RIVIERES CRAYEUSES DE L'ANGLETERRE ET ACTIVITÉS HUMAINES

M. LADLE et D.F. WESTLAKE*

RESUME

Plusieurs rivières qui sont, d'une manière caractéristique, limpides et hydrologiquement stables, prennent naissance dans les terrains aquifères crayeux du Sud de l'Angleterre. Historiquement, ces rivières ont été utilisées en vue de l'organisation des pâturages, de la culture du cresson et de la pêche à la ligne pour truites et saumons de grande taille.

Plus récemment, les techniques modernes d'organisation des pâturages ont rendu nécessaire un meilleur drainage et un contrôle de la végétation aquatique. Actuellement, la culture du cresson est souvent une entreprise généralisée ainsi que l'élevage de la truite arc-en-ciel (*Salmo gairdneri*). Les demandes pour la distribution des eaux et la disposition de rebut comprennent couramment des projets expérimentaux en vue de sceller les lits de petites rivières employées dans le transfert des eaux, et d'assurer le remplissage d'écoulement par pompage dans la nappe aquifère.

Dans bien des cas, les communautés des plantes et des animaux qui se sont développées dans les deux derniers siècles n'ont pas été touchées par ces changements, mais il y a de nombreux cas de modifications de faune et de flore de l'écosystème des rivières crayeuses, causés par les activités humaines.

* *Freshwater Biological Association, River Laboratory, East Stoke, Wareham, Dorset, BH20 6BB (England).*

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INTRODUCTION

In England, the deposits of chalk which give rise to the streams with which we are concerned, occur in two main areas : a relatively small part of Yorkshire and Lincolnshire and a more extensive region in south-east and central southern England.

Owing to the permeable nature of the chalk rocks, large quantities of rain water are retained in the aquifers during the period of heavy winter precipitation and released throughout the remainder of the year. The results of this retention include :

1. Reduction in the amplitude of the annual flow pattern, so that ratios of maximum daily mean flows to minimum daily mean flows are usually less than 10 : 1 and often in the order of 3 : 1 (Avon & Dorset River Authority, 1970).
2. Changes in the chemical characteristics of the water, chiefly the solution of large quantities of calcium bicarbonate derived from the chalk itself.
3. Stabilisation of temperature so that issuing groundwater is usually at a temperature of 10° C - 11° C (CRISP, 1970).

Chalk streams probably flowed originally in ill-defined channels surrounded by alder (*Alnus glutinosa* [L]) and willow (*Salix* spp.) fen, but during the late 17th century up to the 19th century most of this was cleared and drained. The flow was then controlled by the introduction of hatches and weirs concerned with the operation of mills and water meadows. The latter were principally operated to obtain early grass for sheep by controlled flooding of the pasture land in the early months of the year with relatively warm water rich in nutrients (WHITEHEAD, 1968). Recently much land in the catchment area that was formerly permanent pasture has been ploughed for arable crops and ley pastures and the use of inorganic fertilisers on both types of land has greatly increased (TAVERNER, 1962).

TABLE I

Comparison of chalk stream fauna. WHITEHEAD, July 1930, (1935). LADLE (July 1972).
Only numbers in excess of 100 m^{-2} recorded. Numbers 1 000 m^{-2}

	Mud		Gravel		Ranunculus	
	1930	1972	1930	1972	1930	1972
OLIGOCHAETA	1.2	57.2	2.1	2.4	—	—
AMPHIPODA (**G. pulex**)	—	1.2	2.8	0.8	0.6	—
EPHEMEROPTERA	—	—	0.4	0.2	4.5	3.3
TRICHOPTERA	0 4	—	0.8	1.3	—	—
SIMULIIDAE	—	—	—	—	2.8	20.2
CHIRONOMIDAE	0.3	4.0	0.4	0.8	11.7	31.9
SPHAERIIDAE	0.7	5.3	—	—	—	—

Traditionally chalk streams have been used to produce salad crops of watercress (*Rorippa nasturtium-aquaticum* (L) Hayek) in the headwaters and as trout and salmon fisheries in lower reaches.

