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THE POPULATION OF A TROUT STREAM AND THE SURVIVAL OF RELEASED FISH

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SUMMARY

The fish population of a river system was studied by electro-fishing in 25 places, after which 1000 marked yearling brown trout were released at each of 10 sites. In a re-examination 8 to 9 months after the release it was estimated that about 10 per cent. of these were surviving; the survival after 18 months was estimated to be below 5 per cent., and the survival to takable size, at about 3 years of age, at 2 per cent. At no site were the younger age-groups of the natural population truly represented in either season, but the numbers of older fish in the second season were greater than those of the corresponding year classes in the preceding season, showing that the streams receive recruitment of younger fish from other sources. Some evidence is produced to show that 'nursery' streams provide the source of recruitment. The average annual mortality for fish of 2 and 3 years of age is estimated at from 70 to 80 per cent. for the system. It is estimated that there were about 45,000 takable fish in this river system at the beginning of each season. It is shown that the mean lengths of trout decrease with increasing density of population, and that there is a curvi-linear relationship between population density and total weight of all fish per acre. The standing crop at different sites ranged from 1 to 182 lb of trout per acre over the two seasons. The condition factor showed a decrease with increasing age of the fish, and the released fish had a lower factor than resident fish of the same age at all sites. In general there was a relationship between the depth of water and the length of the fish, sections over 14 inches in depth having greater populations of larger fish. A study of the ability of each section of stream to carry fish, based on the lengths and condition factors of the fish, the number and weight of the population per acre, and the ability of each section to absorb additions to the population, shows that where populations were low, conditions were less favourable to the growth and survival of fish.

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THE POPULATION OF A TROUT STREAM AND THE SURVIVAL OF RELEASED FISH

By A. G. Nicholls

I. INTRODUCTION

In two earlier papers (Nicholls 1957a, 1957b) it was shown that on the basis of the rates of stocking various Tasmanian streams the contribution made to anglers' catches from such fish could not have exceeded certain proportions (varying from 2 to 10 per cent.) of the total catches made by anglers. In making these estimates it was assumed that the released fish suffered the same mortality rates as the wild fish, and it was not possible to relate the survivors to the existing population owing to lack of data on the latter. In the light of evidence which showed that in two streams where marked fish had been released no survivors were found 20 months later when the places of release were fished by the electric method, it was thought that the mortality rate of released fish might be higher than that suffered by wild fish, or that the released fish might have become dispersed beyond the area of release. The present paper gives the results of an attempt to follow the fate of released fish and to discover what relationship such fish bore to the natural population when the selected stream was stocked at a comparatively high rate.

The North Esk System was chosen for this experiment for several reasons: (a) it is a compact system which normally carries good fish; (b) it has many tributaries suitable for the release of yearling fish; (c) both these and the main streams are crossed by roads or are accessible from the road at numerous places, conditions essential for a survey with the heavy equipment required for electro-fishing; and (d) in the opinion of anglers, as expressed in the 56th annual report of the Northern Tasmanian Fisheries Association (1954), both the North Esk and St. Patrick's rivers required heavy restocking. It may be noted that during the 10 years up to 1951 this system had been stocked with brown trout at a rate equivalent to an average of 2500 yearlings annually, and that during the four subsequent years the average rate was 3600 annually. Because of the increased rate of stocking it is not possible to state that all or the majority of fish found in the streams during this study were naturally spawned fish, but it will be possible to discover the results of releasing marked fish into the existing population. A general account of the physiography of this area has been given earlier (Nicholls 1957b).

II. METHODS

(a) Method of Operation

During December 1954 and January 1955 sections of the North Esk and St. Patrick's, and their tributaries, were fished at 25 places: 14 in the North Esk and 11 in the St. Patrick's (Fig. 1 and Appendix 1). In June 1955, 1000 marked yearling brown trout were released at each of 10 sites, selected with a view to giving the small fish the best chances of survival. Fish released in the North Esk streams had their left pelvic (ventral) fins removed and those released in the St. Patrick's lost their right pelvic fins. It was intended to fish the same 25 sections again as nearly as possible to 12 months after the initial study, but the summer of 1955-56 was marked by a series of heavy falls of rain at intervals which made it impossible to keep to any set programme. It was not possible to make a start on this work until February 1956, and it was constantly interrupted so that it was not completed until March 21. Even then several of the sections in the main streams could not be worked owing to the increased depth and current and these had to be abandoned. One of the original, and six additional sections, were fished in December 1956.

At each site, which was closed by stop nets at both ends, the length of the stream was measured along its centre, and the width, and depth at the centre, were measured at 18 ft intervals. From these measurements the approximate area of the section fished was calculated and the results expressed to the nearest 5 sq. ft; all fish taken were measured and weighed and scales were taken for age determination.

Care was taken to ensure that as far as possible every fish in each section was captured. When using this method of fishing it has been noticed that occasionally fish are missed, either because on initial contact with the electric field the fish makes a convulsive leap, possibly comparable with the 'jerk' response described by Bary (1956), which brings it out of the water and, on falling back, it may be carried downstream in the current and lost, or, in the case of a small fish,

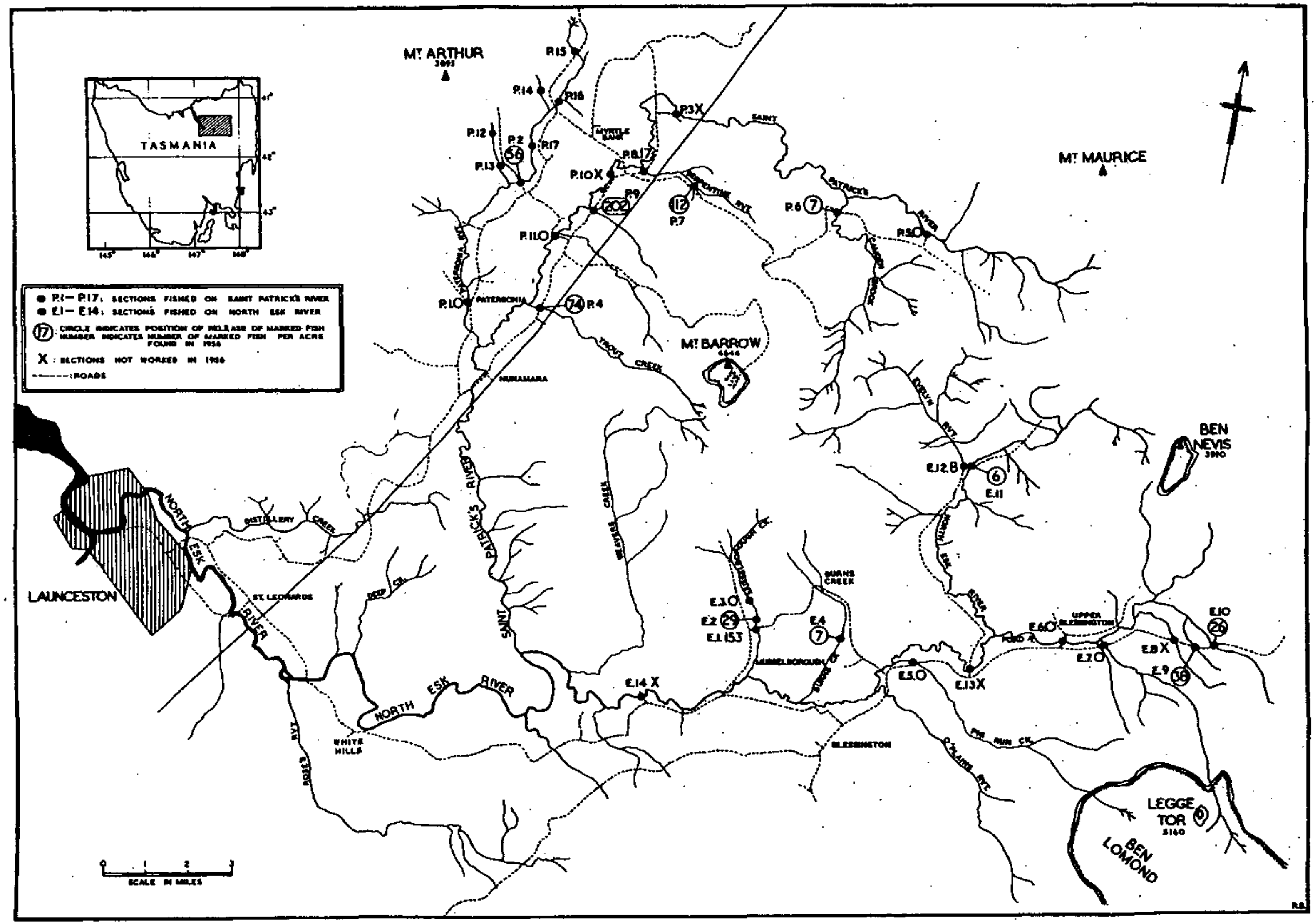

Fig.1. Map of North Esk River basin showing the positions of sections fished. Circles indicate the positions of release of marked fish and the numbers inside the circles indicate the numbers of marked fish per acre found in 1956.

because of the failure to net it rapidly, it becomes 'narcotized' and is carried away. Such cases are noted and by fishing the same section two or three times all such fish are usually accounted for. A proportion of the scale samples contained only replacement scales so that it was not possible to be certain of the age of such fish. On the basis of their lengths these were allocated to their probable age groups, with the possible introduction of a small error.

(b) Efficiency of the Electro-fishing Method

In a population study of a similar nature, Schuck (1945) using the electro-fishing apparatus of Haskell and Zilliox (1941), which results in stunning the fish, found that there was a loss of efficiency in capture, increasing with decrease in fish length. This would appear to be related in part to the difficulty in seeing fish once they were stunned, and it is to be expected that small fish, stunned while hiding below the larger boulders of a stream bed, would not be seen. A similar test was carried out here using continuous D.C. which does not stun the fish. One section of a side channel of the Plenty River about 100 yards long was screened at both ends with fine-meshed nets. This stretch was divisible into four sections of alternating shallow riffles and deeper flat-water sections of approximately similar lengths. These were comparable with those studied by Schuck, but differed in that they were adjacent and the whole was continuous. Sections I and III were pools, up to 3 ft in depth, in which the stream bed was composed of solid rock and boulders of mixed sizes; the deep water was along one side and the bottom rose gradually to shallow water on the other; the width varied from 15 to 25 ft. Sections II and IV were shallow, with fast-flowing water and average width about 10 ft, and depth about 8 in.

