries.

The Kaituna River, fed from Lakes Rotorua and Rotoiti and the hot-spring country, seems an ideal environment for the short-finned female eel. It penetrates well up-stream, co-existing with the long-finned female eel.

On the evidence presented above and further supported by the records given in the Appendix to this Part the distribution of the two species in New Zealand is as follows: The long-finned male eel (*A. dieffenbachii*) and the short-finned male eel (*A. australis schmidtii*) are found only in the estuaries of the large rivers and in the coastal lakes and lagoons; the long-finned female eel is found in all areas of permanent water to which access is possible (see earlier comments on eel barriers); the short-finned female eel is confined principally to the lower reaches of rivers, coastal lakes, and some inland lakes in the South Island; in the North Island, particularly in the Auckland Province, this eel inhabits up-stream waters in the same environment as the long-finned female.

It has been recognised fairly generally overseas (Gilson(20), (Tesch, (29) and Hoover(22)) that the male eels do not frequent fresh water. This fact is supported by the evidence presented for the distribution of New Zealand eels.

The long-finned female eel is not confined mainly to the south and west as Schmidt (*loc. cit.*) maintained. It is found to inhabit all types of water from tiny streams to the largest rivers, coastal and inland lakes, and brackish estuaries and lagoons from Invercargill to Kaitaia—*i.e.*, both Islands of New Zealand.

The short-finned female eel is not distributed throughout all fresh waters of New Zealand. In the South Island it remains principally in the tidal waters of streams and rivers, in the coastal lakes, and some inland lakes. It appears to favour areas where rapid temperature changes do not occur, such as the deeper sluggish parts of large rivers, in lake waters, and in estuaries. In the North Island this distribution also holds. Large rivers, like the Wanganui and the Manawatu, have short-finned female eels penetrating over 100 miles from the sea. In the lake-controlled Waikato River and the deep sluggish waters of the Waipa River large populations of short-finned eels are to be found. Other rivers in the North Island—like the Hutt River, the Otaki River, the Waikanae River—have long-finned female eels up-stream and short-finned female eels in the estuarine, tidal, and super-tidal waters. Many of the tributaries of the Wanganui, Manawatu, and Waipa rivers have populations of long-finned females only.

The exact environmental conditions favourable to the short-finned female eel have not been studied in detail. The chief factors appear to be still or sluggishly-flowing water or spring and lake-controlled water. The largest populations of short-finned female eels in New Zealand were found in Lakes Forsyth and Ellesmere and the Kaituna, Waipa, and Waikato rivers. Further study is required to elucidate the problem of the factors influencing distribution.

Schmidt's statement that the short-finned eel is found mainly to the north and east requires considerable modification; indeed, in the writer's mind the statement is untenable.

HIBERNATION.

During the winter period the eels of most New Zealand waters hibernate into mud-bottomed backwaters, swampy areas, or drains, where they lie for the duration of the cold weather. Japanese workers(26) have indicated a definite correlation of reduced feeding velocity with low water-temperatures in eel populations. It is therefore highly probable that the reduction in water temperature in New Zealand brings about hibernation. Proof of this hibernation was obtained in several ways—firstly, it is well known that during the winter months (except in floods) eel-fishing is not carried out by Maori or white man because the eels are not moving about; secondly, the figures of daily catches in the Southland Acclimatization Society's eel-destruction campaign showed that the average daily catch for fifty pots during the five months from November to March (1937-38) was 130 eels per day, but, with the approach of colder weather in April, the figure fell to an average of 21 per day for the second and third week of this month. During the last few days of trapping the number had fallen to 10 to 12 eels per day, and as so few eels were feeding it was decided to cease systematic trapping. At no time could it be said that all eels had hibernated, as the figures indicate that a few remained, at least in the early part of winter. In the Waikato a party of seven, led by the writer, examined the bed of the Maungututu and Puniu streams at night for about five miles in each case, in bitterly cold weather, in July, 1939. No eels were seen.

Mr. Hobbs supplied the writer with data obtained during observations on fish-movements in Black Creek, Inchbonnie, Westland. Counts of eels feeding in one section of the stream at separate visits, extending over one year, indicated that very few eels were observed during the winter months. Eight inspections were made during the spring and summer months, September to January, and 71 eels were seen. In the autumn and winter months, March to July, eight inspections were made, and a total of four eels seen.

In all areas sampled by the writer during winter months it was found that the greatest majority of the eels hibernated. A few eels, however, remained, even in mid-winter, actively feeding in open water.

No difference was observed in the reaction of the two species or the sexes to the cold temperatures of the winter period.

The hibernation of eels to more equable conditions in the deep mud and sand has been further confirmed by the writer as samples have been removed from such areas during the winter months. These concentrations of eels are not present during the summer months.

DOWN-STREAM MIGRATION.

As maturity (or the most advanced state of sexual development which is reached in fresh water) approaches the female eel commences its down-stream migration to the sea. This often takes place during times of floods or freshes in the late summer or autumn months of the year. Figures indicating the progress of the down-stream migration have been obtained by the writer from the records of the eel-trapping operations of the Southland Acclimatization Society. These are given in Table VI.

TABLE VI.—EVIDENCE OF DOWN-STREAM MIGRATION IN HEDGEHOPE RIVER, SOUTHLAND.

Date Sample taken.	Number in Sample.	Percentage Maturing.	Average Length.
25th November, 1st December ..	193	16.1	74.6 cm.
10th February, 15th February ..	147	9.0	72.1 cm.
7th March	123	5.7	69.7 cm.
19th March	138	4.3	68.8 cm.
2nd April, 9th April	156	1.3	66.3 cm.

In all up-stream populations of eels prior to migration there are between 12 per cent. and 18 per cent. of eels 85 cm. and over. The long-finned female eels of 85 cm. and over are usually down-stream migrants. In Table VI all eels in the population which were over 85 cm. in length were regarded as maturing and preparing for migration. The gradual reduction in the percentage of maturing eels indicates the period and way in which the eels move out of their up-stream habitats.

The small percentage of eels left (1-3 per cent. in April), which should normally be considered migratory, are temporarily delayed in development or in some cases at least become permanently sterile. These latter do not migrate, but remain in the rivers and grow to a great size. The long-finned eel is usually mature at about 90 cm., but latent mature specimens have been secured up to 150 cm. Others larger than this have been observed but not captured.

The migration of the mature eels from the up-stream waters to the sea halts for a time when the tidal region is reached. Here the females join the males, and the two sexes of the two species prepare for their journey to the depths of the ocean. The eels remain in the tidal water for some time, and during this period several changes take place in them. First the gut atrophies; the eels have ceased to feed for some weeks previously, and the gut now shrivels up to a thin strand of tissue. The various parasitic worms which are present in most eels bore their way through the wall of the gut and encyst on its exterior wall. The lateral line cells become very prominent. The eye becomes large and rather more brightly pigmented. The large fat lips of the long-finned female become thin and narrow. The pigmentation commences to change to a bright silver colour. The ovaries of the females and the testes of the males show a rapid development in size. When the majority of these changes have taken place the seaward journey recommences, and the eels pass out to sea for the migration to the spawning-grounds.

The writer has observed several of these mass migrations of almost mature eels, and it would not seem out of place to record some of the details observed. Migrations commence from up-stream waters in January. During February the short-finned males go to sea. Towards the end of February and the first week of March the short-finned females go out to sea. At the end of March the long-finned male commences his seaward migration, and last of all the long-finned females in April or even May.

The migrations were observed at Lakes Ellesmere, Forsyth, and Onoke. In these places the eels are temporarily blocked from access to the sea by sand or shingle banks along the seaboard of the lakes. As the eels congregate from their up-stream haunts and are joined by the male eels from these coastal lakes they form up into a great shoal. They are not visible during the day, as they retire to the deep water of the lakes. During the evenings, however, they move out into the shallow water at the seaward margins of the lakes. With only a narrow bar of sand separating them from their goal (the sea) they move ceaselessly up and down, many of them attempting to wriggle out of the water and go across the bar to the sea. In all the migrations observed by the writer there were countless thousands of eels present. The eels were so thick that the samples required were taken by means of an ordinary fish-hook on a piece of string, used as a gaff. One peculiar feature of the migrations was the fact that the eels had a fairly definite sequence in which they moved; this being the sequence in which they usually go to sea when access is not blocked. The first eels in the shoal were the small short-finned males; these were followed by the short-finned female; next in order was the long-finned male; and then the long-finned female. These latter were divided into two groups—the first contained the main run of long-finned females about 90 cm. in size and the second the large eels which had been delayed in development for a period of years (often up to 180 cm. in size). The large eels remained in the deep water even at night, and were thus more difficult to secure.

During one migration the eels in Lake Ellesmere were unable to get to the sea for a considerable period as the shingle bar had been piled higher than usual. The eels eventually came out of the water and wriggled across the bar; they had not, however been aware of a belt of sand which formed an impassable barrier at the top of the shingle bar. Thousands of the eels became stranded on the top of the shingle bank in the dry sand and died, although some few may have reached the sea.