These streams provide predictable angling conditions, are very suitable for fishing with the dry fly and have an inherent capability to produce very large fish, so the fishing has always been expensive (WESTLAKE **et al.**, 1972).

The characteristic submerged macrophyte of the chalk stream is the water crowfoot (*Ranunculus penicillatus* var. *calcareus* (R. W. Butcher, C. D. K Cook) and the dominant emergent species are usually *R. nasturtium-aquaticum* and *Apium nodiflorum* (L.). BUTCHER (1933) gives an account of the distribution of macrophytic vegetation in some chalk streams of southern England. PERCIVAL & WHITEHEAD (1929) and WHITEHEAD (1935) describe the rich and varied invertebrate fauna characteristic of the chalk stream ecosystem. The plant and animal communities found recently in chalk streams do not differ markedly, with *Gammarus pulex*, Oligochaeta, Chironomidae, Simuliidae, Trichoptera and Ephemeroptera all prominent (Table 1) (WESTLAKE **et al.**, 1972).

HUMAN INFLUENCES

Much of this account will relate to the chalk streams of central southern England which have been the main interest of the Freshwater Biological Association's River Laboratory.

The demand for water for domestic, agricultural and industrial use has increased rapidly in the 20th century. This water is usually abstracted from the aquifers close to springs or streams, from the aquifers of dry valleys or from the downstream reaches of the larger rivers. Groundwater only requires chlorination at most, but river water is usually filtered and stored in a reservoir. Irrigation water is abstracted directly from the adjacent river. There is considerable controversy over the effect of abstraction from the aquifers. Abstraction close to the stream probably reduces stream flow or, in the case of winterbournes which naturally dry up in the summer, the dry period may be prolonged. Abstraction from the aquifers of a dry valley creates a « dry cone » which is refilled in the winter and unless the rocks are atypically fissured, allowing extensive lateral movement of groundwater, the local loss of head is unlikely to have an appreciable effect on springs in adjacent valleys. In most areas abstraction from the chalk is increasing rapidly. In Lincolnshire, abstraction by the North Lindsey Water Board rose from 0.15 m^3s^{-1} in 1960 to 0.53 m^3s^{-1} in 1970 (DAVEY, 1970). In the London area even in 1936 over 1.06 m^3s^{-1} of chalk water were taken for public and industrial supplies from deep aquifers (BUCHAN, 1938). Levels in the chalk in this area have fallen intermittently since at least 1820 (BLYTH, 1964). A consequence of this draw down was an influx of saline water from the Thames estuary into the aquifers (WHITAKER & THRESH, 1916).

In the Wessex area, the impact of irrigation and increased usage of water by large populations of holidaymakers is greatest in the summer months when the peak weekly demand is 67 % of the calculated minimum yield of the aquifers. Even calculated over the year, abstraction is a significant percentage of the annual run-off in the four major catchments (AVON & DORSET RIVER AUTHORITY, 1970, p. 33, Table 11).

Dredging and tree felling in the cause of flood prevention are now commonplace and the resultant rapid run-off encourages erosion and results in increased ratios of maximum to minimum mean daily flows. Urbanisation and the associated road building also produce the same effect by speeding up surface drainage. Greater variability in flow regimes probably tends to produce more extreme ranges of temperature which can affect the rates of all biological processes.

In contrast the proposals to abstract by pumping from the aquifers of winterbournes during the summer months and transfer this water in the sealed beds of these streams will tend to produce more stable annual flow and temperature patterns (FISH, 1973). In some cases, as in the Thames catchment scheme, pumping takes place only in extreme conditions (NUGENT, 1971).

The removal of silt from stream beds in autumn has often been an aim of fishery management. Both trout and salmon spawn in clean gravel with a relatively low content of fine sediment, the area of which is normally increased by selective weed cutting and even raking of the stream bed. ALLEN (1951) has shown that silting during the period when eggs are in the redds may cause reduced survival in streams and LE CREN (1969) suggests that in chalk streams « production [of brown trout (*Salmo trutta L)*] seems to be limited by population density which may be determined by other factors such as low egg survival in rather silty spawning grounds ». Surface erosion of catchments tends to produce silt and sand deposition on the river bed. Many downland pastures and heathland areas are now ploughed, exploited for minerals or used as military training grounds with resultant removal of surface vegetation and consequent scouring of soil by heavy rainfall (usually during the winter spawning period of salmonids).