The area was fished once to collect a sample of the population; 525 marked fingerling brown trout of mean length 5.6 cm (range 4.3 to 6.9 cm) were then distributed throughout the area. The three upper sections each received 150 fish, and the lowest 75. The following day the whole stretch was fished twice. Three of the largest fish taken were opened and their stomach contents examined: a 25 cm sand-fish (Pseudaphritis urvillei C. & V.) contained four of the released fish; a 20 cm brown trout had eaten one; and a 22 cm trout contained only caddis and gastropod molluscs. On the basis of these deaths and of all the large trout captured on the second day an allowance of 7 deaths from predation and one accidental death was made, reducing the total of the assumed population of released fingerlings to 517.

On the first fishing of the second day 242 (47 per cent.) of the released fish were recaptured, and held until the completion of the second fishing operation in which an additional 105 were taken, showing a total of 347 or 67 per cent. for two operations. This is the normal process which has been adopted in making such stream surveys in Tasmania. Several interesting facts emerged from this study. There was clear evidence of downstream migration within 24 hours of release. Contrary to the findings of Schuck there was considerable difference in the relative recovery between the two riffles and the two flat-water sections; the lowest numbers were taken from the shallower sections on both occasions, with very much lower recoveries on the second occasion, suggesting either much lower populations or much greater efficiency in recovery on the first occasion in the shallower than in the deeper sections. From section I, which received only 75 fish, 133 were recovered, showing that the downstream migration was quite considerable. The extent of this migration was estimated on the basis of an even recovery of 67 per cent. throughout the area, it being assumed that in each case about half as many fish remained as were actually recovered from each section. The result showed that 81 (54 per cent.) of the fingerlings had moved downstream from the upper riffle section (IV) to the deeper section below, raising the total population of section III to 231; of these 76 (33 per cent.) had moved to section II, increasing its population to 226; of these, 129 (57 per cent.) had migrated to the lowest section (I) whose population was estimated at 199, an increase of 165 per cent. The most extensive migrations were clearly from the two shallower sections (II and IV) to the two deeper sections (I and III). This migration may have been stimulated in part by the relatively high rate of release but it shows what is likely to happen when a thousand or so fingerlings are released in one place: the urge to move downstream in search of less crowded feeding conditions exposes them to greater predation by the existing population. In the present case predation was not high because the area used for this experiment was a comparatively recently developed side channel of the main stream, not fully populated.

One other interesting observation emerged from this study, relating to the efficiency of the method. The stream bed in the deeper sections was composed in part of large boulders which provide greater depth and thus more shelter for small fish, and permit deeper penetration into this shelter than is to be found in the shallower riffles where the bed was of smaller, and thus more closely packed, stones. Fishing with the electrode at the normal speed of operation passes over such sections before the smaller fish have time to come from the depths, whereas allowing the electrode to rest on the bottom for 5 to 10 seconds at a time frequently produced such fish although none had appeared when the electrode was passed over the top. It is over this type of cover that D.C. has an advantage over A.C. since there is no immediate stunning of the fish and they are able to come out of hiding; perhaps herein lies the explanation of Schuck's finding no difference between recoveries from shallows and depths, since in the deeper sections his small fish would have been stunned and so be lost to sight, whereas those which were readily seen were near the surface, as would also have been those which were taken in the shallower riffles. It is unfortunate that this difference was not realized until section III was being fished for the second time, otherwise the rate of recovery would probably have been much higher, especially in section I. It is probable that this has been the major cause of loss of efficiency in Tasmanian streams since the quick appearance of some small fish, probably those just beneath the surface boulders, has given the impression that the fish react rapidly and that the first-comers represent all that were there. The general conclusion holds, that for fingerling fish the approximate efficiency of the method using D.C. is about 67 per cent. where streams have been worked over twice.

Schuck (1945) gives figures of 50, 81, 92, and 95 per cent. recovery respectively for fish of 0+, 1+, 2+, and 3+ and older, presumably for one fishing operation. A correction made on the assumption that similar percentages of the remainder would be taken in a second operation, indicates a high efficiency of capture for fish over 1 year of age. In the present case there was also a loss of efficiency in the instrument itself, due to the poor conductivity of the water. The machine, designed to give 250 V and 5 A, was on this occasion working at about 200 V. and 0.2 A; this is related to the poor content of dissolved solids in the stream, and it has been observed that in streams where greater amperage is recorded the holding efficiency is much greater.

(c) Temperature and pH

Measurements of temperature and pH were made on March 4, 1955 at a time when the water flow was almost minimal and when the air temperature would be close to the maximum for the year. Temperature was recorded to the nearest 0.5°C and pH was measured with a Lovibond comparator using glass standards. Readings were made between 0945 and 1711 hrs, and the altitude ranged from about 1100 to 1700 ft; the time of day would have some effect on water temperatures at this time of year, but altitude appears to have had a greater effect. Temperatures ranged from 11.5°C to 16.5°C, the majority being between 12° and 15°C, and pH ranged from 6.1 to 7.4, though all but three of the values lay between 6.8 and 7.2.

III. RESULTS AND DISCUSSION

(a) The Survival of Released Fish

At each section the distance fished depended on the accessibility of the site from the road and the straightness of the stream bed, and varied from 150 to 560 ft, with an average at about 350 ft. The average width also varied according to the size of the stream, from 5 to nearly 60 ft, the average being about 20 ft. The actual numbers of fish taken varied from 2 to 122 in 1954-55 and from 1 to 110 in 1956. The total number of fish taken from 25 sections in the first season was 981, of which 887 were brown trout and 94 other species, mostly eels; on the second occasion the total for 20 sections worked was 632 fish of which 34 were other species. Of the 598 trout taken in this season only 75 were marked fish.

Table 1 shows the number of fish per acre in each age group in the two seasons, and the marked fish are separated from the resident population. North Esk sites are numbered E1 to E14, and St. Patrick's sites P1 to P11. Stream measurements and other basic data are given in Appendix 1.

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TABLE 1

NUMBER OF BROWN TROUT PER ACRE IN 1955 AND 1956

Section No.	Age Groups 0+ 1955	0+ 1956	1+ 1955	1+ 1956 Wild	1+ 1956 Marked	1+ 1956 Total	2+ 1955	2+ 1956	3+ 1955	3+ 1956	Older 1955	Older 1956	Totals 1955	Totals 1956 Actual	Totals 1956 Corrected@
E1	0	51	72	17	153	170	202	102	101	102	58	0	433	425	461
*E2	0	0	76	0	29	29	54	86	54	48	0	0	184	163	181
E3	0	10	129	69	0	69	117	138	12	39	0	10	258	266	293
*E4	0	7	100	0	7	7	85	52	8	22	7	0	200	88	96
E5	0	11	82	0	0	0	265	90	163	146	112	90	622	337	299
E6	16	5	93	54	0	54	45	79	37	0	4	5	195	143	138
E7	0	0	18	15	0	15	128	30	0	30	73	0	219	75	88
E8	0	-	0	-	-	-	12	-	12	-	0	-	24	-	-
*E9	0	5	29	16	38	54	70	49	100	33	0	0	199	141	170
*E10	0	0	278	130	26	156	139	104	167	52	0	52	584	364	387
*E11	0	0	39	14	6	20	79	26	0	13	0	6	118	65	69
E12	0	12	39	9	8	17	51	66	12	8	0	4	102	107	103
E13	6	-	39	-	-	-	51	-	21	-	24	-	141	-	-
E14	12	-	67	-	-	-	14	-	12	-	2	-	107	-	-
P1	5	99	262	33	0	33	97	113	29	14	5	4	398	263	281
*P2	0	49	220	30	56	86	40	148	7	25	0	19	267	327	339
P3	0	-	3	-	-	-	6	-	6	-	0	-	15	-	-
*P4	287	66	126	199	74	273	57	25	34	0	11	0	515	364	452
P5	0	0	0	?	?	4?	11	0	0	0	0	0	11	4	5
*P6	0	7	0	13	7	20	12	0	19	0	0	0	31	27	31
*P7	0	132	124	61	112	173	124	41	11	20	0	0	259	366	415
P8	38	484	633	50	17	67	268	217	173	67	29	33	1141	868	1107
*P9	231	74	578	223	202	425	165	74	182	21	99	11	1255	605	811
P10	32	-	79	-	-	-	29	-	4	-	4	-	148	-	-
P11	10	15	42	45	0	45	52	30	10	15	0	5	114	110	119

* Positions of release of marked fish

@ Corrected for error due to greater width of stream section caused by unseasonal rise in river levels in 1956

Sections E8, 13, 14, and P3 and 10 were not fished in 1956

The mean widths of nearly all sections of streams were greater in 1956 than in the previous season, as a result of the temporary raising of the normal summer water levels caused by the heavy rain. Calculations of the numbers of fish per acre for most sections, based on 1956 levels, will yield lower populations than were actually present, and total numbers per acre have therefore been corrected proportionally to the difference between the mean width at each site in the two seasons. Using the corrected values given in Table 1 it is found that the difference in the total population at the 20 sites fished in both seasons represents a fall in the later season to the extent of about 18 per cent. This can be wholly accounted for by the normal mortality which would have occurred during the two months delay before the sections could be fished in 1956. Allen's (1952) figures show that the mean expected mortality for fish older than 1 year, in the two months at this time of year, is about 18 per cent.

Because this estimated fall represents a mean for all sections, at some of which the numbers of fish per acre were higher in the second season than in the first, it must be regarded as only approximate; it is further influenced by the varying numbers of young fish (0+ and 1+) present in each season (shown in Table 1 and discussed in Section III (b)); if these are excluded in making this comparison the fall in numbers in the second season amounts to only about 13 per cent., so that mortality during the two months delay is quite sufficient to account for the lower numbers found during the second season.

Comparison of individual sections shows increases in population between 1955 and corrected 1956 values at six sites only; E1, 3, 12, and P2, 7, and 11, and with the exception of the last, all were at or close to points of liberation of hatchery fish. At four of these the increase was due to the presence in 1956 of 0+ or 2+ and older fish in greater numbers than in 1955, and at only two was there any indication that it might have been due to released fish. At E1 and P7 there were big increases in the numbers of 1+ fish, of which the majority were released fish, suggesting that at these two sites released fish had made a considerable contribution to the population. However, this is not necessarily the truth as it will be shown that the natural populations of 0+ and 1+ fish are not truly represented in these samples.

Of the 10,000 fish released only 75 were recovered. It cannot be assumed that these represent the whole of the survivors since it is certain that some had moved out of the area in which they were released. This is shown

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where two or more sites were adjacent, as at Musselborough Creek (E1, 2, 3) and Serpentine Rivulet (P7, 8). In the first, trout having been released at the middle of the three sites would disclose whether there was migration in either direction, and at the second they were released at the upstream site. In both cases there was downstream migration. Sites E1 and 2 were less than half a mile apart, while nearly three quarters of a mile separated E2 and 3. Sites P7 and 8 were less than two miles apart. It is doubtful if the downstream migration exceeded two miles: no marked fish were found in the main stream at P11, less than two miles below P9 which was still carrying a good proportion of these fish; neither were marked fish found at P1, some four miles below the point of liberation (P2) in Patersonia Creek; nor at E6, a little over four miles below liberations at E9 and 10.