On another occasion in Lake Onoke the eels were able to struggle across the bar as large waves broke over. The Maoris of the Wairarapa took advantage of the unusual conditions and captured a large number for food. These eels usually find access to the sea when a channel is cut through the bar. The local Maoris take advantage of the period of imprisonment to obtain ample supplies of food, as the eels are easily caught in giant hinakis (eel traps) at the seaward margin of the lakes during the evening hours. These hinakis are set at right angles to the beach, and the eels are captured in them as they move up and down along the margin of the lake seeking the outlet. The writer observed seventeen sacks of eels removed in one night's fishing in Lake Onoke. Some 60 tons to 70 tons are caught from Lake Forsyth each year, without noticeably affecting the supply.

The eels are split down the middle and dried in the sun. They are then partly cooked in a salt solution and hung up to dry in the sun before being put away for future use. Eels preserved in this manner will keep in good condition for many months and make excellent eating. Smoked eels are also a delicacy, seldom enjoyed, however, by the white population of New Zealand.

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APPENDIX TO PART I.

The main sampling stations, numbers of each species caught, and the sexes of the eels are indicated. Migratory eels are marked with an asterisk:—

Southland—

Otapiri Stream	3,445	long-finned females.
Dunsdale Stream	1,236	,,
Makarewa River	789	,,
Hedgehope River	6,023	,,
Oreti River—		
Gums	23	,,
Lochiel Bridge	78	,,
West Plains Bridge	98	,,
	61	short-finned females.
Tidal	68	long-finned females.
	73	short-finned females.
Waimatuku Creek (estuary)	25	long-finned females.
	23	short-finned females.
Waiau River (junction with Wairakei)	12	long-finned females.
Waituna Creek	14	,,

Southland—continued.

Waituna Lagoon	7	long-finned females.
	2	long-finned males.
	9	short-finned females.
Mataura River (up-stream)	102	long-finned females.

And 6 smaller collecting stations.

Otago—

Kakanui River—		
Above Maheno	15	long-finned females.
Estuary	17	"
	12	short-finned females.

Canterbury—

Lake Ellesmere	*204	short-finned females.
	*58	long-finned females.
	*25	short-finned males.
	*18	long-finned males.
Lake Forsyth	*157	short-finned females.
	*10	long-finned males.
Waimakariri River (estuary)	83	short-finned females.
	22	long-finned females.
Selwyn River	25	"
Rakaia River	22	"
Hinds River	12	"

Westland—

Lake Poerua	2	short-finned females.
	1	long-finned female.
Lake Mapourika	7	long-finned females.
	3	short-finned females.
Lake Ianthe	10	long-finned females.
	5	short-finned females.
Lake Mahinapoua	8	"
Okarito Lagoon	12	"
	4	long-finned females.
Lake Brunner tributaries	16	"

Wellington—

Hutt River—		
Up-stream	56	long-finned females.
Estuary	72	"
	25	short-finned females.
Wainui-o-Mata River (up stream)	53	long-finned females.
Horowkiwi Stream—		
Up-stream	123	"
Estuary	21	short-finned females.
	6	long-finned females.
Makara Stream (up-stream)	15	"
Otaki River (at forks)	33	"
Lake Onoke	*229	short-finned females.
	*55	short-finned males.
	*125	long-finned females.
	*87	long-finned males.
Waikanae River (up-stream)	24	long-finned females.
Manawatu River (Palmerston North)	22	"
	10	short-finned females.
Wanganui River, Wanganui	58	long-finned females.
	27	short-finned females.

And 23 smaller collecting stations.

Auckland—

Waikato River—	
Mercer	28 long-finned females. 25 short finned females.
Hamilton	57 long-finned females. 83 short-finned females.
Hora Hora	75 long-finned females. 26 short-finned females. (Some hundreds of small migratory eels were secured here.)
Rainbow Rapids	7 long-finned females.
Waipa River—	
Whatawhata	23 short-finned females. 17 long finned females.
Otorohanga	12 "
Kaniwhanawana Stream—	
Just above Waipa Junction	36 long-finned females. 11 short-finned females.
Up-stream 6 miles	43 long-finned females.
Maungatutu Stream—	
Waikeria	34 "
4 miles above Korakonui	83 "
Puniu Stream	26 " 12 short-finned females.
Waihou River—	
Hinuera	44 long-finned females.
Hikutaia	27 " 25 short-finned females.
Below Shaftesbury	15 long-finned females. 3 short-finned females.
Above Okoroire	No eels taken, although extensively searched.
Waimakariri Stream, above Tirau Road ..	Ditto.
Kaituna River, Main Road bridge	32 long-finned females. 30 short-finned females.
Komata Stream Main Road bridge .. .	14 " 6 long finned females.
Piako Stream	68 " 1 short-finned female.
Lake Waihi	5 short-finned females.

And 15 minor collecting stations.

LIFE HISTORY OF THE TWO SPECIES OF FRESH-WATER EEL IN NEW ZEALAND.

II. FOOD, AND INTER-RELATIONSHIPS WITH TROUT.

By D. CAIRNS, Department of Scientific and Industrial Research, formerly Fisheries Biologist to the Marine Department, New Zealand.

Summary.

The food of eels in New Zealand waters has been studied in detail. Analyses of some 10,000 gut contents are given. The competition between eels and trout for food and for existence in the same environment is discussed and the food of the two fish compared.

FOOD.

A COMPREHENSIVE study of the food of eels of both species from the time they entered fresh water until the time they migrated to sea was made, nearly ten thousand eels being examined. The eels studied have been divided into three groups for the purpose of presenting the analyses of the gut contents. The first group includes all eels of less than 40 cm. in length; this group comprises those which have not to any great extent taken up an active feeding existence. They are found mainly under cover of various types and do not feed in the open stream bed but live a semi-subterranean existence. A further reference to their mode of life is made in a later section of this paper.

The second group includes those between 40 cm. and 75 cm. This group includes eels with a mouth gape too small to capture, hold, or swallow large food organisms. This is seen to be of importance in the case of such food as fish and crustacea.

The third group of eels, those over 75 cm., are not restricted in choice of food to any great extent and the larger eels by virtue of their strength can capture and devour a wide range of large food organisms. A considerable number of the total eels captured in this group were found to be empty. This in part accounted for by the fact that many of the eels in this group are approaching maturity and the feeding velocity is retarded. Other factors involved are discussed at a later stage.

All eels captured for an examination of the gut contents were taken by net, spear, hand-line, or eel-pots. Eels captured by these methods were quite satisfactory for food analyses. It was found with eel-pots that a very big percentage of the eels captured early in the evening were empty, indicating that the pots were attracting eels from cover before food had been consumed. By setting eel-pots later in the night it was found that the eels captured could be used for gut-content anaylses.

Size Group up to 40 cm. in Length.

One hundred and eighty-six eels were examined for a study of the food of the eels in this size group. The results are given in Table VII :—

TABLE VII.—FOOD OF SHORT- AND LONG-FINNED EELS (ELVER UP TO 40 CM. GROUP).

Food.	Common Name.	Number of Occurrences.*	Number of Individuals.
Crustacea	Water-fleas, &c. ..	55	208
Oligochæta	Worms	30	92
Coleoptera	Beetles†	22	38
Ephemeroptera ..	May-flies†	17	85
Trichoptera	Caddis-flies†	16	82
Mollusca	Shellfish	14	23
Empty	..	41	..

* Where an eel had more than one type of food in the gut, a separate entry was made for each kind. † Indicates that larvæ were recorded.

A sample of eels taken from the Oreti River just above the Otatara Bridge on 2nd May, 1938, was examined, and the food recorded was as follows:—

Length.	Species.	Food.
Cm.		
17.5	S.F.	Empty.
20.0	”	3 crabs, 4 Amphipods.
15.8	”	2 Amphipods.
19.7	”	1 crab.
16.7	”	Empty.
16.3	”	2 worms, 1 Isopod.
17.8	L.F.	2 crabs.
16.5	”	1 Isopod.
17.1	”	Empty.
12.5	”	1 beetle (larva).
13.2	”	5 caddis-fly larvæ.
12.0	”	4 Isopods.
12.2	”	1 crab.
12.0	”	Empty.
11.8	”	Unidentifiable material.

A sample taken from the up-stream waters of the Horokiwi Stream on 12th October, 1938, contained the following food:—

Length.	Species.	Food.
Cm.		
15.2	L.F.	3 caddis-fly larvæ.
17.4	”	Empty.
15.0	”	1 worm.
12.3	”	2 may-fly larvæ.
13.6	”	1 *Potamopyrgus* sp., 1 small worm.
12.5	”	Empty.
11.1	”	”
11.8	”	5 *Potamopyrgus* sp., 1 may-fly larva.
10.2	”	1 beetle larva.
16.5	”	Empty.
15.4	”	1 worm.
12.5	”	3 worms.
15.0	”	Empty.
16.9	”	”
18.3	”	”
17.2	”	1 may-fly larva.
12.2	”	Unidentifiable material.
13.1	”	Empty.
14.3	”	12 may-fly larvæ.
14.8	”	Empty.
12.0	”	2 caddis-fly larvæ.
11.0	”	Empty.

These two samples represent the food of the two main environments in which eels of this size group are found. The main genera represented are are follows:—

Crustacea: *Paracalliope, Daphnia.*
Oligochætes: *Lumbricus.*
Coleoptera: Unidentified larvæ.
Ephemeroptera: *Ameletus, Deleatidium, Atalophlebia.*
Trichoptera: *Pycnocentria, Olinga, Hydropsyche.*
Mollusca (young): *Potamopyrgus, Isodora, Amphipeplea, Latia.*

In addition to the above types of food, all stomachs were found to contain diatoms and many protozoa. These have not been identified.

