the majority are compatible to fungal development, must be used in the final isolation.

Unicellular organisms offer many advantages in the study of intimate relationships between host and parasite. Already such lines of investigation between the algae (diatoms) and their parasites (chytrids) have revealed valuable information.

I wish to thank all those people, too numerous to mention individually, who have collected and sent me plankton samples or assisted in other ways. I am deeply grateful to Dr J. W. G. Lund and Professor C. T. Ingold for all the help and encouragement they have so kindly given during this investigation.

References

Canter, H. M. (1973). A new primitive protozoan devouring centric diatoms in the plankton. *Zool. J. Linn. Soc.* **52,** 63-83.

Canter, H. M. & Jaworski, G. H. M. (1978). The isolation, maintenance and host range studies of a chytrid *Rhizophydium planktonicum* Canter emend., parasitic on *Asterionella formosa* Hassall. *Ann. Bot.* **42,** 967-79.

Canter, H. M. & Jaworski, G. H. M. (1979). The occurrence of a hypersensitive reaction in the planktonic diatom *Asterionella formosa* Hassall parasitized by the chytrid *Rhizophydium planktonicum* Canter emend., in culture. *New Phytol.* **82,** 187-206

Canter, H. M. & Lund, J. W. G. (1953). Studies on plankton parasites II. The parasitism of diatoms with special reference to lakes in the English Lake District. *Trans. Br. mycol. Soc.* **36,** 13-37.

Canter, H. M. & Lund, J. W. G. (1968). The importance of protozoa in controlling the abundance of planktonic algae in lakes. *Proc. Linn. Soc. Lond.* **179,** 203-19.

Canter, H. M. & Lund, J. W. G. (1969). The parasitism of planktonic desmids by fungi. *Öst. Bot. Z.* **116,** 351-77.

Ingold, C. T. (1944). Studies on British chytrids. II. A new chytrid on *Ceratium* and *Peridinium*. *Trans. Br. mycol. Soc.* **27,** 93-6.

Karling, J. S. (1977). *Chytridiomycetarum Iconographia.* Vaduz, Cramer.

Sparrow, F. K. (1960). *Aquatic Phycomycetes.* Second revised edition. Ann Arbor, Univ. Michigan Press.

Zopf, W. (1885). *Die Pilzthiere oder Schleimpilze.* Encyklopaedie der Naturwissenschaften, Breslau.

ASPECTS OF THE BIOLOGY OF COARSE FISH IN THE DORSET STOUR

R. H. K. Mann

Introduction

Studies of coarse fish communities in Britain, particularly in rivers, have been few in comparison with investigations of salmonid populations. The Dorset Stour is one of the prime coarse fish rivers in this country, and an investigation of the principal species was carried out from 1968 to 1974. Since 1974 only a single mid-summer survey of the populations has been made each year. This article examines some of the results from five species which are of particular interest to anglers; roach *Rutilus rutilus* (L.), dace *Leuciscus leuciscus* (L.), chub *L. cephalus* (L.), pike *Esox lucius* L. and perch *Perca fluviatilis* L. Most of the results have been presented in five papers (Mann 1973, 1974, 1976a, b, 1978).

The study site and methods of fish capture

The River Stour has several chalk-stream tributaries, but its main drainage is from the Oxford and Kimmeridge clays in the Blackmore Vale on the Dorset-Somerset border. Fluctuations in its discharge are therefore more pronounced than those of rivers, such as the Frome at East Stoke, which arise solely from the chalk aquifer. The water has a high ionic concentration (545 μS cm^{-1}, pH 8·0), and the extensive areas of marginal and mid-water plants, principally *Iris*, *Scirpus* and *Ranunculus*, support an

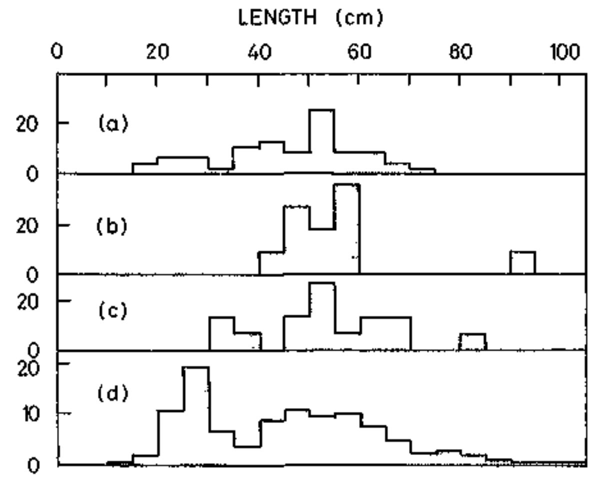

FIG. 1. Length-frequency histograms of pike caught in the River Stour from 1968 to 1978 by (a) Traps (N = 47), (b) Rod (N = 11), (c) Gill net (N = 15) and (d) Electric fishing (N = 415).