Typically, the chemical composition of chalk sources is very stable (CASEY, 1969). Movement of rainfall downwards through the soil into the aquifer is probably very slow, particularly in non-fissured chalk. The water may sometimes take up to 25 years to return to the surface (SMITH **et al.**, 1970) so most seasonal patterns and annual differences are reduced in amplitude. There is some evidence that the increasing use of leguminous crops and fertilisers over the last twenty years and the change from sheep husbandry to cattle over a longer period (TAVERNER, 1940) is producing a gradual increase in the nitrate content of chalk stream water (CASEY, 1975). Nitrate concentrations can now be very high (over 10 mg l^{-1}) where geological conditions favour rapid movement of water from soil to spring or borehole (DAVEY, 1970). It is possible that layers of enriched water may be developing within those aquifers with longer retention times.

The concentration of soluble phosphate in chalk spring water is high compared with many natural waters and it is increased still further in the headwaters by cress bed fertilisation (CRISP, 1970), by surface run off which includes somes domestic sewage and by the effluents of intensive husbandry of cattle, poultry and pigs (Table 2) (CASEY & LADLE in press ; DAWSON in press). In the downstream sections treated sewage effluents from towns add still more phosphate (CASEY & NEWTON, 1973).

Direct toxic pollution is relatively rare in the rural surroundings of the typical chalk stream, but occasional instances occur, as when many gallons of ortho dichlor benzene which had been used as a paint stripper for military vehicles was accidentally released into the River Frome in 1965 causing heavy fish mortality (MANN, 1973 ; CRISP & GLEDHILL, 1970 ; Avon & Dorset River Authority Annual Report 1966). The recent overloading of an activated sludge plant on the lower part of the River Stour by a heavy storm also caused considerable fish mortality. Pollution by silage effluents is widespread and often causes fish mortalities, particularly in the valley of the River Stour, Dorset (Avon & Dorset River Authority Reports 1954-1973).

TABLE II

Concentration of PO_4P and NO_3N in chalk stream waters upstream and downs tream of effluents

	Above Input		Below Input	
CRESS BED FERTILISATION (CRISP, 1970)	P	0.03	209.0	9/10 hours following
	N	83.0	481.0	application
DOMESTIC SEWAGE (CASEY & NEWTON, 1973)	P	109.0	182.0 μgl^{-1}	
	N	2.3	3.0 mgl^{-1}	
CATTLE EFFLUENT (CASEY & LADLE, in press)	P	100.0	> 1 000.0 μgl^{-1}	
	N	no change	no change	

Of all the effluents sampled by this river authority in 1973, 8 % were grossly polluting and only 55 % were classified as satisfactory. Oil pollution due to spillage of domestic fuel oil etc. fas also increased in the last few years but there is no information on its influence on the stream biota.

A survey by the river authority in the 1930s showed that parts of the Upper Frome were « bacteriologically unsuitable » probably due to the inputs from domestic, septic tank drainage. The gradual introduction of mains drainage to treatment plants must have resulted in an improvement since that time.

Algae are present in suspension in most chalk streams and often show a large peak of numbers in the springtime, but most of this is due benthic organisms swept into suspension (MARKER in press). In some instances however, increases of the retention time of water due to the presence of weirs, and enrichment of the water by mineral nutrients, has resulted in the development of massive blooms of truly planktonic algae such as occurs on the River Stour in Dorset (HANSFORD, 1973).

Larger algae can also present a nuisance and *Enteromorpha intestinalis* is now often seen in the lower reaches of the Dorset Stour and in the tidal (but fresh) reaches of the River Frome. The benthic filamentous algae *Cladophora* spp. increase to nuisance proportions where there is excessive addition of nutrients. Phosphate is often implicated as a contributory factor to these growths (BOLAS & LUND, 1974).

