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THE COARSE FISHES OF BRITAIN

being

THE FINAL REPORT ON THE COARSE FISH INVESTIGATION

by

P. H. T. HARTLEY, B.Sc.

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FOREWORD.

The Coarse Fish Investigation was undertaken by the Freshwater Biological Association in 1938 at the request of the National Federation of Anglers, who provided the funds which made it possible. The early history of the Investigation will already be familiar to those who have read the Interim Report which was published by the Association (*Scientific Publication No.* 3) in 1940. When, in the following year, Mr. Hartley joined the Army as an expert on the problems of camouflage, the Investigation came of necessity to a standstill, and it was not until his return to this country in 1945 that he was able to resume the task of analysing the immense mass of data he had collected.

This report, then, should be read as a sequel to the earlier one. It is not intended to be a fully documented scientific paper, but aims rather at setting out in a concise and easily intelligible form the important results of this investigation—important, that is, to the practical fisherman or fishery manager. The full data will be published shortly as a paper entitled "The Natural History of some British Fresh-water Fishes" in the *Proceedings of the Zoological Society of London*. When this appears the scientific world as well as the anglers of Britain will realise the debt they owe to the National Federation of Anglers for having made this research possible, and to Mr. Hartley for the skill with which he has carried it out.

H. CARY GILSON,
Director.

Wray Castle,
November, 1946.

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INTRODUCTION.

WHEN in the year 1937 discussions began between the National Federation of Anglers and the Freshwater Biological Association on the need for research upon the coarse fishes of Britain, questions of the breeding and rearing of large numbers of young fish, more especially Roach, occupied the first place in the programme. It was assumed that deficiencies of numbers and poor qualities of stocks were alike to be made good by the straightforward policy of restocking; and with that end in view the attention of the research officer appointed was to be concentrated first of all upon the best methods of rearing fry to a size at which they could be safely turned down in natural waters.

As discussions proceeded it became obvious that in making this assumption of the universal adequacy of the policy of restocking, a very great deal was taken as proven which was in fact open to question. It was seen that the fundamental problem was not the principles and practice of rearing coarse fish. The investigation of rearing methods was a line of research which would provide the means of fulfilling a policy which was not, perhaps, of universal application. A new orientation was, therefore, given to the research, and it was decided that the first problem was to learn something of the life and growth of non-salmonid fishes in British waters. A good deal of work had been done upon the Continent on species of interest to the coarse fisherman, but the results were buried in the pages of journals not readily accessible. The first need was to provide some standard by which the well-being of the different stocks of fish in British waters could be measured. When such a 'yard-stick' had been provided, then, and not till then, would it be possible to say what steps should be taken to make good the sporting deficiencies of any stretch of water.

The investigation which was begun in 1939 at Barrington in Cambridgeshire was therefore, with the full approval of the National Federation of Anglers, devoted to the general life histories of as many species as possible. Before the research officer joined the Army early in 1941 a considerable mass of data had been brought together, and an interim report had been published—" The Food of Coarse Fish " by P. H. T. Hartley, B.Sc. (Freshwater Biological Association, *Scientific Publication No.* 3, 1940).

Now, five years later, the results of the investigation are presented in the hope that they will provide a basis of knowledge upon which sound policies can be devised for the improvement of fish stocks and the increase of sport. In this report the scientific data, which will be published in full elsewhere, have been condensed as much as possible, but nothing of importance has been omitted and nothing has been concealed.

METHODS OF INVESTIGATION.

ALL the fish handled during the investigation were subjected to the same routine of examination. The length was measured from the tip of the snout to the fork of the tail, except in species with a rounded tail which were measured to the tip of the longest ray of the tail fin. In this account the ' length ' of any fish with a forked tail is the ' length to the fork.' This has been preferred to the over-all length because in many fish, especially those of larger size, the tail is much frayed and the longer rays are broken. In such fish the over-all length can be no more than guessed. All lengths were measured to the nearest millimetre below, that is to say, any fraction of a millimetre in the length was disregarded. Fish of 10·9, 10·5, 10·1 and 10·0 mm. would, for example, all be recorded as 10 mm. long. In this report all lengths have been converted into inches (1 inch = 25·4 mm.).

The weight of the whole fish was then taken to the nearest gram below. Weights are here given in ounces (1 oz. = 28·4 gm.). The roe or milt was examined to see if the fish was adult or immature, and to find the usual date of spawning. The content of the stomach was examined, and the animals or plants contained were identified as far as the state of digestion permitted. In the case of netted fish an estimate was made of the " fullness " of the stomach. This " fullness " was determined upon an arbitrary scale, based upon experience of the usual quantities of food eaten by each species.

Lastly a few scales were taken from the flank of the fish, between the front edge of the dorsal fin and the lateral line, and these scales were used for investigation of age. The scales of a fish are made up of a number of overlapping plates, each a little wider than the one above it. When a scale is looked at from above, the edges of the plates are seen as a number of concentric rings, very like those of a tree (Fig. 1). When growth is fast, each new plate is wide, and the edges are far apart. When growth is slow, the new plates are narrow, and the edges are close together. Usually the last plates laid down before the end of a period of slow growth are but little wider than those above, and have notably irregular edges. From above, the edges of these plates are seen as a dark, scalloped line, running round the scale between the zone of closely packed edges of the plates of the period of slow growth and the more widely spaced edges of the plates laid down during the subsequent period of rapid growth. It has been found that in each year one complete set of plates is laid down, and the edges of these are seen as the wide and narrow rings of the periods of swift and slow growth,

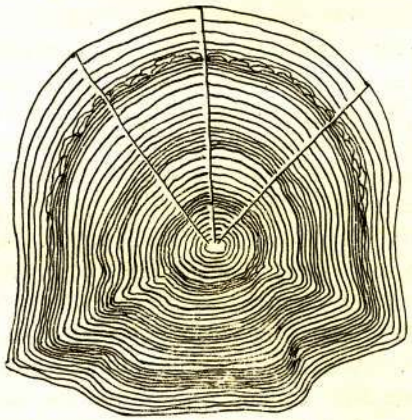

Figure 1. Scale of a Roach three years of age. The fish has spawned at the end of the third year of life, and shows, at the edge of the scale, the first wide rings of the fourth season's growth.

with a well-marked boundary at the end of the latter period. By counting the number of these boundaries, the age of the fish in years can be read directly from the scale. In most freshwater fish these ring-line boundaries are formed at the end of the spawning season.