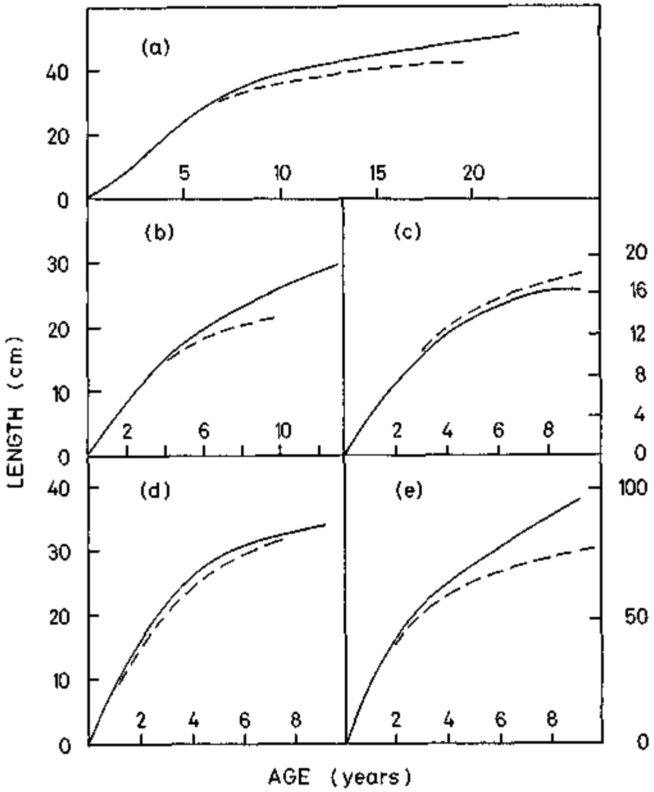

FIG. 2. Growth in length (cm) of fish in the River Stour: (a) Chub, (b) Roach, (c) Dace, (d) Perch, (e) Pike.
Full lines = females, hatched lines = males.

abundant and diverse population of aquatic invertebrates. A full description of the site, which is near the village of Hampreston approximately 5·5 km downstream of the town of Wimborne, is given by Mann (1973). Angling pressure on the study area is low, comprising occasional weekend angling and one or two fishing matches each season.

Most of the fish were caught by electric fishing, using a machine similar to that developed by Moore (1968). The operators generally worked from an inflatable rubber dinghy with the generator on the river bank, but in summer it was possible to wade the shallower areas of the river. In addition some useful material was obtained from gill nets, standard Windermere perch traps and angling, although these methods were very size-selective (Fig. 1).

Age and growth

The growth of fish is most readily measured in terms of length, and the Stour fish were typical of many populations in that, for each species, a plot of length against age produced a curve whose slope decreased with age towards an upper asymptote (Fig. 2). Ages were determined from scales (dace), opercular bones (pike, perch) or both (roach, chub). Roach and chub were both long-lived, up to 13 and 22 years respectively, and the annuli on the edges of scales from older fish were close together and often difficult to distinguish. The operculars were easier to read in this respect, but the innermost annuli could be obscured by thickening of the bone. The two structures were therefore used together to determine the ages of these two species.

The data used to construct the growth curves in Fig. 2 were obtained from two sources; from the observed lengths of individually aged fish, and from lengths back-calculated from the positions of the annuli on the scales or operculars. Scales grew allometrically in relation to the growth in length

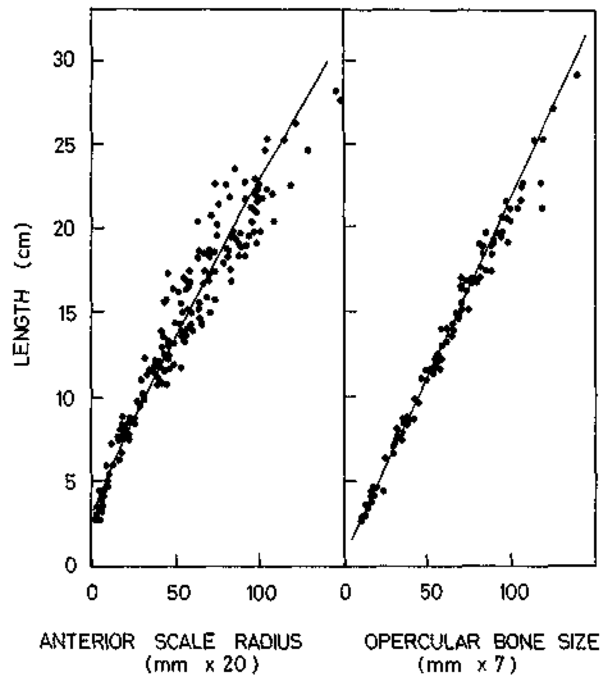

FIG. 3. Relationship between (a) Fish length and anterior scale radius and (b) Fish length and opercular bone size of roach from the River Stour.