In the River Stour in Kent, the effects of abstraction and pollution are well known. Up to about 1949 this river was a productive trout stream with a good hatch of mayfly (*Epherema danica* L.) By 1964 *Cladophora* sp. had replaced higher plants on the worst stretch and many species of aquatic insects were greatly reduced. These changes were associated with large increases in dissolved phosphate and the presence of anaerobic conditions on the river bed. After improvements at the sewage works, *Cladophora* was reduced and higher plants and aquatic insects increased (BOLAS & LUND, 1974).

Of the macrophytes present in chalk streams, *Ranunculus* causes a major problem by its vigorous growth. Dense *Ranunculus* cover in the late spring retards drainage, causes flooding of agricultural land and impedes angling (WESTLAKE, 1968). The control of this plant requires considerable effort and expenditure. In large rivers mechanical weed cutters attached to launches are operated and the cut weed is collected and removed by draglines. The effect of the spring cut is often to forestall the natural die-back of the plants which normally succeeds flowering in May or June (WESTLAKE, 1968 ; DAWSON, 1973), and to stimulate rapid re-growth which often necessitates a second cut in late summer.

The growth of watercress (*Rorippa*) which often follows that of *Ranunculus* in smaller chalk streams (LADLE & CASEY, 1971) is initiated by downstream drifting of small fragments of cress plants which overwinter in the relatively warm waters near the source of the stream (CASEY & LADLE in press) or, in many cases, originate in the debris from cress culture (CASTELLANO pers. comm.).

Of plants introduced by man which have become undesirable weeds in chalk streams, the most notable is *Elodea canadensis* which, after an initially rapid spread, now appears to be integrated into the natural flora.

It is more difficult to find relationships between man and the invertebrate populations. However, as an example, the adult fly *Simulium* (*Simulium*) *austeni* causes considerable distress and creates a medical problem in the towns on the banks of the Dorset River Stour. There is, adjacent to a relatively dense population of human beings in a small town (Blandford Forum), a large population of the aquatic larvae of the insect ; the latter being associated with the presence of rich growths of planktonic algae in the river (see above) at the time of year when this (univoltine) insect is in its larval (filter-feeding) stage. Control of the insect by cutting weeds has been attempted (HANSFORD, 1973).

Other insects have also caused problems where man has modified the flow of chalk streams. On the River Avon in Hampshire, the West Hampshire Water Company's filter beds produce such large numbers of adult chironomidae that the insects have created a local nuisance (Walls pers. comm.) Material identified from the above source included adults of *Micropsectra foliata*. In a chalk stream bed, taken over for use as a channel to transfer a hardwater sewage effluent, the invertebrate population was dominated by *Asellus aquaticus* L., tubificids and *Chironomus riparius* Meigen (EDWARDS, 1958). The latter reached 300,000 m^{-2} at times, and had seven emergences of adults which caused a nuisance in adjacent dwellings. This may be regarded as an extreme case of organic pollution.

Toxic pollution on the River Frome caused some mortality of invertebrates but this was difficult to separate from other influences (CRISP & GLEDHILL, 1970). Weed cutting modifies invertebrate habitats and must favour those species in which the timing of the life cycle or the patterns of behaviour circumvent the effects of cutting.

Angling for trout in chalk streams is based on the use of the artificial fly (SKUES, 1974) and depends largely on the presence of numerous and varied aquatic insects particularly those of the orders Ephemeroptera, Trichoptera and Plecoptera. Attemps by anglers to increase populations of these invertebrates have been little documented but FROST AND BROWN (1967) quote instances of the use of « fly boards » as sites for oviposition, being successful in the case of *Ephemera danica* L. on the River Test at Stockbridge although a similar exercice with *Brachycentrus subnubius* Curt. (Trichoptera) was apparently a failure.