The reading of scales can be learned with a little practice, and greatly increases the interest of a fish when it is captured. The apparatus required is simple—a good pocket lens, a pair of blunt forceps, a few clean microscope slides and a small bull-dog clip. Take a few scales from the flank of the fish just above the lateral line at the level of the front edge of the dorsal fin; clean off the coating of silvery skin by rubbing the scale between two layers of

a duster; sandwich the clean scale between two glass slides together with the clip at one end. Then hold the sandwiched scale up to the light and look for the dark, concentric lines of the annually formed rings. It will be found that these are soon distinguished, and the years of the fish's life can be counted.

There are two simple precautions to be observed:

Do not take scales—or more than one scale—from a fish which is to be returned to the water alive.

Be sure that the scales kept for reading have clearly marked lines running right into the centre. When a scale has been regenerated the middle is usually a maze of small, wavy lines, not running concentrically. Such a scale is useless for age determination.

When the scale has been read and the age determined, the length of the fish (to the *fork* of the tail) can be compared with the lengths for age shown in this report, and it can be decided if the fish be a well-grown, a stunted, or an average specimen.

If the length-for-age relationship is to be used as the basis for the determination of a fishery improvement policy, it may be as well to have the scales of at least a score of fish read by an expert. But the interest of scale-reading is urged upon all anglers, who will find its practice greatly to increase the fascination of their sport.

RESULTS OF THE INVESTIGATION.

IT will be seen that four matters have been regarded as of primary importance:

The size of fish.
The age of fish.
The food of fish.
The age of breeding fish, and the season of spawning.

The practical angler may well be puzzled about the bearing of such questions upon his sport. He may feel inclined to ask 'If a fish be small, and gives me a poor fight, what do I care if it be three or ten or fifty years old ?' 'If the fish will not take my bait, what satisfaction is it to me to know that they are feeding on *this* snail or *that* beetle ?' and 'So long as fish are there to spawn and keep up the stock, does it matter how old they are ?' It is now necessary to show that the four problems of the investigation have, in addition to their intrinsic scientific interest, a very real bearing upon all questions of fish conservation and fishery improvement.

First, the questions of size and age, and the relation between them which we call growth. When we think of growth, our thoughts turn to the way in which we ourselves and our domestic animals and birds have grown—a limited period of rapid growth in youth followed by a long period of maturity when there is no increase in height and when changes in weight are relatively slight and are not directly connected with age. For each species there is an 'average height,' a height dependent largely upon heredity and little upon nurture. If the amount of food available be insufficient for growth to this standard size, then young animals and birds die; they do not continue as stunted, but fairly sturdy dwarfs.

In fish, the process of growth is very different; it may almost be said that there is no 'average length' for any species, though there is an upper limit of length far above the size of most of the fish and only rarely attained.

The fact that the fish usually kept for preservation and exhibition are these rare giants tends to prevent the realisation of the much smaller size of the rank and file. When food is plentiful, fishes will grow swiftly during their immaturity and continue to grow for several years after they have become mature. The most fortunate of the fish living under these favourable conditions may attain the upper limit of size of their species. But when food supplies are scanty, or other conditions are unfavourable, growth is from the first exceedingly slow. As long as there is enough food for some growth to be made the dwarf fish will mature, and breed year after year, though they may grow scarcely at all after the first spawning.

When we are able to compare the average lengths of fish of the same age from different localities, we find ourselves provided with a standard which gives exactitude to our comparison of different populations. We can say that in one district the fish of a certain age are longer than the average—their growth rate is swift; in another locality the fish of the same age are less than the average in length—their growth rate is poor. It must be emphasized that there is no absolute standard; we can but say that growth rates compare favourably or unfavourably with the average of many different populations, or with the growth rate shown in any one district which we have chosen arbitrarily as a standard.

The fundamental importance of this problem of the relationship of age to size may be made clearer by an illustration. Let us assume that the members of an angling club are dissatisfied with the catches from their water, and desire to make improvement, and let us further assume that the fishes caught are all very small. A sample of these fish is taken and their age is determined by the method of scale-reading. If it be found that these small fish are also quite young, then restocking may be resorted to, to increase the supply of takeable fish, for it would appear that the small size of the members of the fish population is not due to over-crowding. Before restocking it will be as well to make sure that there is not a large stock of predators, which are killing off the desired fish before they can attain their full size. But if the small fish are also old (and it has been pointed out that many species of freshwater fish will maintain themselves and even spawn, though very stunted in size), then money spent on restocking would be worse than wasted, for it would but aggravate the problem of over-crowding. Efforts at fishery improvement would be better devoted to increasing the supply of food, or even, it may be, to netting out and destroying part of the stock in order that the survivors may be able to grow to a size when they will give better sport.

Second, the problem of food. We have already noticed that good or bad growth rates will depend, at least in part, on the supply of food. When a slow growth rate indicates an inadequacy of supply, this inadequacy may be due to one of two factors—too many fish of one species, or the extensive competition of some other species for the same supplies. When it is desired to encourage one species in particular, we must know which of the other species living in the same water are eating the same foods. It will not do to confine our studies to the sporting fish alone; we must study all the species present, without regard to their sporting qualities.

Last, the question of the age of the spawning fish. It is certain that the swiftest way to wipe out any animal is to destroy the breeding females, and (except in the special case of gross over-population, which is to be reduced by making drastic reductions of the stock over a limited period) fishery regulations should ensure that every female fish has the chance to spawn at least once before she reaches the size at which she may legally be killed. When the age of female fish at first maturity is known, and their length at that age, size limits can be fixed upon a surer basis than guess-work or local custom.

Species by species, the results obtained in the years 1939-1940 are set out, in such detail as the number of fish may warrant. The greater the number of specimens examined, the more extensively can the results be analysed. In the interim report of the Coarse Fish Investigation (Hartley, 1940) attention was concentrated upon the food of coarse fish. In this report growth—the relationship between size and age—is the principal subject, with some comments upon other matters in connection with the life history of each species.

As far as possible, the tabular form has been used, so that the data for any species can be found as easily as possible. The ages of fish are given in complete years, in accordance with every-day usage.

THE ROACH, *Rutilus rutilus*.

Some 2,100 Roach were examined, of which about half came from the Norfolk Broads. More than 200 came from the Old West River, and 100 or more came from the River Cam at Barrington, the River Granta, the Bridgewater Canal and the Grantham Canal.

Roach of the same age were found to vary enormously in length in any one locality, and therefore the ranges of size as well as the average length of each age-group are given. When there is so much variation in size of fish of the same age, it will be obvious that the average length of each group within a population must be gauged from a large sample, taken without selection. Data derived from only one or two fish may prove misleading in the extreme.