of the fish, whereas the opercular bones grew isometrically (Fig. 3). However, in both cases, it was possible to calculate fish lengths at earlier ages, corresponding to the distances of the annuli from the origin of the operculum or the centre of the scale.

With the exception of the dace, the growth rates of female fish were higher than those of the males, a common occurrence among freshwater teleosts. Also, females were relatively more abundant among the older age-groups. The faster growth and increased survival of the females may be a result of selective pressures because, in absolute terms, older and larger females produce more eggs than younger, smaller fish of the same species. Also they often produce larger eggs which may enhance the chances of survival of the resulting fry (Bagenal 1969, Mann & Mills in press). However, we do not yet understand why female dace do not grow faster than the males, although they too predominate in the older age-groups.

How does the growth of fish in the Stour compare with that in other waters? The river is noted for its specimen fish but, although growth rates were generally high, only that of perch was exceptional. Dace, roach and pike had rates similar to the faster rates reported from other waters; in particular, pike growth was similar to that in Windermere. The chub was unusual in that, although its growth was similar to that of many other European populations, it attained a greater ultimate size by virtue of living longer. Specimens up to 22 years old have been found in the Stour, whereas the maximum reported from other European waters is 14 years in the River Lugg, a tributary of the River Wye (Hellawell 1971). There appear to be several possible reasons for the rapid growth of the perch, which was greater than any previously found in European rivers. Firstly, the population density was very low and in fact appears to have declined since the study began because in 1977 and 1978 only a few individuals were caught in the annual survey. This contrasts with the very high densities of many slow-growing populations described by Alm (1946). But perhaps more important are the relatively high water-temperatures and the fact that perch began to feed extensively on small Cyprinidae, chiefly minnows *Phoxinus phoxinus* (L.), during their first year of life. Minnows are extremely abundant in the Stour (Gunn 1978) and they formed the main prey of perch and an important component of that of pike. Of interest here is the report by McCormack (1970) that a pronounced decrease in the number of perch in Windermere led to an increased growth rate and to the utilization of fish prey at a much earlier age, although not by the 0 group as in the Stour.

The type of growth described so far is that of increase in length from year to year, ignoring changes within a year. In fact all five species showed similar and clearcut patterns of seasonal growth which were typical of those of most fish inhabiting temperate waters. Growth was rapid from late

April to September but was negligible during the winter months. Water temperatures in the Stour rarely fell below 12 °C during the growth period and, conversely, rarely rose above that level during the winter. Fig. 4 shows the growth in length of young dace and roach, together with the mean weekly temperature above 12 °C, plotted cumulatively. The other species, and older fish, showed the same growth pattern.

Does the growth of fish vary from year to year in relation to environmental conditions? From the back-calculated lengths it was possible to compute indices of growth for different years for each species by comparing the length increments in each year with the average of several years. In all five species, above-average growth rates corresponded to warm summers such as occurred in 1959 (exceptional), 1964, 1969 and, most recently, in 1976. Indeed the growth zones on the scales and operculars for these years were usually much wider than in other years, which was most useful in helping to interpret the annuli on some of the more difficult scales and bones.