In estimating the total possible survival it has been assumed that the downstream dispersal tapered off steadily to zero at 2 miles below every point of release. This may be inaccurate because although fish were released at E2, more were found at E1 than at E2, but as pointed out above these two points were very close. For the purpose of estimating the survival in this stream, E1 was taken as the point of release and the dispersal calculated on the basis of 2 miles downstream from E1 and upstream as far as E2. On the basis of these assumptions it has been calculated that about 1100 marked fish could have survived from the end of June 1955 to the time of recapture, a period varying from 7 to 9 months. Thus the mortality suffered during this period would be nearly 90 per cent., compared with a mortality of about 50 per cent. for the natural population over the same period, based on Allen's figures (1952). At normal rates, 30 per cent. could be expected to die during the remainder of that year, so that only about 400 would be likely to attain 2 years of age, and only 80 fish (0.8 per cent.) could be expected to survive to 3 years of age and reach maturity.

About 120 of the 400 fish would have been takable as 2-year fish and the remainder not until they were 3 years of age, by which time they would have numbered only about 60, so that as a result of releasing 10,000 yearling fish in these streams anglers could have expected an addition to the population of 120 takable fish in 20 miles of stream, 15 months after release, or 6 fish per mile in the 2-mile stretch below each of the 10 points of release; and during the following season they could have expected one of these to have survived and to be joined by an additional 3 fish per mile from the slower growing fish. The normal population of takable fish in these 20 miles would have been about 1500. Direct evidence of the survival over 18 months in one section is provided by figures for section P2 which was fished again in December 1956. The numbers estimated to have survived in the 2 miles below this point were 151 in March 1956 and 44 in December 1956, which shows a 4.4 per cent. survival for 18 months. The normal mortality rate for the next 6 months at the end of which the fish would have been 3 years of age is about 40 per cent., which would leave a total of 18 fish out of the original 1000, or 1.8 per cent. The growth rate at this site was such that the fish would be takable at this age, so that not more than 2 per cent. of the fish released here would survive to be available to anglers.

These results support the conclusions of Hazzard and Shetter(1939), Shetter and Hazzard (1941), Randle and Cramer (1941), Needham and Slater (1944), Hobbs (1948), and others. Needham and Slater (p. 34) state "Fingerling trout of a practical size cannot possibly provide significant additions to the creel when they are planted in waters having abundant populations of resident trout," and "It can now be stated with confidence that by far the greater proportion of fish caught are the result of natural propagation." Neither is any advantage to be gained by holding fish in the hatchery until they reach legal size, for although their mortality might be reduced, as Hazzard and Shetter (loc. cit. p. 206) discovered: "the consistent planting of a stream with legal-sized trout during the fishing season will eventually lower the number of adult trout of breeding size to a point where the contribution to the catch from natural spawning is seriously impaired," and "If carried to excess the result would be a stream practically barren of trout except for those planted just prior to and through the season."

(b) The Natural Population and its Mortality

The percentage composition of the population at several selected sites in both streams, in two successive seasons, is shown in Figure 2. The only sites excluded are those with fewer than 15 fish taken in one of the seasons, and those which it was impossible to fish in the second season. This figure shows two important features. With few exceptions, in neither season was a normal distribution of the population found in any section; the majority of sections shows populations greatly deficient in 0+ and 1+ fish. At P4 in 1955 and P7 in 1956 normal distributions were found which showed annual mortality rates constant at about 50 per cent.; at E6 and P8 in 1955 and at P11 in 1956 similar conditions were found, but 0+ fish were inadequately represented. In general there were fewer 0+ fish than 1+ fish in both the North Esk and St. Patrick's, and fewer 1+ fish than 2+ fish in the North Esk.

The second feature is that throughout the North Esk and in most of the St. Patrick's there were larger proportions of 1+ fish in 1956 than of 0+ fish in 1955, and the same relationship applies to the 2+ fish in 1956 and the 1+ fish in 1955 from which they arose. If this disproportion in numbers of fish in each age group had occurred in 1955 only, it would have appeared that there had been a failure in survival of that year class in both rivers, and of that of the preceding year also, in the North Esk. But since it is repeated in the second year, and especially in view of the increase in absolute numbers of 1+ fish in 1956 compared with the 0+ fish in 1955, this cannot be the explanation. It is clear that the population must be maintained by recruitment from nursery streams; these would be small creeks with sufficient flow of water in winter to permit fish ascending for spawning, but falling off in summer so that they were inhabitable only by the youngest fish. One such stream was found (Ration Tree Creek, Nicholls 1957a) in which the population was composed of 77 per cent. 0+ fish, 22 per cent. 1+ fish, and 1 per cent. 2+ fish. Its mean depth was 7.4 inches, and its mean width was 14.3 ft, showing that it was a small shallow stream with a mean cross sectional area of 8.8 sq. ft.

It would be expected therefore that the highest proportions of 0+ fish should be found in similar streams within the North Esk System. In the North Esk and its tributaries no small creeks less than 9 sq. ft in cross section were studied, and this sub-system was notably devoid of 0+ fish at most sites fished, but in the St. Patrick's tributaries four of the seven sites in Figure 2 had cross sectional areas of 6 sq. ft or less, while the other three had areas from 30 to 40 sq. ft. The three largest (P1, 2, and 11) had very low or nil populations of 0+ fish in 1955, and of the four smallest (P4, 7, 8, and 9), two carried large populations of 0+ fish. These relationships were not so apparent in 1956, but the summer of that year was exceptional in that there were successive periods of heavy rainfall (Fig. 3).

To examine the possibility of recruitment from small streams, several sections in tributary creeks of Patersonia Rivulet, one of the larger tributaries of the St. Patrick's, were fished in December, 1956. The upper site in this stream (P2) was fished as a control and several sections

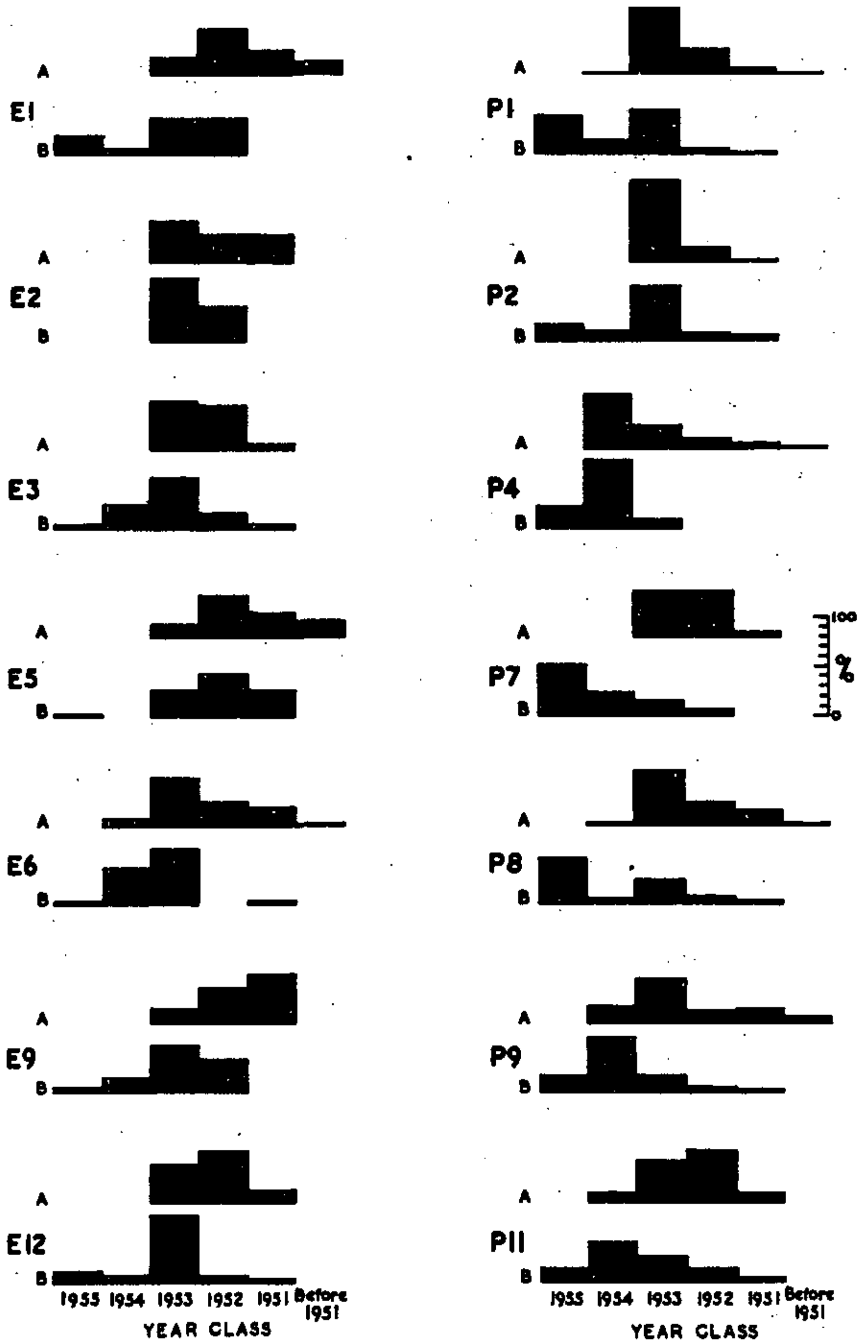

Fig. 2. Percentage composition of the population at selected sites in two seasons : A, 1954-55, and B, 1956.