In Table I the average lengths and the ranges of size of each age-group of Roach from several different localities in England are shown, and they are compared with the lengths of fish of similar age from several waters in Northern Europe. The general similarity of these figures is obvious, and it will be seen that of the English fish the growth in two localities—Madingley Upper Pond and Barrington—where the three-year-old fish are more than 5 inches long, is above the average, and that none of the growth rates are noticeably poor. No English water, for example, shows fish so small for their age as those of the Straus See in Northern Germany. In general it may be said that an average three-year-old Roach should be 4½ inches long; at four years it should measure 5 inches, at five years 5½ inches, at six years a little over 6 inches and at seven years at least 7 inches. Lesser lengths to the fork of the tail will indicate unfavourable conditions, and markedly greater lengths will indicate an environment which in abundant food supply and lack of rigorous competition is well suited to the requirements of the species.

In terms of weight, an average three-year-old fish should weigh 1 oz., at four years 1¼—1½ oz., at six years just over 2 oz., and at seven years ¼ lb.

At least half of the one-year-old male Roach are mature, and 88 per cent. of the three-year-old males are breeding fish. The females mature later. An occasional two-year-old breeding female is found, and at three years old three females in every four are ready for the spawning stock. Except in waters singularly favourable to the growth of this species, a 6-inch limit will therefore

Table I. ROACH.

Average length in inches, and (in italics) ranges in length of British samples.

LOCALITY	Number of fish	AGE OF FISH IN YEARS 0—1	1	2	3	4	5	6	7	8	9
Madingley Upper Pond	50		3·5 *2·7—4·3*	4·0 *2·7—4·7*	5·6 *5·1—5·9*	7·1 *6·3—7·5*					
Barrington	165	1·4 *0·3—2·3*	2·7 *1·9—3·5*	4·2 *2·7—4·7*	5·1 *3·1—6·3*	6·3 *4·3—8·7*	7·1 *5·5—8·7*	8·5 *6·3—9·8*	(9·5) *8·7—10·6*	(9·1) *6·3—10·2*	(10·8)
Bridgewater Canal ...	109				4·6 *3·9—5·1*	5·4 *3·9—6·7*	6·2 *5·1—7·1*	7·4 *5·9—8·2*	(7·7)	(9·6)	
River Granta ...	117			(3·5)	4·6 *3·9—4·7*	5·1 *4·3—5·9*	5·6 *4·3—7·5*	6·5 *5·5—8·7*	(7·5)		
Norfolk Broads ...	1124	1·4 *1·1—2·3*	2·7 *1·9—4·7*	3·6 *2·5—5·1*	4·4 *3·1—7·1*	5·0 *3·5—7·5*	5·3 *3·9—8·2*	6·0 *4·3—8·2*	6·8 *4·7—8·7*	7·8 *5·5—9·0*	8·5 *6·7—9·4*
Grantham Canal ...	171		2·6 *2·3—2·7*	2·4 *1·9—3·1*	4·1 *3·5—9·7*	4·9 *3·9—6·3*	5·6 *4·3—7·9*	6·2 *5·1—7·1*	7·0 *5·9—7·9*		
Old West River ...	216	1·7 *1·1—2·3*	2·6 *1·9—2·7*	3·6 *2·7—3·9*	4·4 *3·5—5·1*	4·9 *3·9—5·9*	5·6 *4·3—6·3*	6·5 *5·1—7·5*			
***Sweden*—**											
Hjalmarens (Alm, 1917)		1·2	2·3	3·1	4·2	5·1	5·9	6·6	7·2	8·0	8·2
Kloten (Alm, 1921)		1·2	2·1	3·2	4·3	5·2	5·8	6·7	7·5	7·9	8·6
***North Germany*—**											
Madu See (Schilde, 1936)		1·9	2·7	3·8	4·7	5·8	7·2	7·9	9·0		
Sakrower See ,, ,,		1·8	2·9	3·6	4·5	5·3	6·2	7·0	8·4		
Muggel See ,, ,,		1·7	2·4	3·3	4·1	4·8	5·4	5·8	6·6		
Grimnitz See ,, ,,		1·8	2·6	3·1	4·0	4·5	4·9	5·7	6·1		
Straus See ,, ,,		0·9	1·3	1·9	2·3	2·8	3·2				
Stettin Harbour (Neuhaus, 1936).		1·7	3·5	4·9	5·8	7·6	9·1	10·2	11·3	12·2	13·3

Figures in brackets are based on small samples.

protect a breeding stock adequate numerically, although it may be as well that the stock should not consist entirely of small fish for it seems possible that an ideal race would not be bred from such a parentage.

At two years old the numbers of males and females in the population are equal ; from that age the proportion of males steadily declines until only 10 per cent. of the seven-year-old fish are males. In the breeding stock in the Norfolk Broads the males are to the females as 1 : 2·49. The spawning season is very short, occupying about a week at the end of May and beginning of June. In 1940 for example, two ripe females were trapped in the River Cam on May 27th, and two running with eggs on May 30th. No more Roach were taken until June 5th. On that day, and subsequently, all the fish trapped were spent. As in most species of fish, the males are ready to spawn before the females. A male running with milt was trapped on April 22nd, 1939.

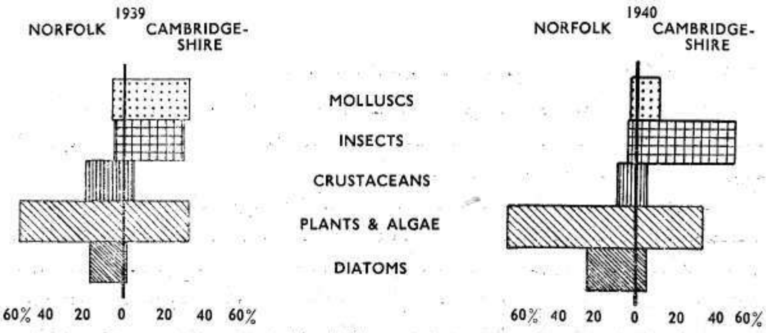

Figure 2. Comparison of Foods eaten by Roach from the Norfolk Broads and from the River Cam at Barrington, Cambridgeshire, 1939 & 1940.

The feeding habits of Roach have been considered at some length elsewhere (Hartley, 1940) and are briefly summarised here:—

1.—Roach eat many different foods ; in most waters they eat more vegetable than animal food.

2.—Small crustaceans (water-fleas) and diatoms (plants of one cell) are the foods of the smaller fish.

3.—Insects, higher plants and green algæ are eaten throughout life ; they become of greater importance in the diet as the consumption of water-fleas and diatoms decreases.

4.—Water snails are the food of the larger fish.

5.—There is a winter fasting period.