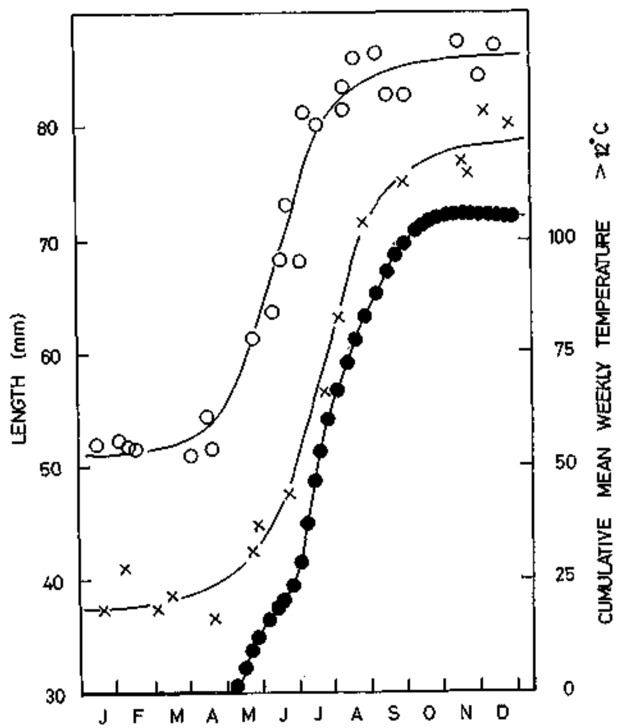

FIG. 4. Seasonal growth pattern of 0 to 1 group dace (open circles) and roach (crosses), and the cumulative mean weekly water temperature over 12 °C (closed circles).

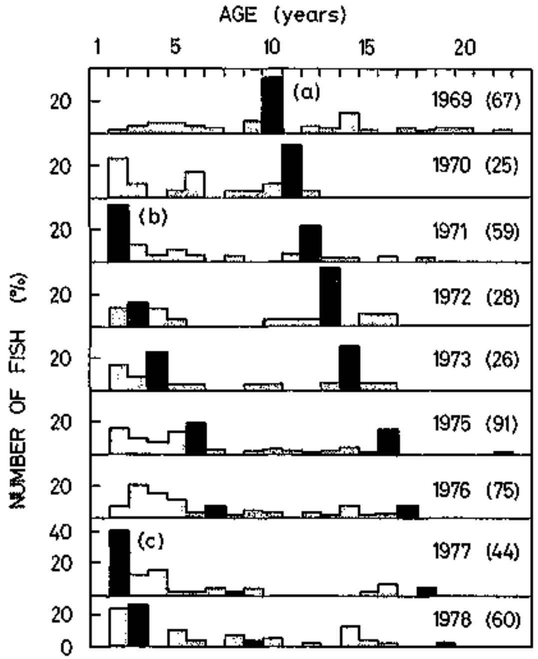

FIG. 5. Age-distribution of chub in the River Stour from 1969 to 1978, with strong year-classes in black: (a) 1959, (b) 1969, (c) 1975.

Figures in parentheses represent the number of fish caught. Note that there was no sample for 1974.

Spawning strategies and their consequences

Each of the five species was distinct in its spawning requirements, being separated from the other species in some way, either in time or space. This niche separation helped to decrease competition for spawning sites and, later, for food for the newly-emerged larvae (principally micro-Crustacea and aquatic Diptera larvae). Thus dace and pike spawned during March and April, the former in fast-flowing, shallow areas and the latter among vegetation in backwaters. Perch spawned during May, their eggs being laid in long skeins on submerged overhanging branches of alder (*Alnus*) and willow (*Salix*), or among the reed beds. Chub and roach spawned during June, the chub using the areas previously utilized by the dace and the roach spawning in the slower-flowing water in reed beds. As a consequence the fry had a sequence of hatching times beginning with dace, then pike, perch, and roach/chub together.

Kipling (1976) has described variations in the recruitment success of pike

and perch in Windermere in different years, and similar variations were a feature of the Stour populations, especially the chub. In Fig. 5 the dominance of the 1959 year-class during the earlier years of study is evident. Other years have produced above-average recruitment (e.g. 1964, 1969, 1975), but none as strong as 1959 although it is too soon to know how strong the 1976 year-class will be. Indices of year-class strength of chub, calculated in a similar way to those for growth, show a strong correlation with water temperature in July and August in the year of hatching, expressed as degree-days over 12 °C. The data for the other species are less convincing, but they are supported by comparable data from the River Frome. It appears that the strength of a particular year-class is related to the growth of the newly-emerged fry during their first few weeks of life, this growth being influenced by water temperature. The detailed mechanisms involved in this complex relationship are the subject of a special study by Dr C. A. Mills at the River Laboratory.

Since dace fry hatch out nearly two months before roach and chub, it follows that a year of good recruitment for dace is not necessarily a good one for the other two cyprinids. This is because the crucial periods of fry life are separated in time. Thus 1964 and 1969 were both years of high recruitment for all three species, but 1962 produced a strong year-class in the dace only. Similarly the cold summer of 1961 was a poor year for all three cyprinids, but 1966 was a poor year only for roach and chub recruitment. It should be noted that warm summers do not always produce strong year-classes of coarse fish. The 1976 year-class of pike in the River Frome was very poor because, in the exceptionally dry spring, the main spawning areas dried up. As a result, few eggs or fry survived but the surviving fry had growth rates considerably above the average. A similar phenomenon was not observed in the Stour where the pike spawn among the reed-beds in the main river, in contrast to the Frome where they mostly spawn in small side-channels.