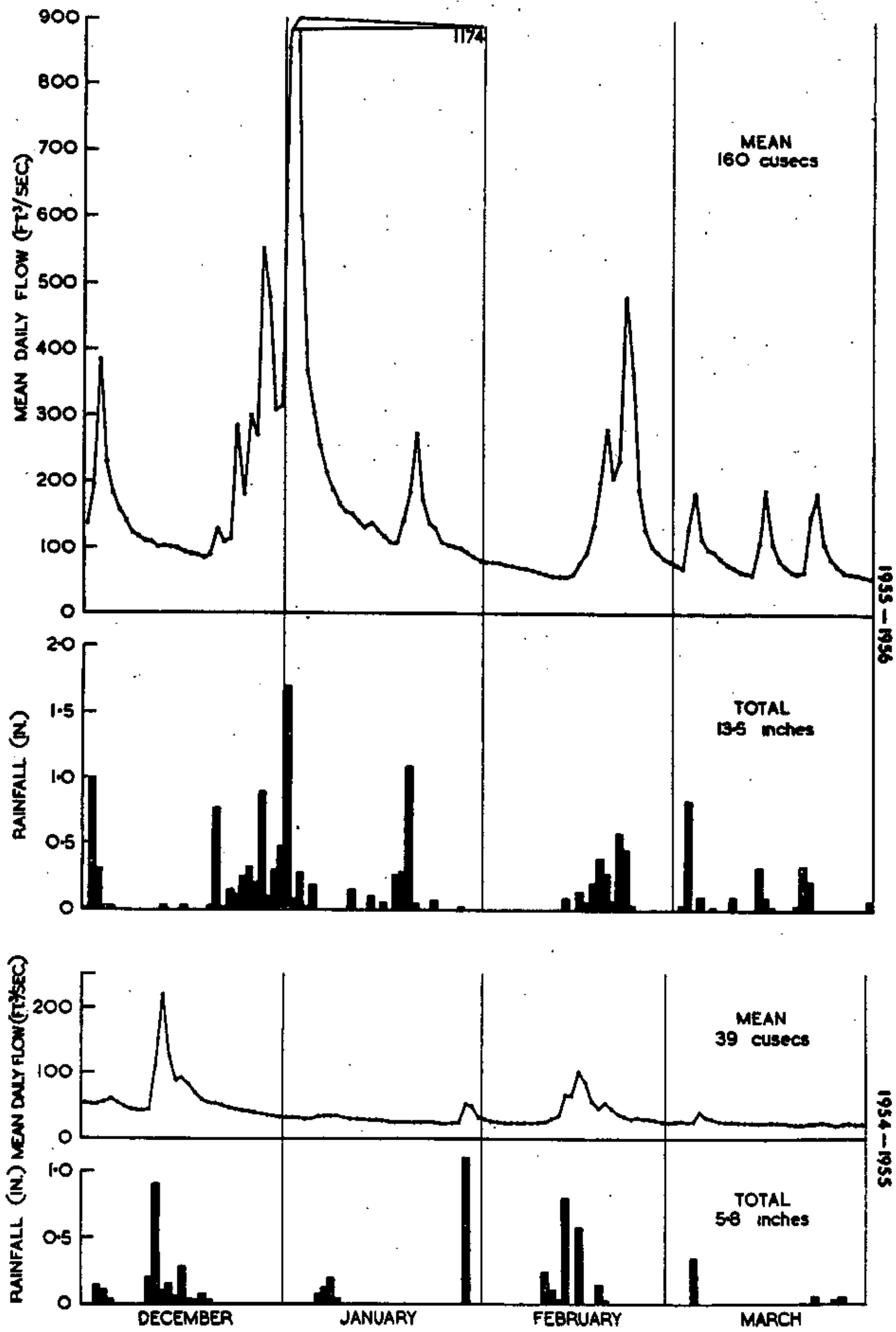

Fig. 3. Rainfall and river flow in the North Esk River in two seasons.

upstream from this position, or in minor creeks, were studied. The highest point reached was almost at the source of the main stream. The results are shown in Figure 4. In this figure the mean relative cross sectional areas of the streams are shown diagrammatically, and the percentage distributions of the populations have been arranged in descending order of cross sectional area. A very clear relationship now appears between the size of the stream and the proportion of young fish (0+ and 1+) in the population; it is clear that young fish are found in increasing numbers and proportions in the smaller and shallower creeks, and it is evident that such nursery streams are the source of recruitment to the stocks of older fish in the deeper sections. Saunders and Smith (1955) in a study of a population of brook trout (Salvelinus fontinalis (Mitchill)) found insufficient fingerlings to provide the stock of older fish, and concluded that the population was maintained by downstream migration.

At P2, although there was no real difference in numbers or weight of fish per acre in March and December 1956, the composition of the population was quite different. The numbers of the 1953 year class found on the three occasions this section was fished were 220, 148, and 94 per acre, showing 33 and 36 per cent. mortalities; for the 1952 year class the corresponding figures were 40, 25, and 0 (38 and 100 per cent. mortalities). The 1954 and 1955 year classes showed increases in December 1956 over the numbers found in March of that year, showing that recruitment had occurred. P12 and P16 are omitted from Figure 4 because fewer than 15 fish were taken; at the others, numbers ranged from 38 to 83. P17 was upstream from P2 in the main rivulet, and shows a greater number and proportion of 0+ fish than P2. P13, 14, and 15, and especially the last which was near the source of the main rivulet, show the characteristics of a nursery stream similar to Ration Tree Creek, but all three showed the presence of a small number of older fish. The absence of 2+ fish from two of these sections, and their poor representation in the third, suggests that the older fish were not part of the normal resident population and their presence can best be explained on the assumption that they were either invaders from the main stream, which was quite close at both P13 and 14, or mature fish which had remained upstream after spawning, at P15. Calculations based on Allen's (1951, p. 91) formula for egg production show that two 4-year females about 30.0 cm in length and three 3-year females about 27.5 cm would have been able to produce the 30 0+ fish taken in the 70 yard section fished at P15, so that ten mature fish were probably there in the winter; only three such fish were found and the other seven might have left the area or have been taken by anglers. No correction has been made for efficiency of the method and it is possible that the number of 0+ fish should have been higher, but although this section was fished only once it was relatively easy to fish and provided little or no deep cover for fingerlings.

Allen (1951) has shown that in the Horokiwi the average mortality rate after the first year is about 80 per cent. He also showed that fish in that stream made little or no spawning migration but tended to make their redds near where they were living. Schuck (1945) on the other hand was able to demonstrate an upstream migration in the spawning season, followed by a return "probably during the winter" to the sites from which these fish were originally taken. In Tasmania it has been shown that the average mortality rate in the rivers of the north west is similar to that found in the Horokiwi (Nicholls 1957a) though in the North Esk it may be somewhat lower; it was tentatively estimated at about 70 per cent. on the basis of representation in anglers' catches (Nicholls 1957b). The mean mortality rates for older fish in all sections fished in the two seasons were 67 per cent. for 2 to 3 years of age, and 80 per cent. for 3 years to older fish. The alternative method of estimating mortality based on the survival from 1955 to 1956 of the 2+, 3+, and 4+ fish (that is the 1953, 1952, and 1951 year classes), for all sites that were fished in both seasons, yields mean values of about 60, 75, and 90 per cent. respectively. Such estimates involve the correction of the 1956 numbers for the difference in area due to the different river levels and for the mortality which would have occurred during the two months delay in fishing. These results suggest that the average rate of 70 per cent. derived from anglers' catches is reasonably reliable. The increasing rates from the third year onwards found from the results of electro-fishing indicate a fairly heavy fishing intensity.

(c) The Total Population

It is difficult to estimate the total population of this river system with reliable accuracy without a more comprehensive survey including many more sections of the stream and its tributaries. The nearest approach that can be made is to apply the average number per mile of all sections fished to an estimate of the total river distance measured carefully on the 2 mile to 1 inch map. This yields the figures given in Table 2, expressed to the nearest 100, in which the numbers of 0+ and 1+ fish have

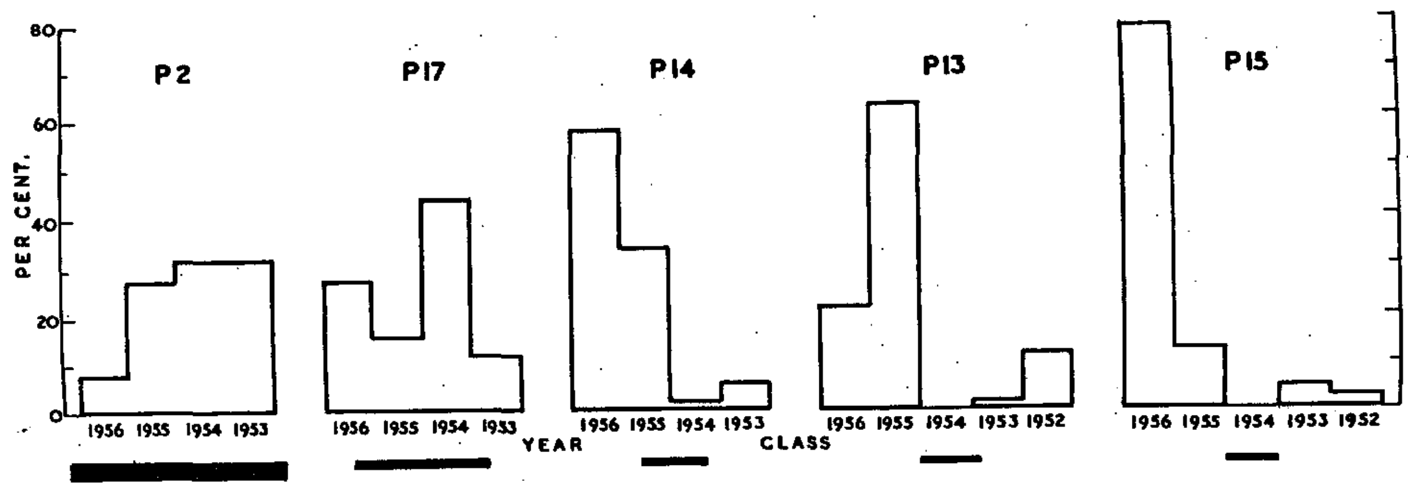

Fig. 4. Percentage composition of the population by age in relation to stream size. The black areas beneath each site indicate the mean cross sectional area of the stream drawn to scale.

been omitted since they are not representative and are therefore of no significance, and the numbers of fish for 1956 have been corrected for the mortality which would have occurred during the two months delay in fishing in 1956.

TABLE 2

ESTIMATED TOTAL POPULATIONS IN THE NORTH ESK AND ST. PATRICK'S RIVERS

Season	River	Age Groups 2+	3+	Older	Totals	Total Takable
1955	North Esk	16300	9000	3300	28600	14700
	St. Patrick's	10200	4400	1100	15700	6400
	System	26500	13400	4400	44300	21100
1956	North Esk	17200	8800	2500	28500	15600
	St. Patrick's	13600	3200	1500	18300	7100
	System	30800	12000	4000	46800	22700

The figures therefore represent the approximate numbers of fish estimated to have been present about January in both years. This method is not likely to exaggerate the estimate and can be regarded as minimal, since the length of the river must be under-estimated when measured from a map. For example, the section worked at P14, a normal winding stream, measured 187 yards along the stream bed but the straight line distance between the two stop nets was 135 yards, showing that the distance measured on the map, which shows this stream as a straight line, was under-estimated by about 38 per cent. The average population per mile covers all sections of the river and includes populations of quite small numbers, so that the average may be regarded as fairly representative. However, this estimate is for those portions of the two rivers and their tributaries lying above section E14 in the North Esk and above the junction of the Patersonia Creek with the main stream in the St. Patrick's. Below these points lie many miles of better fishing water, stretches which were too deep to study with the available equipment. On the assumption that the populations of takable fish at E14 and P11, the lowest points fished, were similar to that of the river below these points, and knowing the approximate distance from the points to Launceston, it is possible to estimate the population in this unfished section.