Figure 2 shows the difference between the diets of the Roach in the River Cam at Barrington and in the Norfolk Broads, in the years 1939 and 1940, and stresses the larger proportion of animal food eaten in the Cambridgeshire river. In Table I the rapid growth rate of the Roach taken at Barrington has been shown, and it is a point of interest that a predominantly animal diet may make for swift growth in this species. This cannot yet be regarded as proven. The animal diet and the swift growth are found together, but may not stand in the relation of cause and effect. Indeed the small proportion of crustaceans and diatoms in the food of the Barrington fish may be rather an expression of the swift growth to a size when such foods cease to be of importance in the diet. This is an obvious line of future experiment into the biology of the Roach.

THE RUDD, *Scardinius erythrophthalmus*.

Just over 250 Rudd were examined. Of these fish, 140 came from the Norfolk Broads, 48 from Madingley Upper Pond and 47 from a pond in the Weald of Kent.

In the relation of age to length the Rudd showed as great a variability as the Roach. In Table II the average length and the range of lengths of each year-group of Rudd are shown, and compared with the size of a population of Rudd from Yxtasjon in Sweden. It will be seen that the fish from Fairhill, in Kent, are of remarkably small size. Their habitat has been described by Professor P. A. Buxton as "a peculiarly nasty black pond in the Weald of Kent "near Tonbridge. It is a pond with very steep sides, about five "feet deep and almost entirely without water weeds. The bottom "is a black and stinking mud and it is much overhung by oak trees. "It carries an enormous population of these little fish . . . ." The stunted growth of this stock of Rudd is doubtless the result of severe over-crowding, and too strenuous competition for the available food.

An average Rudd should be 4½ inches long, and weigh 1½ oz. at three years old, and 5½ inches long and at least 4 oz. in weight at four years.

Table II. RUDD.

Average length in inches, and (in italics) ranges in length of British samples.

LOCALITY	Number of fish	AGE OF FISH IN YEARS 0—1	1	2	3	4	5	6	7	8	9
Norfolk Broads ...	140				5·4 *4·3—6·7*	5·6 *4·3—7·1*	6·4 *5·1—7·9*	6·8 *5·5—7·5*	7·4 *6·3—7·9*	*7·5—7·9*	
Cambridgeshire ...	70			3·6 *1·9—3·9*	4·2 *3·5—5·5*	5·3 *4·3—6·3*	*6·3—7·5*	*5·5—8·7*			
Fairhill, Kent	47				3·1 *2·75—3·1*	3·6 *2·75—4·3*	4·3 *3·1—4·7*	4·8 *4·3—4·7*			
Sweden— Yxtasjon, (Alm, 1922)					4·1	4·8	5·0	5·9	6·9	7·6	7·9

Table III. DACE.

Average length in inches, and (in italics) ranges in length.

LOCALITY	Number of fish	AGE OF FISH IN YEARS 0—1	1	2	3	4	5	6
Barrington ...	230	1.6 *1.1—1.9*		5.8 *3.9—7.1*	7.2 *6.3—7.5*	8.2 *6.7—9.0*	8.4 *6.7—9.4*	8.7 *7.9—9.0*

Male and female Rudd mature at the same age. 27 per cent. of the three-year-old males and 32 per cent. of the three-year-old females are breeding fish, and of the four-year-olds 90 per cent. of the males and 94 per cent. of the females are spawners. In the first two years of spawning the numbers of males and females in the breeding stock are equal; then the proportion of males decreases sharply, and females make up three quarters of the breeding fish five years and more in age. Males are to females in the spawning shoals as 1 : 1·73. The spawning season appears to be in June.

The choice of food shown by the Rudd is wide. In the Norfolk Broads, vegetable foods made up nearly three quarters of the diet, but in two woodland pools—Madingley Upper Pond and Fairhill Pond in Kent—aerial insects were the most important food. Rudd do not feed along the bottom, and eat but few snails and freshwater shrimps. A large Rudd will occasionally turn hunter and eat other fish.

THE DACE, *Leuciscus leuciscus*.

The number of Dace investigated was 237, of which 230 came from the River Cam and its tributary the Shepreth Brook at Barrington. The average length and the range of size of each age-group of these Barrington fish is shown in Table III.

In the Hampshire Avon (Berry, 1935) found a sample of four-year-old Dace to have an average length of 8·7 inches, and some six-year-old fish to be 8·9 inches long. A four-year-old Dace should weigh from 3 to 4 oz.

Although Dace grow so swiftly in their first years of life, they attain neither so large a size nor so great an age as the slower growing Roach. The largest Dace seen was only 9½ inches long, and the oldest was but six years old; the biggest Roach from the same water was 11¼ inches long and eleven years of age.

In Fig. 3 the growth rates of Roach and Dace in the Cam at Barrington are shown, and the different type of growth in the two species emphasized. In the Dace growth is rapid at first and then sharply decreases. In the Roach growth is at a fairly steady rate.

This is especially stressed in the lower curves, in which the *increases* from year to year are shown. This figure emphasizes the danger of arguing from one fish to another though they be closely allied.

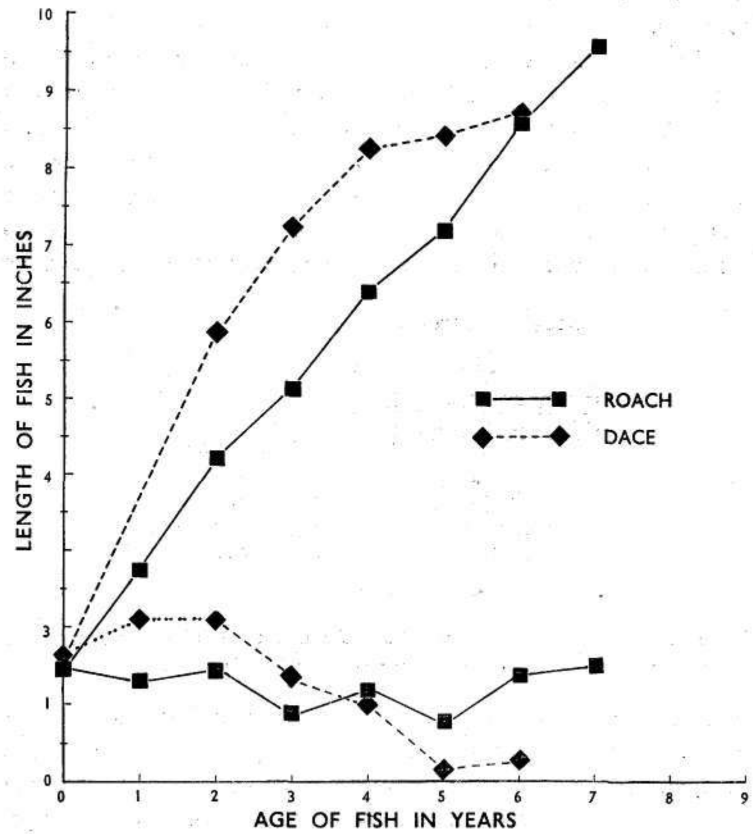

Figure 3. Comparison of Growth-rates of Roach and Dace from the River Cam and Shepreth Brook at Barrington, Cambridgeshire, 1939 - 1941.
Upper curves — Average length of each age-group.
Lower curves — Increment in length of each age group.
(The increment figures for one- and two year-old Dace are averages).