Size Group 40 cm. to 75 cm.

Five thousand eight hundred and seventy-six long-finned eels (all females) were examined and the gut contents recorded. An analysis of the food is given in Table VIII:—

TABLE VIII.—FOOD OF LONG-FINNED EELS (FEMALES) FROM 40 CM. TO 75 CM.

Food.	Number of Occurrences.	Number of Individuals.	Common Name.
Ephemeroptera	854	8,672	May-fly larvæ.
Trichoptera ..	514	4,932	Caddis-fly larvæ.
Mollusca ..	498	2,955	Fresh-water snail and mussel.
Oligochæta ..	368	1,206	Worms.
Diptera ..	256	720	Two-winged flies.
Crustacea ..	232	354	Fresh-water crayfish and shrimp, crabs.
Fish (various)	204	234	Bully, inanga, *Retropinna* or silvery.
Coleoptera ..	121	198	Beetle larvæ and adults.
Trout	73	85	Fry and fingerlings.
Orthoptera ..	63	65	Wetas (adults).
Hemiptera ..	42	73	Cicadas (adults).
Various foods	106	123	Moths, unidentified caterpillars, stone-flies, creeper, dragon-flies, birds, rabbits, &c.
Empty ..	3,698	..	..

Type areas, showing the food of this size group in different environments are given below.

Sample taken Maungututu Stream at Lethbridge's Bridge on 23rd September, 1938, approximately one hundred miles inland (stream consists of pools and fast ripples; bottom is shingle with some fine sand):—

Length.	Species.	Food.
Cm.		
75.0	L.F.	1 worm, 2 slugs.
51.4	"	2 slugs, 1 worm, 1 caddis-larva.
74.0	"	2 slugs, 45 *Potamopyrgus* sp.
70.2	"	1 worm.
60.3	"	1 carp (2 in.).
56.4	"	4 worms.
57.5	"	Empty.
61.8	"	"
61.5	"	1 slug.
57.8	"	3 worms, 1 slug.
51.4	"	3 *Potamopyrgus*.
50.0	"	2 stone-fly larvæ.
46.7	"	2 worms.

The eels in the above sample were feeding in the backwaters and the sides of the pools, often lying on banks of *Riccia fluitans* with their bodies almost completely out of the water. It was from this position that most of the slugs were secured.

Sample taken from Wainui-o-Mata River on 25th November, 1938 (river flows on shingle bed with large pools and swift ripples; eels were taken by spear between midnight and 3 a.m.) :—

Length.	Species.	Food.
Cm.		
45.4	L.F.	13 *Ameletus* sp. (larvæ) (may-flies) 1 *Pycnocentria* sp. (larvæ) (caddis-flies), 1 Chironomid (L.).
46.7	"	8 *Ameletus* sp. (L.).
48.5	"	14 *Corneocyclas* sp., 3 *Potamopyrgus* sp., 2 *Ameletus* (L.), 4 *Olinga* (L.).
54.8	"	1 *Ameletus* (L.), 1 *Pycnocentria* (L.).
46.0	"	2 *Ameletus*.
47.9	"	11 *Ameletus* (L.), 1 *Pycnocentria* (L.).
56.9	"	1 *Pycnocentria* (L.).
52.3	"	Empty.
50.3	"	4 *Ameletus* (L.).
56.4	"	Empty.
58.5	"	3 *Corneocyclas*, 2 *Olinga* (L.), 53 *Pycnocentria* (L.)
65.4	"	214 *Olinga* (L.), 3 *Ameletus* (L.).
72.1	"	1 worm.
69.4	"	3 *Potamopyrgus*.

Twenty-three other eels were obtained in the above sample; the food of these varied from the above only in the numbers of food individuals present. These eels were feeding about the pools, amongst the stones, and occasionally in the faster water. The food is typical of eels taken from such environments.

Sample taken from the Kakanui River at Maheno on 10th February, 1938. Area fished was tidal and super-tidal; little flow in tidal area; approximately one to three miles from the sea; bottom gravel and mud:—

Length.	Species.	Food.
Cm.		
71.2	L.F.	Empty.
52.5	"	"
69.6	"	1 bi-valve, 7 midge (L.), 1 bully.
61.7	"	Empty.
68.5	"	1 bi-valve, 1 caddis-fly (L.).
45.0	"	1 stone-fly (L.), 3 caddis-fly (L.), 2 earthworms.
47.8	"	Empty.
70.0	"	9 caddis-fly (L.), 4 midge (L.).
65.5	"	12 caddis-fly (L.), 25 midge (L.).
75.5	"	6 caddis-fly (L.).
72.3	"	1 bully.
62.4	"	12 caddis-fly (L.).
58.7	"	3 earthworms, 2 midge, unidentifiable material.
55.9	"	Empty.
49.8	"	"
53.2	"	2 caddis-fly (L.).

A sample taken from the Dunsdale Stream in Southland in October, 1937, is of interest because shoals of trout fry were present in almost all of the pools along the stream. The bottom is shingle with large pools, fast ripples, and much cover for eels. The food is as follows:—

Length.	Species.	Food.
Cm.		
72.2	L.F.	2 may-fly (L.).
68.4	,,	1 trout fry.
62.3	,,	4 trout fry, 12 caddis-fly (L.).
54.5	,,	45 may-fly (L.).
74.8	,,	2 trout fry, 6 may-fly (L.).
65.7	,,	1 trout fry.
68.4	,,	150 *Potamapyrgus.*
52.4	,,	32 *Potamopyrgus*, 2 caddis-fly (L.).
70.2	,,	5 trout fry.
60.1	,,	1 trout fry.
68.4	,,	Unidentifiable material.
46.7	,,	3 *Potamopyrgus*, 2 caddis-fly (L.).

Fifty-three other eels were included in this sample, but many were empty. The above is representative of the gut contents of the complete sample. This sample, together with three others of a similar nature (one from the Puniu, one from the Maungututu, and one from the Pakuratahi Streams), indicates the type of food from nursery streams during the hatching and post-hatching period.

Sample from the Piako River, Waikato area, on 4th April, 1938; mud bottom, sluggish in flow, troutless, abundant eel population:—

Length.	Species.	Food.
Cm.		
72.2	L.F.	1 crayfish (fresh-water).
71.8 .. .	,,	Empty.
64.7	,,	,,
68.1		1 leg of crayfish.
63.2	,,	1 eel (S.F. 3 in. long).
52.8	,,	1 weta.
55.7	,,	Empty.
70.6	,,	1 bird.
63.2	,,	1 slug, 1 worm.
60.0	,,	2 worms.
47.2	,,	3 *Potamopyrgus.*
48.4	,,	2 small crayfish.
54.8	,,	Empty.
52.2	,,	,,
65.1	,,	16 *Potamopyrgus.*

Fifty eels were taken in the sample. The above is a fair indication of the food of the remainder.

One thousand six hundred and four stomachs of short-finned eels (all females) in this size class were examined and the food contents tabulated. The results are given in Table IX:—

TABLE IX.—FOOD OF SHORT-FINNED EELS (FEMALES) BETWEEN 40 CM. AND 75 CM.

Food.	Number of Occurrences.	Number of Individuals.	Common Name.
Mollusca	358	8,754	Fresh-water snail or mussel.
Oligochæta	274	1,122	Worms.
Diptera	201	2,401	"True-fly" adults and larvæ.
Crustacea	182	1,008	Fresh-water crayfish and shrimps, crabs.
Trichoptera	163	1,742	Caddis-fly larvæ.
Gobiomorphidæ ..	147	182	Bully.
Coleoptera	115	205	Beetles (adults mainly).
Orthoptera	53	62	Wetas (adults).
Hemiptera	50	72	Cicadas (adults).
Unidentified caterpillars	96	136	..
Fish (not trout or bully)	92	115	Mainly *Retropinna* and *Galaxias*.
Odonata	41	53	Dragon-fly larvæ.
Arachnida	18	21	Spiders.
Empty	854	..	..

Sample areas indicated below give some indication of the type of food taken by short-finned eels in different environments.

Sample area, tidal and super-tidal area of the Oreti River, between West Plains Bridge and the Otatara Bridge (7th March, 1937); top portion good current when tide out:—

Length.	Species.	Food.
Cm.		
72.5	S.F.	12 caddis-fly (L.), 5 *Potamopyrgus.*
65.2	"	7 caddis-fly (L.), 5 *Potamopyrgus.*
67.6	"	20 caddis-fly (L.).
70.2	"	16 caddis-fly (L.), 4 midge-fly (L.).
75.0	"	4 *Gobiomorphus* (bully).
60.3	"	38 *Potamopyrgus,* 2 *Diptera* (midge larvæ).
55.5	"	1 small crab.
62.7	"	Empty.
46.2	"	1 *Potamopyrgus.*
48.2	"	1 bully.
56.3	"	2 bully.
62.5	"	Empty.
68.3	"	2 *Retropinna* (smelt), 3 caddis-fly larvæ.
70.6	"	64 *Potamopyrgus,* 3 caddis-fly larvæ.

Forty-three other eels were taken in the above sample. The diet indicated is representative of the diet in many of the tidal and super-tidal areas which short-finned eels frequent.