Chalk stream trout are large because of their rapid growth (LE CREN, 1969) and they are selective when feeding on emergent insects (FROST & BROWN, 1967. Because of these traits they are much prized by anglers. Changes in the quality and quantity of fish populations are often brought about by angling clubs, river authorities and private individuals. The removal of grayling (*Thymallus thymallus* L.) and pike (*Esox lucius* L.) from trout fisheries because of their competitive and predatory activities respectively are commonplace. Thus, on the waters of the Wilton Fly Fishers' Club on the River Wylye, something in the order of 50,000 coarse fish (mostly grayling) have been removed in the past ten years from about 9.6 km of water. However, there has been little, if any, corresponding change in the numbers of trout caught up to 1972, the last available record (Fig. 1). The fish removed from trout fisheries are often transported to other rivers in the area to increase the populations available to coarse fishermen, but the ecological consequences of such stocking have not been published.

The introduction of « new » species of fish to river systems is more obvious in its effects. The chub (*Leuciscus cephalus* L.) was introduced to be River Avon (Hampshire) in the late 19th century and the barbel (*Barbus barbus* L.) to the River Stour (Dorset) (BERRY, 1935). The first recorded capture of a barbel from the Avon was in 1915 but the species are now abundant in both river systems (the rivers are connected in the tidal region).

On the lower reaches of rivers where coarse fish are abundant, angling is very popular. Anglers introduce many items of bait and ground bait to the water and the quantities used are sometimes very large. In some instances bans have been introduced on the use of certain baits (maggots on the River Avon and hempseed on the River Stour).

Hatcheries and fish farms require water supplies similar to those used for watercress farming. The relatively high returns from sales of rainbow trout to angling concerns and for food has resulted in considerable increases in the number of trout farms situated on chalk stream sources. There are numerous example of joint watercress and trout farming enterprises. Nearly every chalk stream has one or more fish farm, all of which have been established over the past ten years (HILL pers. comm.).

Hatcheries are associated with the current trend towards artificial stocking of many chalk streams with both brown trout (*S. trutta*) and rainbow trout (*S. gairdneri*). The former species has only limited spawning success in chalk streams (LE CREN, 1969). Rainbow trout spawn with some success in streams such as the Lambourne (Berkshire) and the Chess and Beane (Herfordshire) (HUNT, 1972), but are unable to maintain wild populations without artificial stocking.

The erection of dams and weirs on chalk streams for mills, etc. provides barriers to the migration of salmonid fishes. Fish passes are often constructed to facilitate migration and BRAYSHAW (1967) gives an account of the functioning of such a system on the River Avon in Hampshire, concluding that alteration to such a fish-pass may « dramatically and artificially affect the migration locally ».