It has been shown that an average three-year-old Roach should be 4½ inches long. A glance at the figure will show how risky would be the process of arguing that because some two-year-old Dace were already more than 5 inches long, Roach of the same age would be as large. It is of course possible that where one species does well, another normally associated with it will also thrive. But this is by no means certain, and the protection policy for each species must be decided by reference to that fish and that fish alone.

No one-year-old Dace were caught, and only a few of two years. It is not therefore possible to fix the age of first maturity with any certainty, but mature two-year-old fish of both sexes were seen. Of 151 sexed fish, 69 (46 per cent.) were males and 82 (54 per cent.) were females. Here again the danger of arguing from one species to another may be pointed out. It has been said that a 6-inch limit will protect a numerically adequate spawning

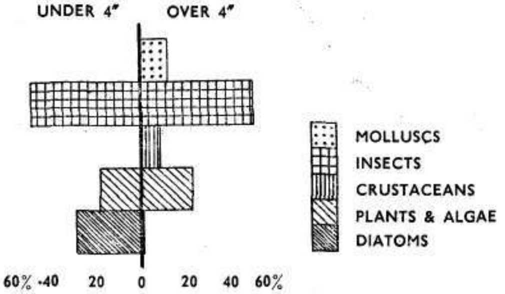

Figure 4. Comparison of the diets of Dace of under and over four inches length. Barrington, Cambridgeshire, 1939 - 1941.

stock of Roach, save in waters quite unusually favourable to the species. The same size-limit would be too small for Dace. Although Dace never grow to a size as large as Roach, a 6-inch Dace would have spawned not more than once. In the upper reaches of the Cam June appears to be the spawning Season. A spent female was trapped as early as June 11th, 1939, and a female still full of eggs as late as July 6th, 1940.

In the Dace, as with so many other freshwater fishes, a change in diet with increase in size was found (Fig. 4). The smaller fish ate large quantities of insects and diatoms and some plant material. The larger Dace ate snails, insects, freshwater shrimps and plants. There is no well-marked fast in this species.

Table IV. BREAM.
Average length in inches, and (in italics) ranges in length.

LOCALITY	Number of fish	AGE OF FISH IN YEARS 0—1	1	2	3	4	5	6	7	8	9	10	11
Madingley Lake	65	3·0 *2·3—3·5*	5·0 *3·9—5·1*	5·5 *4·7—7·1*	8·4 *4·7—13·0*	10·0 *8·2—11·0*							
Norfolk Broads	998	1·8 *1·1—2·3*	3·9 *2·7—5·9*	5·4 *3·1—6·7*	6·4 *4·7—7·9*	7·3 *5·1—9·8*	8·0 *5·9—11·0*	8·75 *5·9—11·4*	9·4 *5·9—12·2*	11·6 *9·4—13·7*	*12·2—14·2*	*13·0—15·3*	*13·4—16·1*
Old West River	90	(1·3) *1·1—3·1*	3·5 *2·7—3·9*	4·6 *3·5—5·9*	5·9 *4·3—7·5*	7·2 *5·9—8·2*	8·8 *6·3—10·2*	*10·6—12·6*					
River Cam, Dimock's Cote	22				(7·4) *5·5—7·9*	7·7 *5·9—8·2*	9·3 *6·7—11·8*						
Grantham Canal	17					10·2 *7·5—11·4*							
***Sweden*—** Hjalmarens (Alm, 1917) Yxtasjon (Alm, 1922)		1·3	2·6	3·8	5·3	6·6 6·1	7·3 6·7	9·0	9·8 7·2	10·0	11·3	11·8	12·4
***Finland*—** (Segerstrale 1932)	...	*1·3—1·7*	*2·6—3·5*	*4·1—4·9*	*5·0—6·1*	*6·1—7·6*	*7·5—8·5*	*8·0—9·4*	*8·7—10·2*	*9·3—11·0*	*10·4—12·0*	*11·2—12·1*	*12·3—12·9*
***Germany*—** Stettin (Neubaur, 1926)					8·1	9·9	12						

Figures in brackets are based on small samples.

THE BREAM, *Abramis brama.*

Some 1,200 Bream were examined, of which a thousand came from the Norfolk Broads. They were found to be just as variable in growth-rate as Roach and Rudd and Dace, the largest fish of some age-groups being twice as long as the smallest. Ranges of size and average lengths of English fish are shown in Table IV and compared with the findings of continental workers. The Bream from Madingley Lake clearly belong to a swiftly growing population, and the lengths of the small sample from the Grantham Canal may also indicate favourable conditions. If the figures from the Norfolk Broads be taken as average (and they compare favourably with results from Sweden and Finland), then it may be said that a healthy Bream should measure 6½ inches to the fork of the tail at an age of three years, 8 inches at five years, 9½ inches at seven years, and just under one foot at eight. In terms of weight an average Bream should weigh just under 2⅓ oz. at three years old, 5½ oz. at five years, 10 oz. at seven years and 1 lb. 2 oz. at eight.

When a sample of the Bream caught during the breeding season was examined, it was at once apparent that the spawning fish made up a relatively small part of the population. One four-year-old male of 11·4 inches, two four-year-old females of 10·6 and 11·0 inches, one five-year-old male of 8·7 inches and two five-year-old females of 7·1 and 11·8 inches were the youngest breeding fish seen. Among the six-year-old fish, 10 out of 16 females were immature, and a seven-year-old male and an eight-year-old female were taken in the breeding season with undeveloped roes. At one or two years old the sexes are equally represented, but in all the older groups the males are in the minority. This change in the proportion of the sexes takes place before the fish become sexually mature. Of all sexed fish, males were 39 per cent. and females 61 per cent. Spawning is completed before the middle of June.

Bream were great eaters of water-fleas ; these small crustaceans were the most important part of their diet, with midge larvæ and water plants next in order. The smaller fish ate many diatoms, the larger ate some snails.

Table V. WHITE BREAM.

Average length in inches, and (in italics) range in length of British Sample.

LOCALITY	Number of fish	AGE OF FISH IN YEARS 1	2	3	4	5	6
England	115	(4.1) *3.5—4.3*	4.5 *3.1—5.5*	4.9 *3.5—7.1*	5.1 *3.5—7.1*	(6.6) *5.5—7.1*	(6.5)
Yxtasjon, Sweden (Alm, 1922)	males. females.			3.1 3.9	3.4 4.0	3.5 4.0	 4.2

Figures in brackets are based on small samples.