Sample area, Lake Ellesmere; lake flooding over marginal flats, eels feeding out over margins in large numbers; sample taken mid-June:—

Length.	Species.	Food.
Cm.		
66.7	S.F.	Digested worms.
65.0	"	Empty.
62.3	"	4 terrestrial caterpillars.
57.8	"	Digested worms.
55.2	"	Digested worms and caterpillars.
61.9	"	Unidentifiable material.
48.3	"	2 spiders, 10 midge larvæ, 1 boatman.
56.4	"	1 slug, 4 worms.
62.8	"	1 caterpillar.
63.4	"	24 Ostracoda, 7 midge larvæ and slug remains.
65.5	"	124 midge larvæ, 3 spiders.
68.2	"	1 aquatic beetle, 6 worms.
72.3	"	1 Isopod, 1 boatman, 1 slug, 1 aquatic beetle.
65.8	"	3 worms.
64.2	"	15 worms.
62.1	"	Empty.

Twenty-one other eels were captured in the same sample. The above represents the food of the eels in the environment mentioned.

The principal genera represented in the food Tables VIII and IX are as follows:—

Ephemeroptera: *Ameletus, Deleatidium, Ameletopsis, Coloburiscus.*
Trichoptera: *Olinga, Pycnocentria, Hydropsyche, Hydrobiosis.*
Odonata: *Synthemis, Austrolestes.*
Crustacea: *Paranephrops, Xiphocaris, Daphnia, Boeckella.*
Mollusca: *Potamopyrgus, Isidora, Myxas.*
Hemiptera: *Melampsalta.*
Orthoptera: *Hemideina.*
Oligochæta: *Lumbricus.*
Diptera: *Chironomus, Austrosimulum, Calliphora, Bombylius.*
Coleoptera: *Odontria, Pyronota.*
Plecoptera: *Stenoperla, Austroperla.*
Neuroptera: *Archichauliodes.*

McFarlane(11) has indicated the main genera in the Ephemeroptera, Trichoptera, Neuroptera, Odonata, Crustacea, and Mollusca. These are from a fairly restricted area in Canterbury and Westland.

The food of the male eel of the two species has not been studied in detail by the writer. Of the 187 non-migratory male eels captured, only 12 contained food. Crabs were the sole diet of these 12.

The first outstanding feature of the food tables given above is the diversity of food on which the eel preys. No fewer than twenty-two different types of animals are recorded in the food of the long-finned eel; the short-finned eel in the more restricted area it frequents is not such a diverse feeder, as only fourteen different foods are recorded from the stomachs examined. The stomachs are from widely-varying types of water in both Islands. The main collecting stations (at which the numbers and species taken are given in the appendix to Part I) are as follows:—

Southland: Oreti River, Makarewa River and tributaries, Waituna Lagoon, Waimatuku Creek, Waiau River, Mataura River.
Otago: Kakanui River.
Canterbury: Lakes Ellesmere and Forsyth, Waimakariri River, Selwyn River.
Westland: Lake Brunner and tributaries, Lakes Mapourika and Ianthe; Lake Poerua and tributaries, Okarito Lagoon.
Wellington Hutt River, Horokiwi Stream, Lake Onoke, Waikanae River, Manawatu River, Otaki River, Wanganui River, Wainui-o-Mata.
Auckland: Waikato River, and some tributaries (including the Waipa and its tributaries), the Waihou and all its main tributaries, Kaituna River, Lake Waihi, and the Piako River.

Comparison of the diets of the two species of eel reveal the following interesting facts: (i) No trout were recorded from any of the gut contents of the short-finned female eels of this group. (ii) The trout taken from the stomachs of the long-finned female eels were all fry or fingerlings; this can be best explained by the fact that the eels at this size cannot swallow large objects. A comparison will later be made with the food of the next size group where the size of mouth has increased considerably. (iii) No Ephemeroptera were recorded from the food of the short-finned female eel; this may in part be accounted for by the environment in which they are found (but short-finned eels in upstream habitats, where Ephemeroptera occur, do not include them in their diet).

The predominance of Ephemeroptera in the diet of the long-finned eels examined may be explained in part by the fact that about 85 per cent. of the eels were from rivers and streams and also that where only a few may-flies were found in the stomach these are recorded, although in bulk of food they represent but little. In rivers and streams with gravel bottoms the main foods are may-fly larvæ, caddis-fly larvæ, small molluscs, worms, various "true" fly larvæ, fresh-water crayfish, larval, and adult beetles. Inanga (adult whitebait), *Retropinna* (smelt), and bully are only poorly represented in the food. During the summer months, cicadas, manuka beetles, moths, and dragon-fly larvæ may supplement the usual diet according to the time at which the main swarms of these hatch out. In lake areas the food of the eels consists mainly of *Gobiomorphus* (bully), *Galaxias* (inanga), worms, crabs (if tidal lagoons), shrimp, crayfish, and *Retropinna* (silvery or smelt).

Eels feed spasmodically, often taking large amounts of food and then resting in hiding while this is digested. Spasmodic feeding and slow growth may be correlated with the large populations of eels which our streams can support. The writer conducted various small-scale experiments on the rate of digestion in the eel. Eels were fed various items of food in pools where they could be later captured. In the case of the larger types of food such as crayfish, bullv, cicadas, fresh-water shrimp, and others, it was possible to identify the food in the diverticulum for thirtv-six hours after ingestion. In some cases this could be extended for a longer period. Smaller types of food could still be identified after twenty-four hours in the gut. Food such as caddis and may-fly larvæ, dipterous larvæ, and others falls in this category.

Many of the eels taken in the samples were empty, and this seemed to indicate that the bait which was used (rabbit in manv cases) had attracted the eels when they would not normally have been feeding. Of the eels captured in baited pots set before dark, 85 per cent. were empty. Considerable numbers of eels were taken by gaff and spear and many of these were emptv (see samples with food Tables VIII and IX). These last had probably come out to take food after a period of rest but had not had an opportunitv of taking any food up to the time of capture. Several samples of eels were taken between the hours of 2 a.m. and 4 a.m. and almost all were found to contain food (see Wainui-o-Mata sample, p. 135B).

Size Group, 75 cm. and longer.

The food of the eels under consideration is shown in Tables X and XI. One thousand seven hundred and fifty-eight long-finned eels and 245 short-finned eels were examined and the food recorded.

TABLE X.—FOOD OF LONG-FINNED FEMALE EELS, SIZE GROUP 75CM. AND UPWARDS.

Food.	Number of Occurrences.	Number of Individuals.	Common Name.
Salmonidæ ..	104	126	Brown or Rainbow trout.
Other fish ..	78	112	Inanga, bully, eels, *Retropinna,* carp, fish remains.
Crustacea ..	52	84	Crayfish and shrimp.
Mollusca ..	36	358	Fresh-water snail, mussel, and limpet.
Ephemeroptera	31	154	May-fly larvæ.
Trichoptera ..	26	182	Caddis-fly larvæ.
Coleoptera ..	25	34	Beetles (adults).
Oligochæta ..	13	19	Worms.
Other food ..	14	126	Diptera (flies), Neuroptera (creeper), Orthoptera (wetas).
Empty ..	1,332	..	..

In comparison with the two former groups of eels, the group 75 cm. and upward shows a much larger proportion of empty stomachs to the total examined.

A sample taken from the Hedgehope River, in Southland (12th December, 1937), gives an indication of the normal feeding habits of the large long-finned eels:—

Length.	Food.	Length.	Food.
Cm.		Cm.	
81.7	1 fresh-water crayfish.	80.0	1 fresh-water mussel, 4 may-fly larvæ.
87.3	Trout remains.	85.6	1 claw of fresh-water crayfish.
91.3	3 *Pycnocentria* (L.) (caddis-fly), 5 *Olinga* (L.) (caddis-fly).	89.3	1 piece fresh-water mussel.
88.8	3 *Olinga* (L.).	90.3	1 trout (20 cm.), 1 trout (9 cm.).
92.7	1 trout (18 cm.).	102.4	38 *Potamapyrgus.*
112.0	Trout remains.	82.6	6 may-fly larvæ, 12 caddis larvæ, 1 beetle adult.
98.7	1 long-finned eel (40 cm.).	89.9	3 worms, trout remains.
99.2	½ trout.	95.4	3 inanga.
115.4	"	92.8	Fish remains.
102.6	1 trout (12 cm.).		

Sixty-three eels in the above sample between 77.3 cm. and 118.6 cm. were empty when captured. This sample was taken between the hours of 9 p.m. and 1.30 a.m. by gaff and spear on four different evenings. A sample in a similar area of stream taken by rabbit-baited pots yielded 134 eels in one night and 142 on another. Of these, only 42 were over 75 cm. in length, and of these 42 only 3 contained food. This is quite typical of baited-pot samples.

A sample of large eels, 75 cm. and over, taken from Hutt River tidal area had the following food in their stomachs:—

Length.	Food.	Length.	Food.
Cm.		Cm.	
81.5	6 fresh-water shrimps.	93.2	3 *Retropinna,* 5 caddis-fly (L.).
93.7	12 *Retropinna* (smelt).	90.5	6 may-fly (L.), 12 caddis-fly (L.).
104.3	1 trout (22.5 cm.).	79.8	Fish remains, 3 may-fly (L.).
94.6	3 bullies, 16 caddis-fly larvæ.	88.8	2 bullies.
82.3	1 bully.	101.1	6 *Retropinna.*
95.9	23 caddis-fly (L.), 4 fresh-water-shrimp.	90.5	1 *Retropinna.*
76.7	16 caddis-fly (L.), 3 fresh-water shrimp.		