In the first season there were 186 takable fish per mile at E14 and 189 at P11; in March 1956 there were 154 at P11, and when this is corrected for the assumed 18 per cent. mortality, it becomes 188. A value of 190 takable fish per mile for the 40 miles of river between Hobbler's Bridge in Launceston and the lowest points fished, gives an estimated total of 7600 fish. These may be added to the estimated 22,000 found above these points, making a total of 29,600 in January of each year. If mortality for the four months which had elapsed since the beginning of the season in September accounted for 35 per cent., under the existing 70 per cent. annual mortality for this river system (Allen (1952) showed about 42 per cent. for this period under an annual rate of 80 per cent.), then the total number of takable fish at the beginning of the season would have been about 45,500.

It is of interest to relate this figure to the estimated total catch given in the survey of the North Esk fishery (Nicholls 1957b Table 28). These figures were subject to a relatively large standard error, but the average for the last five years was 20,000, again suggesting that it is fairly heavily fished, and that anglers normally remove about 44 per cent. of the takable fish available at the beginning of the season. The removal of these fish would be beneficial rather than harmful since it would make possible a better survival and better growth rate for those which remain. Allen (1951, p. 181) discussing mortality due to angling, shows that it may vary from 12 per cent. to 92 per cent. depending upon the intensity of angling, the higher figures coming from parts of the United States. A value between 30 and 40 per cent. would not be unexpected. The rate of removal by angling in this river might account for the lower than usual total mortality, around 70 per cent. per annum, indicated in the survey of the fishery referred to above and supported by the present study.

Some indication of the composition of the population in the eight or ten miles of the North Esk immediately below E14 is given by the 163 fish taken by one angler who fished this section regularly during the 1949-50 season. This sample shows the presence of 4+, 5+, and 6+ fish in proportions which indicate a mortality rate around 70 per cent. Below the section fished by this angler larger fish might be expected. The composition of his catch during the early part of the season was such that the estimated total of 45,500 takable fish would be composed of 900 6+ fish, 3500 5+ fish, 7300 4+ fish, 27000 3+ fish, and 7300 2+ fish. The actual numbers of 2+ and 1+ fish, assuming a constant mortality rate of 70 per cent., would have been 89,500 and 298,000 respectively. Allowing a 50 per cent. mortality from all causes during the fishing season, and 50 per cent. of the survivors to have been females, and knowing their approximate mean lengths at the end of the season, it is possible (using Allen's formula for egg production in relation to length (1951, p. 91)) to make a rough estimate of the number of eggs that could be expected to be spawned in the following winter, by which time the 2+ fish would have become 3 years of age and mature. This totals about 25 million, and if the estimated 298,000 survived to become yearlings the first year mortality would be about 98.8 per cent., which is not improbable. It would seem that this estimate of takable fish at the beginning of the season, while probably on the low side for reasons given above, is nevertheless adequate to maintain the stock even when subject to the heavy fishing which apparently occurs, because of the slightly reduced mortality rates which result.

The error likely to be introduced by not sampling the lowest 40 miles of this river is one which would omit the larger and older fish, and since their reproductive capacity is large relative to their number, correction for this error would increase the number of eggs spawned and so bring the first year mortality closer to the expected 99 per cent. It is highly probable that the number of takable fish per mile would increase downstream progressively as the river widens and deepens.

(d) The Standing Crop

The term "standing crop" is used here as defined by Carlander (1950, p. 222) as "the total amount of fish present at a given moment." To evaluate this it is necessary to have a reliable estimate of the total population of any given stretch of water, and this has been the aim of the present study. As Carlander states, confirmed by evidence produced above (Section II (b)) "electric shockers and nets.....may give a measure of the standing crop, but.....these estimates are subject to considerable error." In the present case no attempt will be made to estimate the standing crop for the river system, but values calculated for each section studied are given in Table 3, expressed as the total weight of fish in lb per acre on each occasion that it was fished. Although there is an error due to inefficiency of the method, since this applies to any significant extent only to fish of the youngest age group, which are the lightest, the error involved in estimating the standing crop without correction for these will be relatively small, and the estimates can be regarded as minimal.

TABLE 3

NUMBERS AND WEIGHTS OF ALL FISH PER ACRE, AND MEAN LENGTHS-FOR-AGE OF TROUT

Section No.	Number of all fish per acre		Weight of all fish per acre (lb)		Mean Lengths-for-age (cm)					
					L_1		L_2		L_3	
	1955	1956	1955	1956	1955	1956	1955	1956	1955	1956
E1	476	476	154 (8)	150 (17)	9.5	8.4	17.9	19.0	23.1	25.9
E2	196	173	56 (4)	75 (4)	10.5	10.6	20.3	20.4	24.6	24.5
E3	257	266	34	56	8.2	7.0	17.5	15.9	20.5	21.0
E4	215	134	60 (3)	62 (18)	9.6	9.3	20.5	20.2	26.5	25.0
E5	622	337	111	72	6.8	6.5	13.8	13.5	18.1	17.7
E6	195	143	60	61	10.9	10.6	22.4	22.5	25.0	28.5
E7	385	133	96 (14)	39 (8)	10.8	10.8	19.8	19.0	25.0	24.0
E8	24	-	5	-	7.0	-	12.5	-	19.0	-
E9	199	141	36	24	8.1	6.8	14.9	14.4	19.6	19.6
E10	584	364	61	67	6.6	7.1	14.3	12.9	18.7	17.8
E11	118	65	19	16	7.6	7.6	16.8	15.1	-	20.0
E12	105	120	17 (3)	30 (3)	9.1	9.2	18.6	18.5	22.3	23.8
E13	150	-	58 (3)	-	10.7	-	20.7	-	25.9	-
E14	138	-	38 (9)	-	12.1	-	23.2	-	28.1	-
P1	524	277	111 (43)	55 (6)	9.1	9.2	17.5	17.0	21.9	24.8
P2	287	339	34 (4)	63 (3)	8.7	8.3	15.9	16.0	20.0	20.9
P3	51	-	14 (5)	-	10.5	-	22.4	-	26.0	-
P4	528	389	32	36 (4)	7.2	8.3	15.3	17.0	19.0	-
P5	14	4	3 (1)	1	9.8	-	17.8	-	-	-
P6	37	27	18 (1)	3	11.0	5.5	19.3	-	22.5	-
P7	270	386	46 (<1)	59 (1)	8.8	9.0	16.7	16.6	-	21.5
P8	1170	918	143 (4)	105 (10)	7.8	7.8	15.4	15.1	19.7	19.8
P9	1288	605	186 (4)	90	6.8	7.5	14.8	14.7	20.1	20.5
P10	166	-	28 (3)	-	9.8	-	19.5	-	25.0	-
P11	136	116	36 (11)	35	10.4	10.4	20.3	20.7	24.3	26.4

The numbers in brackets are the weights in lb per acre of fish other than brown trout (mostly eels) included in the total weights of all fish per ac.

As shown in Table 3 the weights of brown trout per acre ranged from 2 lb to 182 lb at 25 sites in December-January 1954-55, and from 1 lb to 133 lb at 20 sites in February-March 1956. The average values in each season were 53 lb and 52 lb respectively. The mean percentages of brown trout in the total fish population were a little over 90 per cent. in both seasons.

As shown in Carlander's (1950, 1953) summaries, the standing crop for trout streams so far studied ranges from 0 to over 300 lb per acre. Some of those relating to brown trout may be quoted for comparison with values found here. Shetter and Hazzard (1939) in a study of eight sections in three streams in Michigan over a period of four months (June to September) found values for total fish populations ranging from 4 to 177 lb per acre; in these streams up to 11 different species of fish were found including crayfish, and brown trout in competition with brook and rainbow trout comprised only from 0 to about 70 per cent. of the total weight per acre. The weights of the standing crops of brown trout alone ranged from 0 to about 17 lb per acre, and of all trout from about 1 to about 40 lb per acre. These authors found that the carrying capacity of the streams was related to depth of water rather than to the nature of the bottom or of the cover. Schuck (1945) found an average value of nearly 14 lb per acre for brown trout in 13 sections of a stream in New York State, based on samples taken in September over a period of four years. Stefanich (1952) obtained September values for brown trout of 37.5 lb per acre in a Montana stream. Values for all trout (brown and rainbow) sampled in 7 months during a period of 16 months ranged from 44 to 68 lb per acre, comprising from 28 to 80 per cent. of the total fish population. While the total weight of fish per acre found in various sections of the North Esk System is below the middle of the range so far reported for trout streams, in all cases where a comparison has been made with streams in different parts of the United States, the weights of the total populations show a good standard and the percentage of trout in these populations is very high.

(e) Length and Weight of Trout in Relation to Population Density

Consideration of the results obtained by Cairns (1942), Frost (1946), Hartley (1948), Allen (1951), and Burnet (1952), leads to the conclusion that the short-finned eel (Anguilla australis Richardson) which occurs in this river system is a competitor with trout for food. These must therefore be included in any assessment of the effect of density of population on the growth of trout. Table 3 shows the numbers and weights of all fish taken from each section, together with mean lengths-for-age of trout at the end of their first three winters, in both seasons. Statistical analysis shows that the results for the two seasons can be pooled to give mean values representing the growth of fish in each section; it also shows highly significant differences within age-groups between sections.

If mean lengths are plotted against population densities for individual samples it is found that while there is some scatter there is at the same time a general trend in which lower mean lengths are associated with greater population densities. Because of this scatter the trends are more clearly seen when the samples are grouped. The sites have been arranged in ascending order of mean L_1 values in Table 4. These have been grouped so that there is no statistically significant difference between mean L_1 values within each group. Mean L_1 values and mean numbers of fish per acre have been calculated for each group and if these are plotted they show that a curvilinear relationship exists between the length of fish and density of population.