THE SILVER or WHITE BREAM, *Blicca bjoerkna*.

Only 115 White Bream were examined, 88 of which came from the Old West River in Cambridgeshire, and 6 from the lower reaches of the Cam. White Bream were found to be relatively short-lived, for no fish were seen more than six years old. In the first three years (Table V) growth is as fast as that of the Common Bream; then the annual increase in length of the White Bream becomes rapidly less, while that of the Common Bream is maintained. Table V, which shows the growth of the White Bream in England also shows the growth-rate at Yxtasjon in Sweden (Alm, 1922). It seems that White Bream in Sweden and Finland eventually reach a size as large as that of the British fish, but that they are longer-lived and make their growth more slowly. At Hjalmarens in Sweden Alm (1917) took White Bream ten, twelve and thirteen years old, the largest of them 7·2 inches long, and in Finland Segerstrale (1932) examined a twelve-year-old fish 7 inches in length.

White Bream enter the breeding stock much younger than the longer-lived, slower-maturing Common Bream. Some males and some females bred in their fourth year and all the five-year-old fish were mature. June is the main spawning month. Four out of five females netted on June 6th, 1939, were full of eggs, and one was spent. A partly spent female was caught as late as August 6th, 1939.

The food of the White Bream closely resembled that of the Common Bream, with water-fleas as the main food, plants second in importance, and some insects and snails. In this comparatively small species the change from a crustacean diet to snails and insects took place at a smaller size than in the Common Bream; but in both species the change took place at the same stage in the life history—by and large at the time of attaining to breeding condition.

There is a greater or lesser degree of competition for food between most of the members of freshwater fish communities, but the close competition which must exist between Bream and White Bream is one of the puzzles of freshwater fish biology. One would imagine that one species or the other, and probably the smaller one, must go to the wall. It is at least possible that the White Bream is in the process of being crowded out. Its distribution in Britain is much more restricted than that of the

Table VI. PERCH.

Average length in inches, and (in italics) ranges in length of British samples.

LOCALITY	Number of fish	AGE OF FISH IN YEARS 0—1	1	2	3	4	5	6
Eastern England ...	204	2.3 *1.6—2.7*	3.4 *2.3—4.3*	4.3 *2.3—6.3*	5.7 *3.1—8.3*	6.5 *4.8—7.9*	6.3 *5.1—7.1*	
Windermere ...		2.1	4.2	5.2	5.6	5.9	6.5	
Loch Lomond ...		1.5	3.4	4.9	5.9	6.7	7.2	
Sweden—								
Hjalmarens (Alm, 1917)				4.0	5.0	6.3	7.3	
Kloten (Alm, 1921)		1.5	2.8	4.0	4.8	5.4	6.4	
Borgholm ... (Segerstrale, 1933)		1.8	3.5	5.0	6.4	6.2	6.8	
Vastervik ... (Segerstrale, 1933)			3.1	4.1	4.9	5.3	5.9	6.8
Germany—								
Mecklenburg and Brandenburg (Roper, 1936) ...		2.8	3.5	4.0	4.4	4.9	5.3	5.8

Common Bream, and it appears to be less common in the Norfolk Broads than it was when Lubbock (1849) wrote his "Observations on the Fauna of Norfolk" a hundred years ago.

THE PERCH, *Perca fluviatilis.*

The total number of Perch examined was only 204. The small amount of the material has necessitated the massing of data from several waters in East Anglia and the eastern Midlands, between the Trent in the north and the headwaters of the Cam in the south. My colleague, Mr. E. D. Le Cren has kindly put at my disposal unpublished data on the growth of the Perch in Windermere and in Loch Lomond. In Table VI the average size and range in length of each age-group in eastern England is shown, and the growth rate compared with those in Windermere and Loch Lomond and in several Continental waters.

The growth of the Perch in their first year is very like Day's (1880-1884) figure of 2¼ inches at one year, but the size of the fish in their second year is less than his figure of 5 inches at two years. The lengths of the first three year-groups are considerably less than Regan's (1911) figures of 3-4 inches at one year, 5-6 inches at two and 7-8 inches at three.

There is a close similarity in the growth in the three British waters and it seems that this growth is comparable with the swifter of the Continental growth rates, for Segerstrale (1933) quotes the figures from Borgholm as an instance of notably rapid development.

Male Perch enter the spawning stock at an earlier age than the females. Thirty per cent. of the one-year-old males and 92 per cent. of the two-year-olds were mature. No one-year-old breeding females were seen but three quarters of the two-year-olds were in breeding condition. It is suggested that the size limit for Perch must be at least 6 inches so as to allow each female to spawn at least once.

THE PIKE, *Esox lucius.*

The Pike examined numbered only 94, of which 61 fish came from the River Cam and Shepreth Brook at Barrington. There is evidence from Continental and North American waters that the growth rates of Pike may vary greatly from one locality to another,

Table VII. PIKE.

Average length (in inches) and range in length at Barrington ; average length in Windermere.

LOCALITY	Number of fish	AGE OF FISH IN YEARS 0—1	1	2	3	4	5	6
Barrington	61		7.5 *3.9—11.0*	11.1 *9.4—15.8*	12.25 *8.7—17.3*	13.3 *11.0—17.3*	(15.0) *13.4—18.1*	
Windermere ...		6.2	9.9		13.8	15.6	17.8	20.5

Figures in brackets are based on small samples.

so the results from the different localities have not been massed, and only the Barrington figures are here reproduced (Table VII) together with some unpublished data on growth of Pike in Windermere, kindly supplied by my colleague, Dr. W. E. Frost.

It must be stressed that little importance is to be attached to the Barrington figures. The numbers are small, the fish were young and the waters in which they were caught were confined and shallow. Alm (1921) in Sweden, quotes 6·8 inches at one year, 10·6 inches at two years and 13·85 inches at three years as a typical

Table VIII. Fish food of Pike: numbers of food fishes found in Pike from five different localities.

	R. Cam and Shepreth Brook	Norfolk Broads	Old West River	Grantham Canal	Windermere (Allen, 1939)
Number of fish examined	61	16	8	6	103
Brown Trout ...	—	—	—	—	2
Eel	1	—	—	—	—
Gudgeon ...	7	—	3	—	—
Minnow ...	3	—	—	—	9
Roach	2	6	9	3	—
Bream ...	—	2	—	—	—
Loach	2	—	—	—	—
Bullhead ...	3	—	—	—	—
Perch	—	—	—	—	42
Stickleback ...	20	—	—	—	8

'bad' growth rate, and certainly the findings of most other workers indicate a much swifter development.