In this sample, thirty-six of the eels in the size class under consideration were empty. *Retropinna retropinna* (silvery) were plentiful and fresh-water shrimp and bullies were in good quantity. This sample is typical of the food in tidal sections of the river. Farther down the river near the estuaries, crabs are important and flounders and young mullet are occasionally secured.

The results of the examination of 245 stomachs of short-finned female eels in this size group are included in Table XI:—

TABLE XI.—FOOD OF SHORT-FINNED FEMALE EELS 75 CM. AND UPWARDS.

Food.	Number of Occurrences.	Number of Individuals.	Common Name.
Trichoptera ..	37	315	Caddis larvæ.
Mollusca ..	32	212	Fresh-water snail.
Oligochæta ..	17	28	Worms.
Crustacea ..	15	32	Fresh-water shrimp and crayfish.
Other foods ..	10	28	True-fly adults, bully, *Retropinna,* &c.
Empty ..	167	..	..

A sample from the lower Waikato River near Mercer (7th January, 1938), had the following food in them:—

Length.	Food.	Length.	Food.
Cm.		Cm.	
77.8	3 fresh-water shrimps.	75.7	53 caddis-fly larvæ.
75.3	14 *Potamopyrgus*, 3 caddis larvæ.	76.3	54 caddis-fly larvæ, 1 *Diptera* larva.
90.5	1 caddis-fly larva.	77.7	1 fresh-water shrimp, 1 *Potamopyrugus*.
81.7	1 bully, 15 *Potamopyrgus*.	75.0	1 *Retropinna*.
84.4	3 fresh-water shrimps.		
82.4	6 fresh-water shrimps.		
85.7	83 *Potamopyrgus*.		

Fourteen of the eels in the sample were empty. Fresh-water shrimps were particularly abundant in the region where these eels were caught. The eels were speared. The sample is typical of the food of short-finned eels in their normal environment. The percentage of short-finned female eels over 75 cm. in any population of short-finned eels is very small and in many cases is less than 5 per cent. This makes the procuring of extensive gut-content data for this size class a difficult task.

The genera represented in the four tables are essentially the same as for the group 40 cm. to 75 cm. (p. 138B). The outstanding fact in a study of the food of the long-finned eel is the predominance of trout in the diet. It must be remembered that the size group includes the large eels and that as these grow they eat larger food animals, notably trout and other fish. The other fish consumed include *Galaxias* (adult whitebait), *Gobiomorphus* (bully), *Retropinna* (smelt), carp, eels, and lamprey. Approximately half of the total shown as other fish in Table IX is attributable to fish remains, and quite a number of these "remains" could reasonably be held to be trout. A detailed study of the eel as a predator on trout is included later.

The food of the long-finned female eel in this size group is not restricted in any considerable extent by the gape of the jaws. The tendency of the larger eels to take larger food is also observed in the case of trout (p. 146B). Food such as may-fly larvæ, caddis-fly larvæ, and dipterous larvæ forms a very minor part of the diet of the eels of this size class. In upstream waters they eat mainly trout, crayfish, bully, inanga, and other *Galaxidae*, *Retropinna* or smelt, and eels. In tidal waters the diet is little different; here, however, fresh-water shrimp, crabs, mullet, and young flounders are often included.

The food of the short-finned eel is represented by only seventy-eight gut contents. This number is insufficient for a discussion or a comparison with the gut contents of the previous size group (40 cm. to 75 cm.). It is noted, however, that no trout were recorded in the gut contents examined.

EEL-TROUT INTER-RELATIONSHIP.

Eel as a Predator on Trout.

For many years now the problem of the eel as a predator on trout and of the actual damage which the eel inflicts over a period of time on a trout population has been discussed and argued from many angles. Little factual evidence has ever been presented on the problem save perhaps the occasional report of an eel having been taken with a large trout in the gut. The presentation, therefore, of the analyses of the gut contents of several thousands of eels in the foregoing pages is of interest to all who are concerned with the problem of fish conservation and in particular with the eel-trout relationship. Evidence is also presented from a study of the number of eel-scarred trout taken in anglers' catches. Finally, in this section the problem presented by eel-less waters is discussed.

Gut Content Data.—The fact that no trout were taken from the stomachs of the short-finned female eel of any size group can be linked with the evidence which has already been submitted concerning their distribution in the various water systems in New Zealand. The short-finned female eels could only swallow fry or fingerlings, but as they are confined largely to the lower reaches of the rivers they have little opportunity of preying on the nursery stocks in the spawning areas. This is a fact of considerable importance from the point of view of fish conservation. The case of the long-finned eel is totally different, however. This eel has been shown to penetrate to every type of water in the country.

Reference to Tables VIII and IX reveals that long-finned eels between 40 cm. and 75 cm. are to a minor extent preying on trout. These eels have a small mouth-gape and are only capable of capturing and killing trout of small size. This is borne out by the fact that the trout present in their stomachs were either fry or fingerlings. Damage to the fry and fingerling stocks will also be limited by the size of the diverticulum in the gut. In the gut-content analyses some records have been taken from eels living in troutless waters, some from areas where trout are comparatively rare, and some from parts of rivers and streams where only very large trout were present (see appendix to Part I). It is worthy of note that the size group under consideration comprises approximately 75 per cent. to 80 per cent. of the active feeding population of eels in upstream waters. During the hatch of fry from the natural redds or when liberations of fry are made, the damage inflicted by this eel can be of great importance. The predatory instincts of this eel may not be as strongly developed as in the large eel, as the diet of the smaller size group indicates a predominance of insect, crustacean, and molluscan food. The collection of gut-content material represents all months of the year and all environments. The trout fry recorded were taken from eels in the vicinity of spawning-beds during the emergence of fry (samples taken in the Pakuratahi, Dunsdale, Maungututu, and Puniu Streams). From the fish conservation point of view, the long-finned eel of 75 cm. and upwards is also of the greatest importance. Figures obtained during the sampling by the writer (Table VI) have shown that approximately 15 per cent. to 20 per cent. of most of the upstream population of eels consist of this size class (see sample analysed in Part I).

In the Hedgehope system, in Southland, over 10,000 eels were removed from approximately fifteen miles of river. This makes an average of about 650 eels per mile of river, and this is not considered to be a badly eel-infested area. For every mile of the river in this instance there would be nearly 100 eels over 75 cm. The gut-content figures (Table X) show that the major item of the diet of this size group of eels is trout. The damage to the adult trout population from this predator must be enormous over a period of one year. A comparison with the food of shags is not at this time possible, but no stream in New Zealand to the writer's knowledge has a shag population which could in any way compare with the figures given above. No one who has ever observed the black shag at work will deny that it eats trout, but as a predator it cannot compare with the eel.

The large eels represented in the size group under consideration have a predominantly fish diet. The mouth-gape is very large and the diverticulum of the gut capable of holding a large quantity of food. Eels in this group have been found with trout weighing 480 g. to 890 g. (1 lb. to 2 lb.) swallowed whole. The methods of catching the trout have been observed. Trout seeking shelter under banks and weed are stalked from the rear until within striking distance. A quick twist of the eel brings it below the trout and the jaws clasp it usually about the region of the vent. If the trout is small it is killed by the crushing of the jaws and swallowed whole. If it is a large trout it may be bitten and shaken vigorously until it is in halves. Several eels may participate in the stalking and tearing to pieces of one trout. The writer observed two eels at dusk stalking a trout of about 600 g. ($1\frac{1}{2}$ lb.). One of the eels made the capture, but the trout was torn into two pieces with great commotion, and shared by the two eels.

When fry and young trout are being captured the eels sometimes lie in the shallow water or ripples between pools, often with the back exposed. As the fry and other young trout tend to shoal in the lower ends of pools and just above the ripples mentioned above, the eel makes his capture by a quick dart in among the defenceless fish. This method of capture has been observed by the writer on numerous occasions. Fry and fingerlings are also captured while sheltering under banks, logs, and other cover, or may be stalked by the eel.

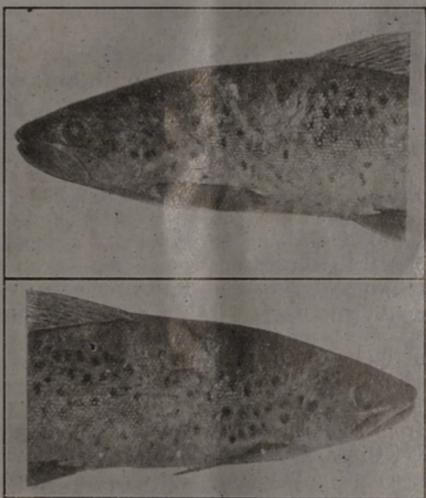

FIG. 11.—Eel-scarred Trout.

Eel-scarred Trout.

It can readily be imagined from the account of the capture of larger trout by eels that a percentage escape death by wriggling away from the grip which holds them. Very often it may be as a result of a fairly small eel attempting to take too large a trout. Evidence is, however, left on these trout in the form of the jaw marks of the eel. This eel scar, as it has been called, is usually found on both sides of the body about the region of the vent. Occasionally it is found just behind the head (Fig. 11). The scar is formed by the small teeth of the eel, which remove the scales of the trout and bite into the flesh. It can be distinguished easily from any other injury by the fact that the trout is marked on both sides of the body where it has been gripped by the eel, and on one side can be discerned the mark of the vomerine band of teeth. These later are a central band of teeth traversing the roof of the mouth of the eel (see Figures, Part I).