TABLE 4

GROWTH OF FISH AND POPULATION DENSITY

Group No.	Section No.	Mean L_1 (cm)	Group Means L_1 (cm)	Group Means No. of fish/acre	Sub-Group No.	Section No.	Mean L_2 (cm)	% Increment L_1 to L_2	Mean % Increment	Sub-Group Means L_2 (cm)	Sub-Group Means No. of fish/acre	Group Means L_2 (cm)	Group Means L_3 (cm)
I	E5	6.7)			IA	E8	12.5	79	79	12.5	24		
	E10	6.8)				(E5	13.7	104)				13.9	18.5
	E8	7.0)	6.9	547	IB	(E10	13.8	103)	104	14.0	633		
	P9	7.2)				(P9	14.7	104)					
II	E3	7.6)				(E9	14.7	88)	94	15.1	558		
	E11	7.6)			IIA	(P8	15.3	96)					
	P8	7.8)	7.8	405		(P4	15.8	98)				15.5	19.8
	E9	7.8)			IIB	(E11	16.2	113)	115	16.4	177		
	P4	8.0)				(E3	16.5	117)					
III	P2	8.5)			IIIA	(P2	16.0	88)	88	16.8	347		
	P7	8.9)				(P7	16.7	88)					
	E1	9.0)				(P1	17.3	88)					
	E12	9.1)	9.0	262		(E1	18.2	102)				17.8	23.2
	P1	9.2)				(E12	18.5	103)	105	18.9	199		
	P6	9.2)			IIIB	(P6	19.3	99)					
	E4	9.5)				(E4	20.4	115)					
IV	P5	9.8)			IVA	(P5	17.8	82)	82	19.1	134		
	P10	9.8)				(E7	19.5	81)					
	P11	10.4)				(P10	19.5	99)					
	P3	10.5)				(P11	20.4	96)	95	20.4	156	20.8	25.4
	E2	10.6)	10.5	143	IVB	(E2	20.4	92)					
	E13	10.7)				(E13	20.7	93)					
	E6	10.8)			IVC	(P3	22.4	113)	111	22.5	130		
	E7	10.8)				(E6	22.5	108)					
V	E14	12.1	12.1	138	V	E14	23.2	92	92	23.2	138	23.2	28.1

If L_2 and L_3 mean values are plotted a similar relationship is found. For L_2 values the groups are not homogeneous and statistical analysis shows that the differences within each group are quite significant for groups II, III, and IV, and at the 5 per cent. level for group I. These groups can be subdivided into two or more sub-groups, but owing to the considerable variation in length at the end of the first winter, grouping the L_2 values for mean lengths loses some of its significance. Growth rate is shown more accurately by considering the percentage increments from L_1 to L_2, and if these are calculated for each section it will be seen that within each group there exist sub-groups with different growth rates. These are shown in Table 4 together with the mean L_2 values for each sub-group. Statistical analysis shows no significant difference in the mean lengths within sub-groups. When mean population densities are calculated for each sub-group it is found that the lower percentage increments from L_1 to L_2 within each sub-group are consistently related to a higher population density. If it is attempted to carry this analysis to L_3 values it is found that owing to the spread of these values, and the few fish in many samples, no statistically significant difference is found within each group. The percentage increments from L_2 to L_3, which vary from 16 to 52, can be used to arrange the samples in further sub-groups which bear a relation to the mean population density for those samples within each group.

There is one obvious exception to this general trend, in which the fish at E8 were among the lowest size-group ~~at the end of their first winter and showed the lowest~~ percentage increment recorded, and yet they numbered only 24 fish to the acre. Only 2 fish were found at this section in 1955, one 2+ and one 3+, and in 1956 this creek was not worked because it carried no water. It is probable that it had been diverted for irrigation, sawmilling, or other purpose and could not be regarded as a typical stream inhabitable by trout, and may be omitted from further consideration. It will be seen that although, when the sections are grouped as in Table 4, the growth shows a relationship to the mean number of fish per acre for each group, these means are based on figures which themselves show some variation, and the largest populations do not necessarily fall into the group with the lowest growth rate. Station P8, for example, had a higher mean population for the two seasons than did P9, yet growth was better at P8; similarly P6 with quite a low mean population did not show such good growth as E4, 6, or 7, with higher population densities. Clearly other factors are concerned here and without going into detail as to the reasons, presumably related to food production for which no data are available in this study, it should be possible to discover which sections showed the best conditions for trout growth. Light is thrown on this question by a study of the weight of fish per acre in relation to population density.

Table 5 shows the mean number of fish per acre for arbitrary groups and the corresponding mean weight of fish per acre. Since the 0+ fish vary in their proportional representation and contribute only an insignificant amount to the weight, these have been excluded.

TABLE 5

MEAN NUMBER AND MEAN WEIGHT OF FISH PER ACRE

Grouped Numbers of Fish/Acre	Mean No. of Fish/Acre	Mean Weight of Fish/Acre (lb)	No. of Samples in Group
1-100	31	9	7
101-200	145	43	17
201-300	259	46	7
301-400	354	67	5
401-500	445	136	3
501-600	545	87	3
601-700	622	111	1
over 1000	1095	165	2

Within each group there is considerable scatter, with a general upward trend shown only in the groups for 1-100 and 301-400 lb per acre. When the means are plotted there is relatively little scatter and the points lie about a straight line with a suggestion of curvilinearity. One point only lies far off the curve, that for the mean value of 445 fish per acre with an unduly high value of 136 lb per acre. This group contains section E1 in both seasons, and P8 in 1956, and it is the former which is responsible for the high value. In both seasons the number and weight per acre were remarkably close, averaging 450 fish and 152 lb per acre. The stream at this point deepened into a large pool as it passed under a bridge. It may be stated that, in general, there is a close relationship between the number and weight of fish per acre.

(f) The Condition Factor

Condition factors have been calculated for each fish, and means for all fish of each age group. Comparison of the values within age groups and sections between seasons showed that in most cases there was no reason why they should not be pooled. As between sections, and as between age groups within sections, there is considerable variation and this is best shown by grouping sections with similar values. Because the 2+ fish were the most numerous they have been used as the basis for grouping, and sections have been arranged so that there is statistically no significant difference between the mean values for 2+ fish within a group. Under this arrangement there is no significant difference between the means within any age group except for the 1+ fish in Group I and the 4+ fish in Group III, which show differences significant at the 1 per cent. level. The grouped mean values are given in Table 6.

TABLE 6

GROUPED MEAN K VALUES FOR FISH OF EACH AGE GROUP

Group No.	Section No.	Age Groups 1+	2+	3+	4+
I	E12, 14, P5, 11	1.19	1.06	1.10	1.08
II	E1, 6 P1, 2, 3, 4, 6, 7, 8, 10	1.25	1.17	1.12	1.09
III	E2, 3, 4, 5, 7, 9, 10, 11, 13, P9	1.34	1.26	1.17	1.11

When the values for fish of the same age are compared as between groups highly significant differences are found for 1+ and 2+ fish; differences significant at the 1 per cent. level for 3+ fish; and no significant difference for 4+ fish. The variation shown in fish from different sections is therefore probably real. If fish of different ages are compared within groups, highly significant differences are found in Groups II and III, and at the 1 per cent. level in Group I, indicating that the observed fall in condition with increasing age is also real.

A comparison between the resident and released fish at sections of release shows that the former had a much higher mean K value (1.38) than the latter (1.20) in the North Esk; in the St. Patrick's the difference was smaller (means: 1.20 and 1.10 respectively). Klak (1941) has drawn attention to the fact that in certain Virginian streams, although released fish were of the same average length as the native fish of the same species, the condition of released fish was considerably lower than that of resident fish over a period of four years. He concluded that: "hatchery fish are handicapped, even when planted as fingerlings in streams exceptionally rich in food, because hatchery conditions prevent them from perfecting their natural foraging ability" (p. 285).

(g) Population Density and Total Weight in Relation to Volume of Water

Shetter and Hazzard (1939) in a similar study noted that in general, shallower shaded sections with submerged cover produced the greatest number of 0+ fish, and that an average stream depth of 14 in. or more was the only habitat characteristic that could be definitely correlated with a greater than average population of trout and other fish. Schuck (1945) found greater numbers of larger fish present in areas of greater depth and volume of water, and greater numbers of fingerlings in sections with greater velocity and area, the large fish being defined as those of 3 to 5 years of age. This did not prove to be the case here; no correlation existed even when the sections were arranged in two groups: those with mean depths greater or less than 14 inches. The shallower sections had a mean value of 80 per cent. younger fish and 20 per cent. older, and those with greater depths and volumes had mean values of 78.5 and 21.5 per cent. respectively, showing differences too small to be regarded as significant.

This difference in the results is probably due to the very different growth rates found in different parts of this system, so that 'larger' fish are not necessarily equivalent to older. It would seem better to use the legal minimum of 9 in. as the criterion, when this is done the expected result is found, with mean values of 18 per cent. larger fish in the shallower sections and 40 per cent. in the deeper sections.

It seems that in the North Esk System takable fish are distributed throughout but are found in increasing proportions downstream. The only large fish taken in this system (a 21 inch fish weighing 3½ lb) was found at the lowest section fished, where the stream was at its widest. The mean weight of trout for these two groups were 75 and 30 lb per acre respectively. It is of interest to note that the mean numbers of eels were the same in both groups, showing a relatively greater ratio to trout in the deeper sections, and their respective mean weights were 3 and 7 lb per acre, indicating an increase in size in the deeper waters. Owing to the limitations of the method used to fish these waters, in which road access was essential, it may be expected that in most cases the sections fished were also those most heavily angled. This would result in estimates of the population being lower than in the less accessible reaches and it is probable that the figures given here are minimal on that account. Only a few sections were heavily overgrown with vegetation and at one in particular (E5), which was difficult to fish, the number of fish per acre was the highest in the North Esk. Only two other sites exceeded the number taken here, and they were in the St. Patrick's (P8 and 9) and although there was less cover for fish, conditions were not good for angling. This agrees with the findings of Needham, Moffett, and Slater (1945) who found a much greater population of trout in a section of river closed to angling than in a comparable section which was open to angling.

IV. CONCLUSIONS

In the stream survey described by Schuck (1945) the extent of the loss due to inefficiency of the method was known and appropriate corrections were applied to the number of fish caught, from which he estimated annual survival rates for fish from 0 to 5 years of age and over, including mortality due to angling. From these figures the mortality rates were approximately 76, 54, 50, 77, and 62 per cent. respectively, and are comparable with the figures given here which include angling mortality. By maintaining a controlled creel census over the period of the investigation he was able to show that angling was responsible for the greater mortality of the older age groups. He was also able to demonstrate that mortality among takable fish due to angling accounted for only about 15 per cent. of the total, and that a considerable natural mortality in these fish occurred during the summer, not traceable to any obvious cause. This mortality due to angling is close to the value found by Allen (1951) for the Horokiwi, but must also be related to the intensity of fishing. Although no reliable data are available to indicate the intensity of fishing in the North Esk System, the mortality due to angling is probably about 40 per cent.