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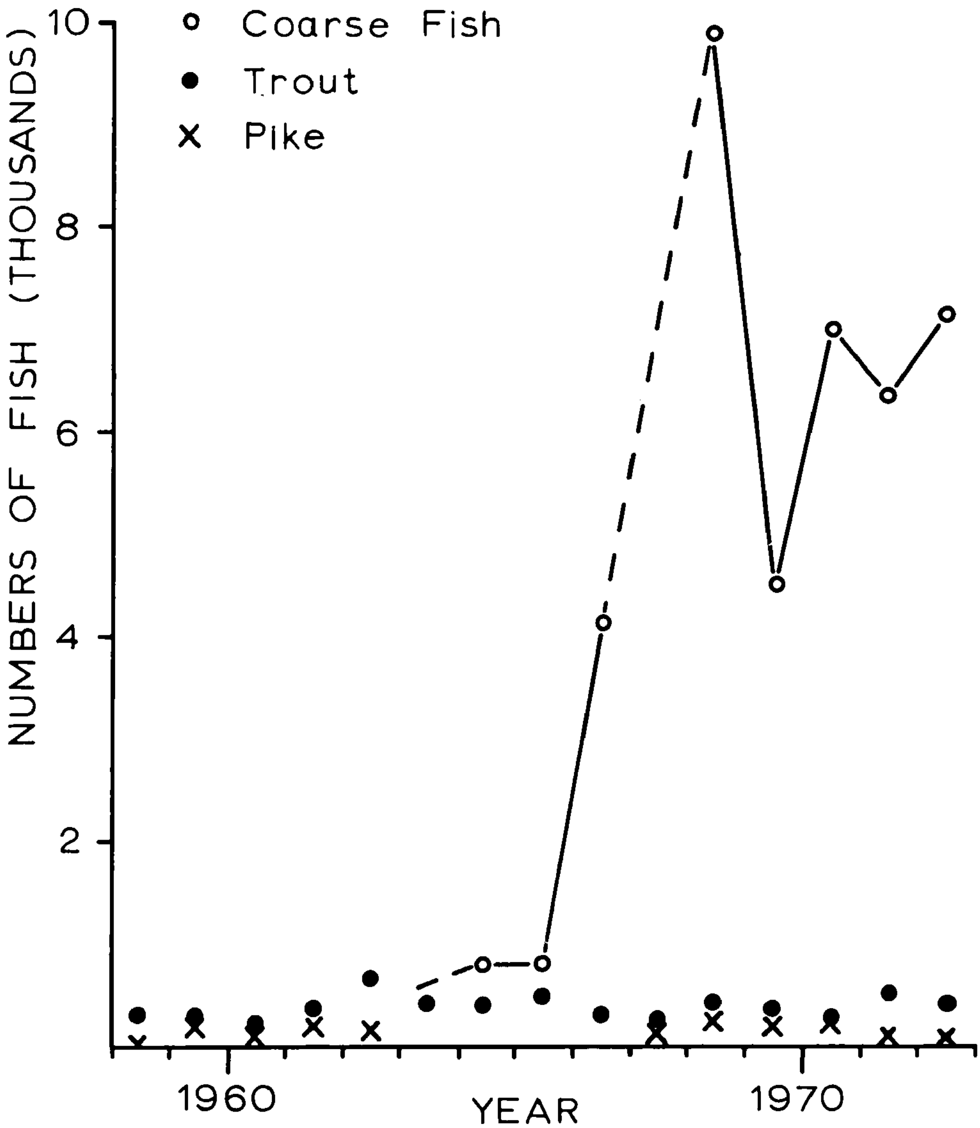

Figure 1 : Summary of annual coarse fish (mostly grayling) and pike removal from the waters of the Wilton Fly Fishing Club on the River Wylye and its relationship to trout catches (Avon and Dorset River Authority 1958-1973 Ann. Reps.)

REFERENCE

ALLEN, K.R., 1951 — The Horokiwi Sream. A study of a trout population. *Bull. mar. Dep. N.Z. Fish.* 10, 1-231.
Avon and Dorset River Authority, Ann. Rep. 1965-66 59 pp.

BERRY, J. 1935 — Freshwater development of *Salmo salar.* PhD thesis, Univer- of St-Andrews.

BLYTH, F.G.H., 1964 — A geology for engineers. Edward Arnold, London.

BOLAS, P.M. & LUND, J.W.G., 1974 — Some factors affecting the growth of *Cladophora glomerata* in the Kentish Stour. *Wat. Treat. Exam.* 23, 25-51.

BRAYSHAW, J.-D., 1967 — The effects of river discharge on inland fisheries. In *River management* (ed. Isaac, P.C.G.), 102-118. Mac Laren, London.

BUCHAN, S. 1938 — Underground water supply of the county of London. *Trans. Instn Wat. Engrs* 43, 129 pp.

BUTCHER, R.W., 1933 — Studies on the ecology of rivers. I. On the distribution of macrophytic vegetation in the rivers of Britain. *J. Ecol.* 21, 58-91.

CASEY, H., 1969 — The chemical composition of some southern English chalk streams and its relation to discharge. *River Bds Ass. Yb.* 1969, 100-113.

CASEY, H. 1975 — Origin and variation of nitrate nitrogen in the chalk springs, streams and rivers in Dorset and its utilisation by higher plants. In *Conférence on nitrogen as a water pollutant.* IAWPR Tech. Conf., Copenhagen 1975, Vol. 2.

CASEY, & LADLE, M., 1976 — Biology and chemistry of the South Winterbourne. *Freshwat. Biol.* 6, (in press).

CASEY, H. & NEWTON, P.V.R., 1973 — The chemical composition and flow of the River Frome and its main tributaries. *Freshwat. Biol.* 3, 317-333.

CRISP, D.T., 1970 — Input and output of minerals for a small watercress bed fed by chalk water. *J. appl. Ecol.* 7, 117-140.