The lengths of three-year-old Pike from two localities in Sweden were 18·0 and 19·2 inches (Alm, 1917 and 1921), and in Wisconsin, in the United States of America, three-year-old fish were no less than 23·3 inches long (Van Engel, 1940). Day (1880-84) records of Pike that "growth does not always correspond with the amount of food consumed in that well fed Pike in aquaria do not grow as fast as fish living in open waters" Allee (1932) records

of the American Yellow Perch (*Perca flavescens*) that the size attained "appears to be directly related to the size of the water." It is probable, therefore, that the lengths given for the Barrington fish in Table VII are minimal, in that the larger members of the age-groups occupy the deeper lies and wider hunting grounds, while the slower-growing fish are confined to shallows where restricted quarters will further reduce their already low speed of growth.

The youngest spawning Pike seen were three-year-old females, the smallest of which was a fish of 11·6 inches, trapped on June 6th, 1940. According to Rawson (1932) males mature at one year older than females. The breeding season is prolonged, lasting from early spring to mid-summer. A female still full of eggs was trapped on June 5th, 1940, and a newly-spent male on July 11th of the same year.

To many anglers not the least interesting part of the natural history of Pike is the effects of the predatory habits upon other fish. In Table VIII the fish foods of Pike in several localities in East Anglia and in Windermere (Allen, 1939) are compared. It is a matter of some interest that 38 recognizable fish from Pike stomachs at Barrington did not include one Brown Trout, although this species was numerous in both the river and the brook from which the Pike were trapped.

COMPETITION AMONG FRESHWATER FISH.

WHEN the scales from a sample of fish have been read, and the condition of the fish has been decided by the comparison of their age with the standards given in this paper, it remains to discover the reasons for the good, average or stunted growth which has been discovered, and to discuss the steps to be taken to improve the fishery.

If growth be found to be good it is improbable that the owners or lessees of the water will feel desire to make alterations, or lively concern with the causes of a state of affairs so happy. If the swiftly growing fish be very few in number, a restocking policy may well be adopted, a policy in which caution must be exercised to make sure that the favourable conditions are not over-exploited. A water in which a hundred fish to the acre will grow swiftly may be capable of supporting twice that number without in any way reducing the increase in size of the individuals. It is improbable that growth will be so good if the density of population be increased to 1,000 fish to the acre.

In any water there is a definite amount of material which can be turned into fish flesh; but all this material is not in the shape of fish food. A considerable part of the supply is potential; that is to say it is a store of substances which can be elaborated into food, but normally exist in a state in which fish cannot take them in. At the beginning of the story there is a supply of nutrient material in solution in the water—carbon dioxide, compounds of phosphorus and nitrogen, iron and many other substances which need not concern us here. These dissolved nutrient materials are used by plants, with the assistance of sunlight, to build up more plant material and so to increase the supply of vegetable food. The plant foods in freshwaters exist in two main forms: firstly, minute, enormously numerous, unattached plants of one cell each, either contained in a little glassy box of silica, as in the diatoms, or naked; and secondly, the higher plants, usually but not always rooted in the mud. Plants of both kinds may be utilized directly

as food by fishes, or they may provide food for the many tiny animals —water-fleas and shrimps, beetles, caddises, creepers (nymphs of Ephemeroptera) and snails—which are eaten by fish.

If the unicellullar plants become too numerous, they may make it impossible for fish to live in the same waters; such a thing happened in Denmark in 1938 and 1939. If the rooted plants grow too thickly they may provide a cover so dense that the fish cannot get at the insect and snail life swarming within it. It is probable that this density of cover is often a limiting factor in the amount of the food available to fishes. In shallow waters where there is little or no current, reeds and sedges may eventually grow across from bank to bank, and destroy the fishes' habitat completely. But in spite of these possible dangers and disadvantages, plant growth remains the all important basis of the supply of fish food, as it is, indeed, the basis of all animal life.

In the presence of a limited supply of food there will be competition between one fish and another, unless the fish population is very sparse when there will be enough, and more than enough, for all. When questions of fishery improvement are under discussion this factor of 'struggle for existence' must never be forgotten.

When the growth of the fish is found to be average or worse, then the reason must be sought before a policy of improvement can be laid down. In many cases the question of major importance will be the way in which the food supply is utilized. Competition may be of two kinds—competition within one species, or competition between a number of species. When competition is severe between the members of one species, it is obvious that a restocking policy would be disastrous, for it would but result in a more severe 'struggle for existence' and a yet more stunted growth in the competing fish. Beckman (1941) in his interesting account of the improved growth of Rock Bass (*Ambloplites rupestris*) which followed a drastic reduction in the density of population, writes " Too often in the past, the problem of stunted fish has been aggravated by the legal protection of the runts, and even by further stocking." When one species alone is found, or greatly dominates the population, an improved growth-rate can be obtained in two ways:—

1. By reducing the density of population.
2. By increasing the capacity of the water to produce food.

The density of population may be reduced by netting or trapping operations, by the abolition of rules or customs for the return of fishes to the water, or by the reduction of size limits. This last method may be temporary.

The production of food may be increased by manuring the water with fertilisers and, in waters which have recovered from a pollution which has at some time decimated the fauna, by the introduction of snails or shrimps. The manuring of ponds has been fully dealt with in the Freshwater Biological Association, Scientific Publication No. 6, to which reference should be made. The fertilization of ponds and of stretches of canals or small canalised rivers is easy, but the fertilization of rivers of any size is a thing which has not been attempted, and may not be possible.

It is fully appreciated that the suggestion that fishing may be improved by the removal of fish may seem strange, and in water which has been so treated the angler may get fewer bites per day. But when the policy of reduction of numbers has been boldly carried out, the fish which are caught will be well grown and healthy. For some years before the war the Ouse and Cam Fishery Board used to net numbers of Roach and Bream from the lake at Madingley. It was noticeable that the growth rate of fish in this population, which underwent regular and drastic reduction in numbers, was unusually swift. It is suggested that it is more satisfactory to bring to the bank one Roach of 1 lb. and two of ½ lb. than a hundred 1 oz. 'tiddlers.' A fishing competition in a water which had undergone thinning of the stock would be for specimen fish rather than for total weight. Whether this be desirable it is for anglers to decide.