Evidence has been obtained from anglers' diaries as to the number of trout in their catches which were eel scarred (Table XII) :—

TABLE XII.

Source of Information.	River.	Number in Sample.	Percentage scarred.	Size of Trout.
Anglers' diaries	Waikato River (above Arapuni)	24	8.3	12in. and over
"	Waikato River (below Arapuni)	138	2.1	"
"	Waikato River (sundry tributaries of main river)	15	6.6	"
"	Waipa River and tributaries ..	102	7.8	"
"	Waihou River and tributaries above Okoroire	117	0.0	"
"	Waihou River and tributaries below Okoroire	59	10.0	"
"	Ohinemuri River and tributaries	128	14.0	"
"	Kaueranga River and tributaries	27	14.8	"
"	Awakino River	63	15.9	"
"	Ongarue River	55	5.5	"
"	Mokau River	48	12.5	"
"	Marokopa River	35	31.4	"
D. F. Hobbs.	Mangawhero River	81	17.3	"
I. McKay	Wainui-o-mata River	211	0.0	9in. to 12in.
		114	0.0	12in. to 14½ in.
		124	16.1	14½in. and over
Writer	Main Southland and Waikato Rivers	156	13.4	12in. and over

All groups of trout which had been scarred by eels were 12 in. or over, except in the case of the data presented for the Wainui-o-Mata River. In this case the trout are divided up into three size groups. The lower two groups have no eel scars recorded in them. The indication from this data that the larger size group showed the greatest number of scars was tested out on some of the other groups. The material obtained by Mr. Hobbs in the Mangawhero River on further analysis indicates that of 56 fish between 12 in. and 14 in., 4 (or 7.1 per cent.) were eel scarred, whereas of 25 trout of 14 in. to 21 in. in length, 10 (or 40 per cent.) were eel scarred.

The material from some of the anglers' diaries on analysis shows the same thing. Of 264 trout between 12 in. and 14 in., 7 (or 2.6 per cent.) were eel scarred, whereas of 163 trout over 14 in. in length 60 (or 36.8 per cent.) were eel scarred. In the writer's sample there were 93 trout between 12 in. and 14 in.; of these, 5 (or 5.4 per cent.) were eel scarred. Sixty-three trout were over 14 in. in length; of these, 16 (or 23.8 per cent.) were scarred.

From the above figures it is clear that the larger the trout grows the more capable it becomes of wriggling free from the grip of the eel. Very few eel scars are found on fish below 12 in., because the trout in this size group are practically incapable of breaking free and are usually swallowed whole.

The sample recorded from the Waihou River above Okoroire shows no eel scars on 117 trout. This area of water has been shown (see distribution data) to be free of eels.

The sample from the Waikato River shows the lowest percentage of eel-scarred trout. This river contains a very large population of big long-finned eels and a large population of big trout. It seems possible that in the more extensive area of water available the eel is less successful in stalking and killing trout.

Eel-less Waters.

Further evidence as to the effect of eels on a trout population is afforded in a rather indirect way by a study of the trout populations of eel-less waters in New Zealand. Reference has already been made to several areas into which eels cannot penetrate because of natural barriers. Trout have been acclimatized above these barriers. A study of such a trout population in the upper water of the Waihou River (above Okoroire) revealed that a very large head of rainbow trout (*Salmo irideus*) were present. This population of trout appears to be out of all proportion to the spawning-areas available and to the liberations which have been made. In one day's fishing in this stream the writer landed 75 fish; three other rods in the same day landed 185 fish between them. The writer returned 68 fish to the stream, these being below the size limit of 12 in. The other three rods took a total of 12 sizeable fish between them. These figures give some idea of the large population of small trout which frequent this water. Trout-fishing becomes aggravating in this water because of the monotony with which undersized fish have to be removed from the line. Streams of a similar nature (in the Waikato area), such as the Puniu and the Maungututu, although spawning streams, do not hold the immense head of fish which the upper Waihou does. The impression is given that the absence of eels in the upper Waihou River is responsible for the large stocks of trout, as heavy losses of fry and young trout are seen to take place when eels are present. The two streams, the Puniu and Maungututu, which contain a more normal head of fish have the usual population of eels.

A similar condition also exists in the Little Waimakiriri Stream, a tributary of the Waihou River above the eel-barrier. Large numbers of small fish are present in this stream, and the same explanation seems justified.

Eels are also absent from Lakes Rotorua, Rotoiti and Taupo. The growth and abundance of trout stocks in these areas may also be attributed to some extent to the lack of eels in the nursery streams flowing into the lakes and also the absence of the larger eels in the lakes themselves. The Hamurana Stream and the Ngongotaha Stream, flowing into Lake Rotorua, both carry very large stocks of small rainbow trout similar to the stocks in the upper Waihou waters.

The absence of eels from the upper tributaries of the Wangaehu River has also been reported (see section on eel-barriers). Large stocks of small fish are also reported from these tributaries.

Some special cases of eel damage to trout stocks are recorded by Armistead(30). The following case was brought to the notice of the writer by Mr. A. E. Hefford (Director of Fisheries Research). Young quinnat salmon about one year old and marked by fin-clipping were released into the hatchery backwater at the Government Hatchery, Hakataramea. A short time later 19 eels were removed from the backwater, individuals weighing between 1¾ kg. and 7½ kg. (4 lb. to 17 lb.) (7 were over 4½ kg. (10 lb.)). The gut contents of these eels included 114 young quinnat salmon. The concentration of fairly large numbers of young quinnat would account for the high number of fish in the stomachs, but it is hardly likely that they were more concentrated or helpless than fry emerging from spawning-beds under natural conditions.

The extent of the predations of eels upon trout is indicated by the direct evidence from the gut contents, showing especially the damage caused by the long-finned female eel in nursery streams. Further, the number of eel-scarred trout has been shown to be a definite indication of the damage caused to larger trout populations. Finally, the evidence afforded by eel-less waters indicates the concentration of trout stocks which exist in them and appears to be directly correlated with the absence of eels.

Competition with Trout for the same Food. (Food of Trout compared with that of Eels.)

The food of trout in New Zealand waters has been studied by (Hudson (31), Stokell(32), and Phillips(33). Other records of trout gut contents appear in the literature but were not directly suitable for comparison with the food of the eel. The details are set out in Table XIII:—

TABLE XIII.—FOOD OF EELS AND TROUT COMPARED.

Type of Food.	Trout (Figures indicate Number of Individuals).				Eels.	
	Hudson.	Phillips.	Stokell(i).	Stokell(ii).	L.F. Eel, 40 cm. to 75 cm.	S.F. Eel, 40 cm. to 75 cm.
Trichoptera	4,241	13,064	34	5,549	4,932	1,742
Ephemeroptera	529	1,493	..	485	8,672	..
Mollusca	21	1,661	5	40	2,955	8,754
Diptera	42	176	..	193	720	2,401
Coleoptera	90	77	..	204	198	205
Hemiptera	23	27	..	52	73	72
Crustacea	1	47	..	..	354	1,008
Oligochæta	..	17	..	1	1,206	1,122
Fish (not trout) ..	2	..	209	2	234	297
Trout	..	..	..	..	85	..
Plecoptera	16	48	1	4	18	..
Neuroptera	18	127	..	17	23	..
Hymenoptera	4	7	..	..	22	..
Arachnida	4	8	..	11	15	21
Lepidoptera	..	1	..	9	12	..
Orthoptera	3	2	..	..	65	62
Odonata	..	..	..	3	17	53
Various and unidentified	..	..	..	..	16	136*
Total stomachs examined	60	90	66	79	2,178	750

* Large numbers of unidentified caterpillars are included in this figure.

Hudson's material was obtained from stomachs of stream- and river-inhabiting trout. The fish were taken from the South Karori (19), Mungaroa (3), Waikanae (8), South Canterbury (9), Upper Selwyn (12), Wainui-o-Mata (7), and Waingawa Gorge (2) areas (figures in parentheses indicate number of trout from each area). The average length is not indicated. Phillips's material was obtained from the gut contents of trout captured from the various rivers of the Wellington Province. Thus, most of the trout would be feeding in shingle-bottomed streams and rivers. The average length of the trout in this sample is given as 15.7 in. Stokell(i) in Table XIII refers to a sample of sixty-six trout taken from Lake Ellesmere. The gut contents (recorded by Stokell) of these trout indicate the chief food of these fish as bully, *Retropinna*, and inanga, represented quantitatively in the order mentioned. Stokell(ii) refers to a sample obtained from the Hororata River, a shingle-bottomed river with a fair population of resident brown trout. The average size of the first sample is given as 21.7 in.; the average size of the second sample is 12.4 in.

The size group of eels chosen for comparison of food with the trout is the size group which contains the greatest proportion of the active feeding population of eels in all rivers and streams and also represents the largest numbers of gut contents examined. This size group (40 cm. to 75 cm.) also represents the medium class of eels (no small eels being included and no very large eels).