The strength of the strongest year-class of chub (1959) was 17 times that of the weakest (1958), a range greater than that found in the other two cyprinid species, roach (×5) and dace (×4). However, because of their long reproductive life – female chub mature at age 4 or 5 and continue to spawn up to age 22 – there is little danger of a sequence of poor year-classes, as occurred from 1960 to 1963 inclusive, endangering the survival of the population. The shorter-lived roach and dace do not produce such dominant year-classes as the 1959 chub but neither, it appears, do they have such poor years of recruitment. Selective pressures have not, therefore, led to such an increase in longevity. The strategy of the chub appears to be unusual in fish populations living in relatively predictable environments, such as the Stour, being more usually associated with populations inhabiting very unpredictable environments in which the amount of recruitment each year is extremely variable (Mann & Mills in press).

Examples of the latter are the populations of trout *Salmo trutta* L. and bullhead *Cottus gobio* L. in the River Tees (Crisp et al. 1975).

Conclusions

The dynamics of the fish community of the River Stour are complex. Although the component species show some similarities, as in the shapes of the annual and seasonal growth curves, in most other respects each species occupies a distinct niche in the ecosystem and has a life-history strategy peculiar to itself. In this short review a few aspects of just five species have been discussed, but the Stour at Hampreston holds 17 species, of which 12 are common. Any of the relationships or diversities suggested here will therefore be made far more complex when all the species are considered.

I wish to thank Sir Richard Trehane and Mr R. L. Harding who allowed access to the study site, the Wimborne and District Angling Club for use of their rod catches, and to the many who have assisted in the sampling programmes: Messrs D. R. Orr, H. Leatham, P. van M. Ewens, W. R. C. Beaumont, Mrs I. M. Gunn (née Orwin) and Dr C. A. Mills.

References

Alm, F. (1946). Reasons for the occurrence of stunted fish populations with special regard to the perch. *Rep. Inst. Freshwat. Res. Drottningholm* **25**, 1–146.

Bagenal, T. B. (1969). Relationship between egg size and fry survival in brown trout *Salmo trutta* L. *J. Fish Biol.* **1**, 349–53.

Crisp, D. T., Mann, R. H. K. & McCormack, J. C. (1975). The populations of fish in the River Tees system on Moor House National Nature Reserve, Westmorland. *J. Fish Biol.* **7**, 573–93.

Gunn, I. M. (1978). The biology of cyprinid fry. University of Reading. M.Phil. Thesis. 304 pp.

Hellawell, J. M. (1971). The autecology of the chub, *Squalius cephalus* (L.), of the River Lugg and Afon Llynfi. I. Age determination, population structure and growth. *Freshwat. Biol.* **1**, 29–60.

Kipling, C. (1976). Year class strengths of perch and pike in Windermere. *Rep. Freshwat. biol. Ass.* **44**, 68–75.

Mann, R. H. K. (1973). Observations on the age, growth, reproduction and food of the roach *Rutilus rutilus* (L.) in two rivers in southern England. *J. Fish Biol.* **5**, 707–36.

Mann, R. H. K. (1974). Observations on the age, growth, reproduction and food of the dace *Leuciscus leuciscus* (L.) in two rivers in southern England. *J. Fish Biol.* **6**, 237–53.

Mann, R. H. K. (1976a). Observations on the age, growth, reproduction and food of the pike *Esox lucius* L. in two rivers in southern England. *J. Fish Biol.* **8**, 179–97.

Mann, R. H. K. (1976b). Observations on the age, growth, reproduction and food of the chub *Squalius cephalus* (L.) in the River Stour, Dorset. *J. Fish Biol.* **8**, 265–88.

Mann, R. H. K. (1978). Observations on the biology of the perch, *Perca fluviatilis* in the River Stour, Dorset. *Freshwat. Biol.* **8**, 229–39.

Mann, R. H. K. & Mills, C. A. (in press). Demographic aspects of fish fecundity. In *Fish phenology: anabolic adaptiveness in teleosts* (ed. P. J. Miller). *Symp. zool. Soc. Lond.*

McCormack, J. C. (1970). Observations on the food of perch (*Perca fluviatilis* L.) in Windermere. *J. Anim. Ecol.* **39**, 255–67.

Moore, W. H. (1968). A light-weight pulsed D.C. shocker. *J. appl. Ecol.* **5**, 205–8.