In many waters in addition to competition between the members of one species, there may be competition between one species and another. It has been pointed out that most species of freshwater fish "have more or less generalised feeding habits, and are enabled to maintain themselves in the face of varying circumstances by flexibility of behaviour," but be the choice of diet never so catholic, a species will often be so placed that there is no possible food which it can enjoy without competition. In Table I it has been shown that the growth of the Roach in the Cam at Barrington is better than growth in the Norfolk Broads, and in Fig. 1 the larger amount of animal food eaten in the first

of these two localities is shown. It is at least probable, though not proven, that growth in the Broads would be swifter if the great numbers of Bream in the waters of east Norfolk did not compel the Roach to rely so much upon vegetable food. Competition between species is far more difficult to prove than competition within a species, but the study of foods makes it possible to make intelligent guesses at the sharper contests. It is probable, for example, that if Ruffe could be exterminated in the Norfolk Broads the Perch would grow faster. It is probable that the Eel is the worst enemy of the Brown Trout. It is probable that the Roach and the Rudd are species not in serious competition with one another, for the Rudd seek most of their food in mid-waters or near the surface.

Before an improvement policy is decided it is, therefore, necessary to consider the whole fish population and to try to understand the relations between one species and another. It may be possible to reduce one species while introducing another and more desirable one—those that desire Roach fishing may net out their Bream. Again the numbers of a lightly regarded species may be heavily reduced before manuring a water, so that the main harvest of the fertilization may be reaped by the fish of the best sporting qualities. So variable is the feeding behaviour of most coarse fish that there is a very real risk that one species may change its diet when presented with a suddenly increased supply of some food, and so come into competition with a second species which it had not previously affected.

It may be felt that these remarks upon competition are vague and full of reservations, and it must be admitted that our knowledge of freshwater fish communities does not permit the quotation of clear-cut and abundantly proven examples of the effect of one fish upon another, but the general principles for the guidance of improvement policies are clear :—

1. When fish are large and young.	A moderate amount of stocking.
2. When fish are large and old.	No change.
3. When fish are of average growth.	Fertilization of the water, and removal of competitors as far as is practicable.

4. When fish are small and young.	Fertilization of the water and removal of competitors.
5. When fish are small and old.	Drastic reduction of stock, and introduction of predators if necessary. Temporary reduction of size limits. Fertilization of the water after reduction of stock.

It is feared that the fish of many British coarse fish waters are in category 5.

THE KEEP-NET.

IN many districts the use of a keep-net is compelled by Fishery Board regulations or by local custom. It is contended that its use keeps up the stock, and if stock be regarded only in terms of numbers this is true. But it is very doubtful if fish that have been removed from the hook and kept, perhaps for hours, in the confines of a keep-net are desirable as members of the community. On a certain river I have seen fish thrust into a keep-net, after being unhooked with a viciousness which suggested that their captor hated the very sight of them; and on another river I have seen the water in a keep-net turbid with the displaced scales of the Roach and Bream jostling against each other. For a considerable period the food eaten by a wounded fish, or one from which many of the scales have been displaced, goes into the formation of scar tissue or the regeneration of the lost scales and not into growth, and the fish becomes one more poorly grown 'runt' to lower the general quality of the population.

It is suggested that in many waters the use of the keep-net should be abolished, that lightly hooked fish should be at once returned to the water and the rest killed. The population would be reduced in numbers, but only in the most favoured waters would the stock in terms of weight be appreciably lessened. The result of such a policy would be fewer and better fish; if this be desirable it is for anglers to decide.

FISHERY BOARD REGULATIONS.

ANGLING for coarse fish comes under the control of the Salmon and Freshwater Fisheries Act, 1923, in which it is laid down that any change in the bye-laws of a fishery board must receive the sanction of the Minister. This regulation makes the alteration of bye-laws a process which the fishery boards are reluctant to undertake with any frequency. It will have been noticed that reference has been made to reduction of size limits as a method of improving poorly grown stocks, and the objection will be raised that it is neither advisable nor easy to make such a change, when, after a few years, it will be desired to increase the limit once more. This is a perfectly sound objection. But the fact remains that conditions within a population of fish are rarely stable, especially when efforts are being made to improve the growth of some species and reduce the numbers of others. If an arrangement could be made by which fishery boards could vary size limits at relatively short notice (within, perhaps, certain prescribed lengths), fishery regulations would be rendered more realistic and the task of those who desire to bring about an improvement in stocks would be rendered easier.

MUD AND WEEDS.

IN many angling waters the accumulation of mud along the bottom is regarded as undesirable, and much effort and money is expended in dredging it out. A thick layer of mud has obvious disadvantages, but it must be remembered that within the mud lies stored a large part of the stock of manurial salts which make for fertile growth of lower plants. These small plants are the food of water-fleas and other food organisms, and so provide the raw material of fish growth. When mud is dug or dredged, channels are cleared, deep, holding 'lies' are created near the banks, the growth of rooted water plants is checked and at the same time, stored fertility is withdrawn from the water. Some of the nutritive matter may be returned to the water by the leaching action of trickling rain, but much is lost. The angler's lot has been made easier, but the fish's lot has been made harder by the reduction of the power of the habitat to produce food. It is, therefore, suggested that if a water be so choked with mud as to necessitate cleaning out, some degree of manuring may be desirable after the operation, and that at all times the dredging of mud should be kept to a minimum.

A considerable part of the stock of nutrient salts is buried, at certain seasons, at such a depth in the mud that it is not readily available for the growing diatoms and algæ. Dragging a chain harrow to and fro across a pond, or down a stretch of canal will stir up the bottom and should make more nutrient materials available for plant growth, but this should not be done in hot weather, because the disturbance of the mud may cause absorption of the oxygen in the water and lead to suffocation of the fish.

Rooted plants growing out of the water are another source of annoyance to anglers, making access to the water's edge difficult and in small ponds and stews advancing so rapidly from year to year as greatly to reduce the areas of open water. It has been mentioned, in the discussion of the growth of Pike, that fish in confined surroundings grow less for the same amount of food than those in spacious waters. As a small water is 'grown up' it must be expected that the growth of the fish will deteriorate. The larger plants, reeds, reed-mace and bulrushes are useless as fish food, and cut they must be. But it must be recalled that they have drawn nourishment from the waters in which they grow, and when there is reason to believe that growth of fish in the district is not all that is desirable, it is as well that this should not be lost. The cut plants may be piled near the banks in order that the products of decay may be washed back by the rain, or they may be dried and burnt and the fresh ashes scattered on the water. In all cases, when policy is concerned with fishery improvement alone, and vexed questions of drainage do not arise, the aims should be to remove obstructions to sport without removing anything of the fertility which is stored in the water and in the muds below.

CONCLUSION.

The first task of the Coarse Fish Investigation is now completed. By the use of scale-reading, and the comparison of lengths and ages, the growth rates of several species have been calculated and a standard of comparison provided for the estimation of the well-being or poverty of different stocks of fish. By the examination of foods the degree of competition between each species and its neighbours can be gauged. The application of this knowledge in the framing of fishery improvement policies should ensure that the methods to be used are really likely to improve both the growth and condition of the fish in the waters under review, and the sport of the anglers who fish for them.

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