Schuck's estimate of the total population in the 4.17

miles of stream studied shows about 625 fish per mile compared with the average value of 600 in the North Esk; (no allowance has been made here for inefficiency of the method). No comparison between numbers of takable fish is valid since the legal minimum size in Crystal Creek was 7 inches compared with 9 inches in Tasmania. Schuck also derived certain conclusions regarding the survival of fingerlings released from a hatchery into this stream; he found a maximum of 6.3 per cent. survival over one year compared with 24.1 per cent. for wild fish of the same age; the results presented here show close agreement in that the survival over 9 months was estimated not to exceed 11 per cent. Comparable figures for the survival of the natural population over that period are not available because they were not truly represented in the catches. That this is so is shown quite clearly from the actual capture of fish from section P2 on two successive occasions. In March 1956, 9 months after liberation the number of 1+ fish per acre was 86, of which 55 were marked; in December of the same year the corresponding numbers of fish, which were now 2+, were 94 and 17 respectively. These figures show that while there had been a mortality of nearly 70 per cent. among the marked fish during the 9 months, there had been an increase in the numbers of resident fish to the extent of nearly 150 per cent., indicating extensive recruitment.

The results of this study clearly indicate that in the North Esk System some fish spawn in the deeper and wider sections, but that where they do so the mortality suffered by the young is greater than normal and too high to permit any real contribution to the stock, or to enable them to maintain the population of takable fish at the level at which it is quite clearly existing. Greeley (1932) has discussed mortality at spawning, and this is further considered in Appendix II. The main source of fish to maintain the stock must come from the numerous shallow tributary creeks and the headwaters of the system, where the numbers of young fish have been shown to be greatly in excess of those required to produce the numbers of older fish found there; a reversal of the conditions found in the downstream sections. Inefficiency of the method cannot account for the small numbers of young fish found in most of the sections fished in 1954-55, and the increased proportions of young fish found in 1956 indicate that there had been a downstream migration, probably related to the heavy rainfall which occurred in that season.

Downstream movement of fish has been demonstrated by a number of workers. Cooper (1953) showed it to exist in released fish and to be closely related to temperature, occurring only when that was 50°F (10°C). Needham and Cramer (1934) using a two-way fish trap also demonstrated a strong downstream movement with no apparent correlation with water temperatures, but taking place in spring and coinciding with rising, but not maximum, stream flows; lack of food and shelter were suggested as factors responsible for the migration. It will have been noted that the downstream migration of young fish which had occurred by February 1956 was associated with rising river levels, but it is probable that in normal years this takes place towards the end of summer, or with the first rains of autumn.

Needham and Slater (1944) have shown that under certain conditions it is possible to anticipate the success of releasing trout when the weight of the resident population is known. This is based on the known survival rate of released fish, but since in their case the fish were released into individual screened sections of experimental streams accurate figures for survival could be obtained because no fish could escape. In the present case the fish were released into open streams and were free to move; that they did so has been shown. It is, however, possible on the basis of the estimated survival for each 2-mile section over which they were assumed to have dispersed, to compare the numbers of fish surviving in such sections with the total resident populations of all fish in these sections. These figures are given in Table 7. If these pairs of figures are plotted it appears that a relationship exists whereby the higher the resident population the better the survival of released fish, which suggests that the resident population is already making good use of the available food but that the stream is able to carry additional trout to the extent of about 14 per cent. of the resident population.

TABLE 7

RESIDENT POPULATION AND SURVIVAL OF RELEASED FISH

Section	No. of all Fish in 2 Miles	No. of Survivors in 2 Miles	Survivors as % of Total Fish
P6	150	21	14
E11	240	13	5
E4	480	14	3
E9	670	104	16
E10	700	26	4
E2	870	318	37
P7	880	148	17
P4	1100	116	11
P9	1100	220	20
P2	1700	151	9

Each of the population factors which has been considered in the study of these streams seems to have contributed something to the question of the ability of each section to support fish; that in some the released fish showed a better survival than at others, and that growth rate and condition also varied from place to place, and it may have appeared that some of these streams could be restocked to advantage. It seems then that consideration of these factors together, for each separate site, should give a reliable measure of stream conditions and show whether additional stocking in some places might be of value. For this purpose 2-year fish will be used for the assessment of growth and condition, since they predominated in every case.

The results of such an analysis can be summarized as follows: in the North Esk, E1 and 5 appear to be good sections of stream carrying large numbers and weights of fish per acre, but, because either the length or the condition was below average, they are considered to be fully stocked. E2, 3, 4, 6, 7, 9, 10, 13, and 14, are moderately good sections, apparently fully stocked, and where fish were released at only one place did the absorption exceed 16 per cent. of the resident population. At E2 it amounted to 37 per cent. and the implication that this section could have carried more fish is supported by both length and condition which were above average; E13 and 14 could also probably have carried more fish. It is clear that these sections would have been repopulated by down-stream movement of fish. E8, 11, and 12 are poorer sections, with relatively low numbers and weights of fish per acre, and the below average lengths and condition factors suggest that they were fully stocked.

In the St. Patrick's, P1, 8, and 9 are regarded as good sections, carrying above average in numbers and weights of fish per acre, but since the lengths or condition factors tended to be below average it is concluded that they are fully stocked; P9 absorbed released fish to the extent of 20 per cent. of the resident population. P2, 4, 7, 10, and 11 are moderately good sections carrying about average numbers and weights of fish per acre, and as lengths and condition factors tended to be low, these are considered to be fully stocked. P3, 5, and 6 are considered to be poorer sections in which the numbers and weights per acre were all quite low; the length was below average (except at P6) and the condition was average to low. The facts suggest that these sections were fully stocked; the absorption of released fish at P6 was equivalent to 14 per cent. of the very low resident population. Those sections which carried very low populations and at first sight might appear to be in real need of restocking have all been shown to be in poor sections, probably incapable of carrying larger stocks of fish. These observations are based on conditions during the middle of the season, at which time the stock will have been depleted by angling, and before the normal downstream migration of young fish has taken place, so that any deficiencies in the population apparent at that time would be made good later in the year by natural means. It has been shown that even heavy stocking with hatchery fish is of little value in these streams.

Of considerable practical interest here is the extent of the protection afforded to fish by the application of the legal minimum length of 9 inches. It is clear that as any year class ages its weight increases but its numbers decrease. Allen (1951) and others have shown that the optimum time to crop a stock is when the weight of any particular year class is at its maximum. From the mean weights of fish of each age taken at each site during this survey, and assuming a 70 per cent. annual mortality after the first year, the total biomass of each age group has been calculated for each site. This shows, rather surprisingly, that for the 22 sites for which data were available the 1+ age group had a greater mass than the 2+ at 17 of the sites; they were about equal at 3 sites; and the 2+ had the greater mass at 2 sites. In every case the biomass of the 2+ fish was greater than that of the 3+ fish. This suggests that for most of the sections of river examined the optimum time to fish the population is during the fish's second year and that there is considerable wastage of fish because anglers are unable to retain the younger fish owing to the imposition of the 9 inch size limit. These calculations have been based on the lengths and weights of fish measured at about the middle of the growing (and angling) season, so they may be regarded as representing average conditions for the season. Because increase in weight is more rapid than increase in length they distort the relationship in favour of the 1+ fish when compared with conditions at the beginning of the season, but correspondingly they fail to do justice to the same fish when taken at the end of the growing season.

In places where the population was dense and the growth rate was low there is a case for a reduction of the minimum legal length. Allen (1954) has discussed the effect of size limits on the yield and his Figure 4 is a chart from which the protection afforded by different minimum lengths may be estimated for fish over a range of lengths. Knowing the mean lengths of fish of each age group and using his chart to estimate percentages takable, the total weight per acre of fish available to anglers, based on the actual occurrence of such fish in each section, has been calculated, and the figures are given in Table 8 for the existing 9 inch size limit and for 8 inch and 7 inch size limits.

TABLE 8

TOTAL WEIGHTS OF FISH PER ACRE AVAILABLE TO ANGLERS UNDER DIFFERENT SIZE LIMITS

Section No.	Minimum Legal Lengths 9 inch Total Weight (lb)	8 inch Total Weight (lb)	7 inch Total Weight (lb)
E1	98	130	140
E2	31	39	42
E3	5	10	24
E4	32	42	44
E5	30	52	76
E6	48	49	50
E7	59	76	81
E9	6	19	29
E10	2	16	33
E11	0	4	13
E12	4	9	12
E13	41	47	51
E14	18	19	24
P1	17	32	41
P2	1	4	9
P3	8	9	9
P4	5	10	17
P5	1	2	3
P6	17	17	17
P7	5	13	28
P8	21	47	75
P9	72	99	122
P10	8	12	17
P11	13	18	20

The figures show that in sections where growth was good, or the population was sparse (as at P6) little addition to the available weight is made by reducing the size limit, but where growth was poor or the population was dense, considerable relative increases in the weight available to anglers follow. The averages for the 24 sections included in this Table show a 43 per cent. overall increase as a result of a reduction of one inch, and an

80 per cent. increase if it were reduced to 7 inches. A reduction in the size limit would thus give anglers the benefit of fish which would otherwise be wasted to natural mortality. It is to be noted that very considerable increases occur where the population is densest and it is to be expected that the effect of lowering the size limit would be to thin out the population and thus enable a better growth for the remainder, though as Allen (1954) has shown, the relationship is not direct but is dependent on a number of other factors.