A comparison of the food of trout and eels as set out in Table XIII indicates that the eel is a definite competitor with the trout for the same types of food. The genera represented are essentially the same in both cases. Trichoptera (caddis-fly) occupy an important position in the diet of both fish. Ephemeroptera (may-fly) are prominent in the diet of the long-finned eel and well represented in the case of the trout. The absence of this group in the diet of the short-finned eel has already been discussed The absence of Ephemeroptera from the gut contents of the lake-living trout (Stokell(i), Table XIII) is attributable to the same reasons. Mollusca (fresh-water snails, &c.) are represented in the diet of both fishes. The food of the short-finned eel, however, consists to a large degree of this type. This may once again be due to the environment in which it is so regularly feeding. Diptera (true two-winged flies) are well represented in the food of both species of eel and of the trout, except in the case of the lake-feeding trout examined by Stokell. There is sufficient evidence, however, to indicate open competition in river and stream environments. Hemiptera (cicadas, &c.) are evenly distributed in the material presented. Crustacea (fresh-water crayfish and shrimp) seem to be very much more favoured by eels than trout. The short-finned eel is particularly fond of the fresh-water shrimp and other small crustaceans. The long-finned eel, especially the larger sizes, feeds freely on the fresh-water crayfish. Oligochæta (worms) are found almost solely in the diet of eels, as indicated by Table XIII. In the smaller-stream-living trout (Hudson, Phillips, and Stokell(ii), Table XIII) fish form a very minor part of the food. In the larger trout (Stokell(i), Table XIII) found in the mouths of rivers and in lake areas, the food consists largely of fish (bully, inanga, and *Retropinna* being favourites, in that order). The medium-sized group of eels also account for considerable quantities of these, but reference to Table IX (food of large eels) indicates that eels of the large-size group are feeding extensively on a fish diet. Indeed, it is possible that the effect of the combined competition of the eel and the trout on the stocks of small indigenous fish may be a factor in the reduction of trout stocks in many waters, both in size and numbers, in the last twenty-five or thirty years.

A comparison of the food of eels and trout from the same area of water is given below. The long-finned eel in the medium-size class is compared with trout of medium size; both inhabit a shingle-bottomed river of moderate gradient.

Cm.	*Trout.*	Cm.	*Eels.*
36.7 ..	300 Ephemeroptera (may-flies).	45.3 ..	15 Ephemeroptera.
	56 Trichoptera (caddis-flies).		1 Trichoptera.
	2 Diptera (true flies).		1 Diptera.
	1 Coleoptera (beetles).	25.0 ..	8 Ephemeroptera.
40.0 ..	43 Ephemeroptera.	46.5 ..	14 Mollusca.
	19 Trichoptera.		4 Trichoptera.
	1 Coleoptera.		2 Ephemeroptera.
41.5 ..	232 Trichoptera.	45.0 ..	1 Ephemeroptera.
	3 Neuroptera (creeper).	51.7 ..	227 Trichoptera.
	6 Ephemeroptera.		3 Ephemeroptera.
42.6 ..	7 Trichoptera.	48.7 ..	11 Ephemeroptera.
	2 Neuroptera.		1 Trichoptera.
	1 Coleoptera.	55.6 ..	15 Ephemeroptera.
	1 Crustacea (crayfish).	50.3 ..	4 Ephemeroptera.
42.0 ..	19 Trichoptera.		2 Trichoptera.
	13 Ephemeroptera.		1 Mollusca.
	2 Neuroptera.	42.3 ..	13 Ephemeroptera.
	1 Mollusca (fresh-water snail).		5 Trichoptera.

Cm.	*Trout.*
44.6 ..	28 Trichoptera.
	15 Ephemeroptera.
	4 Neuroptera.
	1 Coleoptera.
31.6 ..	5 Trichoptera.
	5 Ephemeroptera.
	2 Neuroptera.
25.5 ..	20 Trichoptera.
	2 Neuroptera.
36.9 ..	2,100 Trichoptera.
	2 Neuroptera.
	1 Coleoptera.
32.5 ..	805 Trichoptera.
	1 Neuroptera.
26.5 ..	80 Trichoptera.
25.0 ..	3 Trichoptera.
	2 Neuroptera.
	1 Ephemeroptera.
24.7 ..	7 Trichoptera.
29.0 ..	433 Trichoptera.
31.5 ..	182 Trichoptera.
	3 Ephemeroptera.
32.6 ..	49 Ephemeroptera.
	46 Trichoptera.
	6 Neuroptera.

Cm.	*Eels.*
57.8 ..	5 Emphemeroptera.
52.6 ..	2 Trichoptera.
46.5 ..	12 Ephemeroptera.
	9 Mollusca.
	1 Coleoptera.

The main genera represented are as follows:—

Ephemeroptera: *Ameletus, Deleatidium.*
Trichoptera: *Pycnocentria, Olinga.*
Neuroptera: *Archicauliodes.*
Coleoptera: *Odontria.*
Mollusca: *Potamopyrgus.*

The close approximation of the two diets is readily seen by reference to this comparison of gut contents from the same section of water.

A study of the gut contents of 36 large eels (all over 90 cm.) from a tidal area of river revealed that 22 of them had been eating fish. The order of preference was trout, *Retropinna,* bully, inanga, eels, and flounder. Other food included fresh-water snails, Diptera larvæ, and Trichoptera larvæ in small numbers. A study of the food of 66 trout (Stokell (i), Table XIII) of large size reveals that 209 fish had been eaten, the bully being the most popular, followed by the *Retropinna* and inanga. The non-fish diet was negligible.

It can thus be established that the eel is a serious predator on trout, especially in the nursery streams, and that the competition between the two fish extends to the main articles of food which are common to both. A study of trout populations in eel-less waters has given the impression that the absence of eels is of great benefit to trout stocks.

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LIFE-HISTORY OF THE TWO SPECIES OF FRESH-WATER EEL IN NEW ZEALAND.

III. DEVELOPMENT OF SEX. CAMPAIGN OF EEL DESTRUCTION.

By D. CAIRNS, Department of Scientific and Industrial Research, formerly Fisheries Biologist to the Marine Department, New Zealand.

Summary.

The development of sex of the two species of fresh-water eel in New Zealand has been studied, and the sexual organs of both male and female eels are described, together with information as to the size at which maturity is reached.

Full details of an organized campaign of eel destruction are given, including the methods used, the results obtained, and the cost of the operations.

DEVELOPMENT OF SEX.

TESCH (29), in a paper on sex and growth of eels, has attempted to link the development of the sex organs of the fresh-water eel with the environment. He supported Mazza (34), Grassi (35), D'Ancona (36), and Ehrenbaum (37), who asserted that all eels under a certain size are not sexually defined, and that the sex organ of the young eel is capable of developing either as a male or female according to the environment in which it is found. In a series of experiments Tesch took a large sample of the immature eels from an area in which it had been proved by extensive sampling that almost 100 per cent. of the adult eels were males. This sample of immature eels was removed to a box filled with running water situated in the aquarium building of the Amsterdam Zoological Gardens. Part of the catch was examined immediately after capture and it was found that all were developing as males. One year after, no change was noted when a sample was examined, but at the end of two years in this environment the remarkable fact was discovered that all the eels remaining in the sample were females. The writer can add an observation made in New Zealand waters. During studies in the Horokiwi Stream, in the Wellington Province, a migration of small eels occurred upstream from tidal waters. These young eels were examined a day after they had taken cover in the water-cress at the side of the stream and were found to be developing as males. The typical lobed appearance of the gonad was unmistakable. A further sample was examined about four weeks later and could reasonably be presumed to belong to the same migratory stock. Even in this short time the lobed appearance of the gonad had commenced to disappear, and microscopical examination revealed that the typical female gonad was beginning to form. After a further period of three months in the fresh water these young eels were unmistakable females, although not well developed. The

FIG. 12.—Sex organs of male eel.

eels were between 45 cm. and 60 cm. in length when the migration upstream occurred. This supported the hypothesis of Tesch and others. The migration into the Horokiwi Stream took place during a heavy fresh, and the eels had come from the waters of the north arm of Porirua Harbour, where the eel population is principally male. No male eels have been found by the writer in any of the fresh-water streams of New Zealand. Further extensive experiments would be required to prove the hypothesis of Grassi, Tesch, and others (*loc. cit.*) beyond all doubt, but much evidence has already been collected which supports the hypothesis that the environment largely determines the sex of the young eel—if in fresh-running water, a female; if in brackish or salt water, a male. Up to what period this may be reversed by a change of environment is not known.

Sexual development was first seen at about 45 cm. in the case of the long-finned eel and 40 cm. in the case of the short-finned eel. In each case this is approximately a year or so after the commencement of active feeding. The sex organs of the fresh-water eel were first described by Syrski(38) in 1874. Since that date many other workers have made studies of the sex organs. See Cunningham(39), Grassi and Calandruccio(21), Murie(40), Gilson(20), Walters(41), and others. The male sex organ (Fig. 12) consists of a large number of flat petal-like smooth lobes situated in a band on either side of the intestine. Within the separate lobes tubes are developed for the transference of the sperms to a common duct which passes back to open near the vent. It seems probable that the opening of the vent is used for the extrusion of the sperms, as the gut is almost completely atrophied before the eel leaves fresh water.