CRISP, D.T. & GLEDHILL, T., 1970 — A quantitative description of the recovery of the bottom fauna in a muddy reach of a mill stream in southern England after draining and dredging. *Arch. Hydrobiol.* 67, 4, 502-541.

DAVEY, K.W., 1970 — An investigation into the nitrate pollution of the chalk borehole water supplies. North Lindsey Water Beard, Scunthorpe. 167 pp.

DAWSON, F.H., 1973 — The production ecology of *Ranunculus penicillatus* var. *calcareus* in relation to the organic input into a chalk stream. PhD thesis, University of Aston in Birmingham.

DAWSON, F.H., 1976 — The annual production of the aquatic macrophyte *Ranunculus penicillatus* var. *calcareus* (R.W. Butcher C.D.K. Cook) *Aquat. Bot.* (in press).

EDWARDS, R.W.F., 1968 — The invertebrate fauna of the effluent channel. In *A field and laboratory investigation of fish in a sewage effluent.* Allen, I.R.H., Herbert, D.W.N. & Alabaster, J.S.). *MAFF Fishery Invest.* series 1, 6 (L) 5-6. HMSO, London.

FISH, H., 1973 — Water quality aspects of the Lambourne Valley pilot scheme. *Publ. Hlth.Eng.* 1, 13-21.

FROST, W.E. & BROWN, M.E., 1967 — The trout. Collins, London.

HANSFORD, R.G., 1973 — A report of a one year investigation into the biology and possible control of the biting black-fly, *Simulium austeni*, in the Stour valley, Dorset. *Report to local Councils*, 26 pp.

HUNT, P.C., 1972 — A brief assessment of the rainbow trout, *Salmo gairdneri*, in britain. *Fish.* Mgmt. Vol. 2, 2, 52-55.

LADLE, M. & CASEY, H., 1971 — Growth and nutrient relationships of *Ranunculus penicillatus* var. *calcareus* in a small chalk stream. *Proc. Eur. Weed Res. Coun. 3rd int. Symp.* Aquatic Weeds 1971, 53-63.

LE CREN, E.D., 1969 — Estimates of fish populations and production in small streams in England. In *Symposium on salmon and trout in streams*, Vancouver 1969, ed Northcote, T. 269-280. MacMillan Lect. Br. Columbia Univ.

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, 707-736.

NUGENT, Lord of Guildford, 1971 — The Lambourne Valley pilot scheme. *Salm. Trout Mag.* 191, 34-55.

PERCIVAL, E & WHITEHEAD, H., 1929 — A quantitative study of the fauna of some types of stream bed. *J. Ecol.* 17, 282-314.

SMITH, D.B., WEARN, P.L., RICHARDS, H.J. & ROWE, P.C., 1970 — Water movement in the unsaturated zone of high and low permeability strata using natural tritium. *Proc. Symp. Int. Atomic Energy Auth.*, Use of isotopes in hydrology, 5, 73-87.

SKUES, G.E.M., 1974 — Nymph fishing for chalk stream trout and minor tactics of the chalk stream. Black, London.

TAVERNER, L.E., 1962 — Mid-century agriculture. *Proc. Dorset nat. Hist. archaeol. Soc.* 83, 130-137.

WESTLAKE, D.F., 1968 — The biology of aquatic weeds in relation to their management. *Proc. 9th Br. Weed Control. Conf.* 1968, 372-381.

WESTLAKE, D.F., 1968 — The weight of water weed in the River Frome. *Ass. River Auth. Yb.* 1968, 59-68.

WHITEHEAD, H., 1935 — An ecological study of the invertebrate fauna of a chalk stream near Great Driffield, Yorkshire. *J. Anim. Ecol.* 4, 58-78.

WHITEHEAD, J.B., 1968 — The management and land use of water meadows in the Frome Valley, Dorset. *Proc. Dorset nat. Hist. archaeol. Soc.* 89 257-281.

WHITAKER, W. & THRESH, J.C., 1976 — The water supply of Essex. *Mem. Geol. Surv.* 54, 52.