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APPENDIX I

TABLE 1

BASIC DATA FOR 1954-55

Section No.	Name of Stream	Date	Length of Section (ft)	Mean Width (ft)	Mean Depth (in)	No. of Fish Taken			Weight of Fish Taken (lb)		
						Brown Trout	Eels	Other Species	Brown Trout	Eels	Other Species
E1	Musselborough Ck.	2.xii.54	195	15.4	11.1	30	3	-	10.16	0.53	-
E2	Musselborough Ck.	3.xii.54	278	14.4	9.5	17	1	-	4.72	0.38	-
E3	Musselborough Ck.	6.xii.54	252	14.8	9.8	22	-	-	2.94	-	-
E4	Burn's Ck.	7.xii.54	402	14.1	7.5	26	2	-	7.33	0.41	-
E5	Pig Run Ck.	8.xii.54	324	13.2	9.2	61	-	-	10.88	-	-
E6	Ford R.	9.xii.54	384	28.0	12.8	48	-	-	14.70	-	-
E7	Phillip's Ck.	9.xii.54	450	5.3	6.3	12	9	-	4.50	0.75	-
E8	Unnamed Creek	10.xii.54	288	12.6	5.9	2	-	-	0.39	-	-
E9	Ford R.	10.xii.54	399	18.7	5.8	34	-	-	6.22	-	-
E10	Unnamed Creek	10.xii.54	204	7.7	5.1	21	-	-	2.19	-	-
E11	North Esk R.	17.xii.54	432	15.4	12.9	18	-	-	2.91	-	-
E12	Evelyn Rvt.	17.xii.54	404	29.1	13.0	26	1	-	3.69	0.75	-
E13	North Esk R.	20.xii.54	369	39.4	17.0	47	3	-	18.38	1.03	-
E14	North Esk R.	21.xii.54	426	57.7	20.2	61	17	-	16.44	4.88	-
P1	Patersonia Rvt.	13. i. 55	384	23.3	14.6	82	24	2⁴	14.09	8.65	0.13⁴
P2	Patersonia Rvt.	14. i. 55	301	21.7	18.3	40	3	-	4.52	0.56	-
P3	St. Patrick's R.	17. i. 55	324	42.4	18.1	5	11	-	2.94	1.44	-
P4	Trout Ck.	18. i. 55	366	10.4	7.2	45	1	-	2.77	?	-
P5	St. Patrick's R.	19. i. 55	360	43.4	11.3	4	-	1=	0.91	-	0.25=
P6	Camden Bk.	19. i. 55	306	22.1	18.8	5	-	1=	2.78	-	0.13=
P7	Serpentine Rvt.	20. i. 55	396	9.7	6.4	23	-	1+	4.03	-	0.03+
P8	Serpentine Rvt.	21. i. 55	444	10.2	7.0	119	3	-	14.45	0.44	-
P9	Unnamed Creek	21. i. 55	396	6.7	6.2	76	1	1+	11.01	0.22	0.01+
P10	St. Patrick's R.	24. i. 55	330	36.5	20.3	41	5	-	6.97	0.81	-
P11	St. Patrick's R.	24. i. 55	252	33.1	14.4	22	4	-	4.84	2.06	-

⁴ Blackfish; = Rainbow Trout; + _Galaxias_ sp., weight estimated; ? not weighed.

TABLE 2

BASIC DATA FOR 1956

Section No.	Name of Stream	Date	Length of Section (ft)	Mean Width (ft)	Mean Depth (ft)	Number of Fish Taken: Brown Trout Total	Brown Trout Marked	Eels	Other Species	Weight of Fish Taken (lb): Brown Trout	Eels	Other Species
E1	Musselborough Ck.	9. ii.56	154	16.7	15.9	25	9	3	-	7.84	1.00	-
E2	R Musselborough Ck.	2. ii.56	285	15.9	11.1	17	3	1	-	7.42	0.41	-
E3	Musselborough Ck.	9. ii.56	270	16.3	9.3	27	-	-	-	5.73	-	-
E4	R Burn's Ck.	2. ii.56	384	15.3	9.0	12	1	6	-	5.91	2.50	-
E5	Pig Run Ck.	8. ii.56	333	11.7	8.8	30	-	-	-	6.86	-	-
E6	Ford R.	8. ii.56	330	26.8	14.0	29	-	-	-	12.47	-	-
E7	Phillip's Ck.	3. ii.56	478	6.2	6.8	5	-	4	-	2.06	0.56	-
E9	R Ford R.	3. ii.56	353	22.7	8.3	26	7	-	-	4.50	-	-
E10	R Unnamed Creek	3. ii.56	204	8.2	7.7	14	1	-	-	2.56	-	-
E11	R North Esk R.	6. ii.56	412	16.3	12.8	10	1	-	-	2.50	-	-
E12	Evelyn Rvt.	6. ii.56	378	27.8	12.7	26	2	3	-	6.50	0.78	-
P1	Patersonia Rvt.	16.iii.56	373	24.9	17.2	56	-	3	-	10.41	1.31	-
P2	R Patersonia Rvt.	16.iii.56	314	22.5	23.3	53	9	2	-	9.67	0.50	-
P4	R Trout Ck.	10. ii.56	408	12.9	8.3	44	9	2	1+	4.00	0.39	0.02+
P5	St. Patrick's R.	19.iii.56	241	49.7	13.3	1	-	-	-	0.17@	-	-
P6	R Camden Brook	19.iii.56	255	25.7	26.2	4	1	-	-	0.52	-	-
P7	R Serpentine Rvt.	20.iii.56	389	11.0	6.8	36	11	2	-	5.69	0.13	-
P8	Serpentine Rvt.	20.iii.56	402	13.0	7.4	104	2	4	2=	11.38	1.21	0.04=
P9	R Unnamed Creek	15.iii.56	454	9.0	10.1	57	19	-	-	8.47	-	-
P11	St. Patrick's R.	21.iii.56	240	36.1	20.1	22	-	1	-	6.95	?	-
P2	Patersonia Rvt.	12.xii.56	360	21.9	21.3	53	3	6	-	10.94	3.09	-
P13	Unnamed Creek	12.xii.56	364	5.8	6.9	49	-	-	-	6.06	-	-
P14	Unnamed Creek	13.xii.56	562	6.6	8.8	83	-	1	-	2.66	0.31	-
P15	Patersonia Rvt.	14.xii.56	207	4.9	6.5	38	-	-	-	2.39	-	-
P16	Patersonia Rvt.	14.xii.56	203	11.5	5.9	14	-	-	-	1.81	-	-
P17	Patersonia Rvt.	14.xii.56	387	13.6	9.8	43	-	2	-	6.67	1.80	-

= Rainbow trout, 0+ fish, weight estimated;
? Not weighed;
+ *Galaxias* sp., weight estimated;
@ Allowance for fish seen but lost;
R Position of release of 1000 marked fish in June 1955.

APPENDIX II.

THE NATURAL PREDATORS OF TROUT IN TASMANIA

It was stated above (Section IV) that natural mortality among the young fish was likely to be greater in the deeper and wider sections of a stream than near the headwaters. Some consideration of the reasons for this are given here. Greeley (1932) has shown that during spawning, unattached males of the same species, and males of other species, accompany spawning fish and avail themselves of opportunities of darting in and seizing ova being shed. This has been observed to occur in Tasmania. It is known from several sources that the Platypus (<u>Ornithorhynchus anatinus</u> Shaw and Nodder) also causes some loss of eggs and young fish. Lord and Scott (1924) refuted the claim that it ate fish but show that being well equipped for burrowing, and using this method for collecting much of its food, it could well disturb spawning redds and consume ova. Burrell (1927) states that the natural food of the platypus, in order of preference, consists of shrimps, earthworms, and insect larvae, and that it also eats tadpoles, molluscs and water-weed. He points out that it comes to the surface to chew its food, and states in connection with one kept in captivity for a considerable period that it would not touch "river fish" even though they were "shrimp-size and served alive." On the other hand Harris (1956) states that the platypus eats small fish. It is clear from Burrell's account that it would not inhabit very small creeks where the banks could not accommodate its burrows, but they have been taken occasionally in the larger streams when electro-fishing, and it is in such places that the population of small trout has been found inadequate to maintain the existing population of older trout. It is probable, therefore, that it is responsible for some of the mortality of the eggs and that it would also eat recently hatched alevins, since these are of similar size to shrimps.

The following account, based on factual evidence relating to predation on young trout in Tasmanian waters, has been summarized from a statement prepared by Mr. H.V. Jones, Chief of Staff of the Salmon and Freshwater Fisheries Commissioners, whose observations are the result of over thirty years' association with the freshwater fisheries of the State. He lists the following mammals and birds, not necessarily in order of importance. The platypus, golden-bellied water rat (<u>Hydromys chrysogaster</u> Geoff.), blue (or white-faced) heron (<u>Notophoyx novaehollandiae</u> Forster), Black Duck (<u>Anas superciliosa</u> Gm.), silver gull (Larus novae-hollandiae Stephens), bittern (Botaurus poiciloptilus Wagler), and cormorant, all species, of which four are known to occur in Tasmania: the black (Phalacrocorax carbo L.), the little black (P. sulcirostris Lesson), the white breasted (P. fuscescens Vieillot), and the little pied cormorant (P. melanoleucus Vieillot). All of these, in his personal experience, are known to have fed on trout at one stage or another, as noted below. Not included in his list, are both species of trout and the native freshwater flathead, or sandy (also locally known as pike) (Pseudaphritis urvillei C. & V.) which have been referred to in the preceding pages. It is also probable that the introduced perch (Perca fluviatilis Rondel) and possibly the native blackfish (Gadopsis marmoratus Rich.) eat young trout.

Mr. Jones has observed platypus on spawning beds in streams and on the shores of lakes; at the Great Lake rainbow trout have been seen spawning along the shores of Swan Bay and platypus going from redd to redd disturbing them; three platypus have been observed at the same time working over spawning beds at Mountain Creek, Lake Sorell. In the hatcheries considerable damage can be done by platypus, and when captured there, have disgorged quantities of partly eaten fish, up to 3 inches in length, of which they normally eat the head and leave the body. The reverse is the case with the water rats which frequent the hatchery and take fish up to 5 inches in length from the ponds, eating the body and leaving the head and fins. If allowed access to the hatchery buildings they will also eat large quantities of eggs, though their chances of obtaining these in nature are considerably less.

Of the birds, Mr. Jones regards the blue heron as the worst predator where fish are concentrated, as in shallow rearing ponds, though ducks would rank high here. Of the heron he states that when killed and examined at hatcheries they are found to contain large numbers of fish up to 3 inches in length; one contained 237 trout up to 1¼ inches long. It is found on most of the rivers and around lakes and would cause its greatest damage when rivers are reduced to pools, and at such times and places where shallow conditions enable it to wade among the fish; recently many were disturbed on a visit to the Liawenee Canal when the flow was reduced and the fish concentrated in pools. The wild duck will take spawn and small fish, and has been seen on the spawning beds at the Great Lake, Lake Sorell, and Lake Leake. Ducks destroyed at the Plenty hatchery have had young fish in the gut, and on one occasion practically cleaned out one small rearing pond containing 8000 trout fry.

Sea-gulls destroyed at hatcheries have been found to contain fish up to $1\frac{1}{4}$ inches, and one bird had eaten over 50 young fish and also quantities of ova. The bittern, which is found around the shores of rivers and lakes, was seen to take a fish about 4 inches long on one occasion. As for cormorants, they are very troublesome at the hatcheries at times, and those shot on inland waters occasionally contained trout. Although most of this factual support for predation on trout by various species comes from the hatcheries, this is to be expected since it is there that the fish are concentrated and most easily taken, and it is also at such places that observations are most likely to be made. These notes show that the species listed will all feed on young trout.