The female sex organ (Fig. 13) is situated in the body cavity in a position similar to that of the male gonad. When immature it is a delicate pinkish band on either side of the gut, one edge of which is attached to the body wall and one end free. As maturity approaches, the bands widen and become creamy-yellow in colour. When the maximum development in fresh water is attained they are a yolk-yellow and in the form of an extensively-convoluted frill. (The outer edge of the ovary is much longer than the inner attached edge). The eggs (ova) are situated on the lamellæ on the outer side of the ovary and may number up to four or five million. They are probably liberated in the body cavity and passed out of the vent. The ova may be seen by the aid of a magnifying glass (× 10) in some of the well-developed eels.

FIG. 13.—Sex organs of female eel.

The sex organ of the male eel is fully developed (as far as the fresh-water life is concerned) at about 55 cm. to 65 cm. in the case of the long-finned eel and 45 cm. to 50 cm. in the case of the short-finned eel. The female of the long-finned eel reaches the same stage at about 85 cm. to 95 cm., but odd individuals remain sterile for many years and are known to the Maori as kokupu-tuna (large eel). The female of the short-finned eel is fully developed (see above) at 75 cm. to 85 cm.—the largest specimen taken by the writer in two years and a half of sampling was 92.5 cm. long.

SOUTHLAND EEL-DESTRUCTION CAMPAIGN.

Extensive campaigns by acclimatization societies could reduce the damage caused by eels considerably, and it would seem that the expenditure of some of the money available for fish conservation could be made in this direction. In this connection some of the details obtained by the writer (see also Cairns(42), pp. 7-9) during the Southland campaign of 1937-38 are presented in Table XIV.

TABLE XIV.—EELS TAKEN IN THE SOUTHLAND CAMPAIGN.

(Records from Hedgehope, Dunsdale, and Otapiri Streams.)

Month.	Days fished.	Number of Pots used.	Number of Eels taken.	Average Number per Day on Basis Fifty Pots.	Weight.
					lb.
November	10	17	461	138	1,608
December	25	17	1,119	130	3,916
January	24	38	2,454	135	9,426
February	24	50	3,204	133	10,427
March	24	50	3,195	133	9,306
April	24	40	1,191	49	3,366
Total	..	..	11,624	..	38,000

The average weight of these eels dropped from 3.4 lb. in November to 2.8 lb. in April. There was, however, a slight rise in January to 3.8 lb.—this was probably caused by the movement downstream of the maturing eels. At the time when consistent trapping was being carried out these eels would be passing through the trapping area on their way to the sea. The fifty pots were in the charge of two men, who baited and set the pots in the late afternoon and lifted them the following morning. The pots were made of wire-netting tied over hoops of iron, being about 4 ft. 6 in. in length, 1 ft. 3 in. in diameter, with an inverted cone of wire-netting set in at one end and forming the trap. This cone was 1 ft. in depth. At the opposite end there was an opening into which the bait could be inserted and hung in a separate wire basket. A long piece of stout rope attached to one end completed the pot. These pots were baited with condemned rabbits from the Invercargill Freezing-works, which were found to be the most efficient bait, after trials had been made with livers and fish offal. The rabbits were approximately twice as efficient as either of these latter. The pots were always placed at the head of pools where the ripples were fast, and the blood from the bait would attract the eels from their haunts. Pots set in the still waters of the pools failed very often to yield any results at all, as the eels probably escaped by nosing round the basket until the entrance was discovered. Pots set at the heads of the pools in the rips of fast water tend to keep the eels facing upstream against the current and consequently keep them in the pots.

Each stretch of the river was trapped twice. A survey of the trapped areas was carried out by the writer after the trapping had been done, and it was found that the great bulk of the eels had been removed. In one night, over a distance of three miles of "trapped" river, only six eels were captured by the gaff and three were missed. This area had been trapped three weeks previously.

The approximate cost of labour for the two men for five months was just over £200. The cost of the pots would be about £30 for fifty. Transport of the men to and from work was a further item of expense. The total for a season's operations in which two men are engaged should not be greater than about £300. In view of the great damage which eels have been shown to do to trout stocks, this cost for fish conservation is not excessive. Two men working consistently in a society's district for a number of seasons could reduce materially the number of eels present in the main fishing waters.

The eels removed by pots are mainly between 45 cm. and 100 cm. Below this size range are the small eels which have not yet taken up active feeding in open water, and above this size group are the eels which are as a rule too large for the average pot. (If the pot is made too large in the opening the main size group of eels can escape too easily.) The small eels offer no problem as far as fish conservation is concerned, because they do not prey on trout, as has been shown from the gut contents and from the fact that they are not actively feeding in the open water. The large eels which are not caught in the pots are in very small numbers, being probably only about 2 per cent. of the total population of eels in any water. These eels can, however, be captured by following up the usual pots with a series of pots with a large opening suitable for this size of eel.

The replacement of eels in a water system is very slow. Mass migrations of adult eels above 75 cm. upstream seem to be rare. The replacement of the size class of eels removed by the traps will therefore be almost solely by growth—that is, growth of the smaller specimens left in the streams by the trappers. As the largest size of eel which is left is about 45 cm. in length, it will be approximately four to five years before this fish reaches the size at which it can do any damage to the trout stocks. Thus the expenditure on cleaning out the eels can be regarded as spread over the period of four to five years. The trapping, however, must be done thoroughly and the complete water system trapped. At certain points in some rivers netting eels may be possible. Such a convenient place is to be found near meat-killing works, where the eels congregate at the killing season. Nets used at the Makarewa works, in Southland, have caught many thousands of eels at these times.

The trapping of the adult eels may seem to some to be futile and a never-ending job when countless thousands of young eels are coming in from the sea each year. In order to counteract this, it would be possible to trap these elvers in their annual run. This is done in England and on the Continent, where large industries have been built up round the eel fisheries. In England, for instance eels were caught in the mouth of the Severn as they were migrating from the sea and were shipped in special boats to parts of the Continent. Here they were used as food after they had been fed in specially prepared ponds until they reached marketable size. The canning of elvers is also an industry which is worth investigation in this country. The elvers as they come from the sea should be equal in food value to the much-prized whitebait. If the reduction of the adult stocks of eels followed the commencement of trapping the elvers as quickly as the reduction of the adult whitebait has followed the trapping of the young fish, then it would not be long before the eel would become very scarce. This, however, is not envisaged by the writer. Sufficient has been given above to indicate that the method of trapping eels from water systems can give good results from point of view of the numbers removed and the period for which the streams remain comparatively free from reinfestation. No data have yet been collected to indicate the effect on the trout stocks either as far as growth is concerned or as far as population changes are concerned. The indications from the eel-less areas, however, point to the possibility that trout stocks would benefit greatly by the removal of the eels, both from the aspect of its predatorial instincts and its competition for food.

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TABLE V.

Length, in Centimetres.	Weight of Short-finned Eel (Females).	Weight of Long-finned Eel (Females).
45* (18 in.)	185 g. (6½ oz.)	224 g. (8 oz.)
47.5	218 ,,	280 ,,
50.0	252 ,,	350 ,,
52.5	336 ,,	420 ,,
55.0	378 ,,	563 ,,
57.5	445 ,, (16 oz.)	588 ,, (1 lb. 5 oz.).
60.0 (24 in.)	473 ,,	668 ,,
62.5	623 ,,	702 ,,
65.0	653 ,,	812 ,,
67.5	714 ,,	924 ,,
70.0 (28 in.)	835 ,, (1 lb. 14 oz.)	1,036 ,, (2 lb. 5 oz.).
72.5	863 ,,	1,114 ,,
75.0	1,030 ,,	1,235 ,,
77.5	1,042 ,,	1,391 ,,
80.0 (32 in.)	1,279 ,,	1,475 ,,
82.5	1,311 ,, (2 lb. 14½ oz.)	1,698 ,, (3 lb. 12½ oz.).
85.0	1,363 ,,	1,892 ,,
87.5	1,420 ,,	2,032 ,,
90.0 (36 in.)	1,587 ,,	2,169 ,,
92.5	(Limit of length and size in samples taken)	2,337 ,,
95.0	..	2,670 ,, (6 lb.).
97.5	..	2,978 ,,
100.0 (40 in.)	..	3,560 ,,

† One hundred eels were measured for each size and the average weight recorded.

The table above indicates clearly that the long-finned female eel increases in weight much more rapidly than the short-finned female, although the latter at each age-group is greater in length.

N.B.—The above table is an expansion of Table V given in Part I, p. 60B.

Cairns.D

Eels; Life-History of the 2 Species of N.Z.Fresh-water Eel

Cheviot 21 Jan 75 HQ			
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BRITISH SYSTEM OF MEASURES AND WEIGHTS WITH METRIC EQUIVALENTS.

All measurements, as is now universal in scientific publications, are given in the metric system. As many of the readers may not be familiar with this system, the following figures indicate the relationship with the British system.

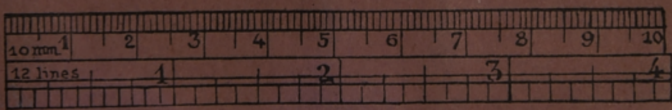
Measurements.

1 inch	=	2.5 centimetres
1 foot	=	30.5 „
1 yard	=	91.5 „

Weights.

1 ounce	=	28.7 grammes
1 lb.	=	453.6 „
2.2 lb.	=	1 kilogramme (1000 grammes)
1 stone (14 lb.)	=	6.35 kilogrammes

CENTIMETRES.



INCHES