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Invasion by Zander and the Management of Fish Stocks [and Discussion]

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Phil. Trans. R. Soc. Lond. B 1986 **314**, 571-582
doi: 10.1098/rstb.1986.0073

Phil. Trans. R. Soc. Lond. B **314**, 571–582 (1986)
Printed in Great Britain

Invasion by zander and the management of fish stocks

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In 1976 it became evident that the zander (*Stizostedion lucioperca* (L.)) had been illegally introduced into waters coming under the jurisdiction of the Severn–Trent Water Authority. Since that time the species has established self-sustaining populations in a 35 ha lake and a 40 km length of canal system, with the start of a similar trend being observed for the River (Lower) Avon. The mechanism of invasion in terms of distribution and population growth suggests that, although the species can rapidly become established in a suitable habitat, further colonization of new reaches of a watercourse (if unaided by man) can be slow. The impact on recipient fisheries depends on the rate of expansion of the zander population and the ability of resident prey communities to withstand an additional predator. In an enclosed lake, management of fish stocks has proved possible. For open-ended watercourses, the monitoring and control of zander populations is difficult, but continual cropping by anglers is recommended, to maintain a diversity of species.

Introduction

The zander (*Stizostedion lucioperca* (L.)) is a piscivorous member of the perch family, native to eastern Europe. It is now also widespread throughout western mainland Europe and is extending its range in England.

The earliest recorded successful introduction of zander to an English water was in 1878, when 23 fish were put into two lakes in the Woburn Estate, Bedfordshire (Sachs 1878). Many years later, in 1963, the first release into an open-ended watercourse occurred when 97 ex-Woburn zander were stocked into the Great Ouse Relief Channel; after this introduction, rapid colonization of the river systems of East Anglia took place (Wheeler & Maitland 1973; Linfield & Rickards 1979).

In 1976 it became evident that the zander had been illegally introduced into waters coming under the jurisdiction of the Severn–Trent Water Authority (STWA). An attempt is being made to monitor the spread of the species within the catchment and its effect on resident fish stocks (Hickley & North 1983). This paper presents a summary of findings up to the end of 1985.

Methods

Monitoring the spread of zander into new reaches of a watercourse relies on captors volunteering information to the STWA Fisheries Offices. To encourage this, an illustrated publicity sheet entitled 'Have you seen a zander?' is distributed to tackle dealers and other places frequented by anglers.

Where populations are known to occur or to be establishing themselves, regular surveys are

carried out. Canals are sampled by electric fishing, from a boat, with boom-mounted pendant electrodes operated from a pulsed DC control box powered by a 250 V AC portable generator. Seine nets are used for sampling lakes. All zander caught are retained; other species are returned to the water. Within the main river system, sampling is difficult; therefore, although occasional electric fishing surveys are carried out, the status of the zander population is primarily derived from details supplied by anglers.

Scales taken from zander and representative specimens of prey species are used for age determination. In addition, zander corpses provide information on feeding and reproductive state.

The relative strengths of year classes and mean annual survival rates for roach (*Rutilus rutilus* (L.)) in Coombe Abbey Lake were assessed according to the methods described by Mann (1973). Theoretical production was calculated by substituting smoothed growth rates and mean numbers into the production equations outlined by Chapman (1971), the former derived from a fitted Bertalanffy (1957) model and the latter from the survival curves.

Distribution

(*a*) *General*

The first zander reports were in 1976, for Coombe Abbey Lake and a short section of the Oxford Canal, both sites being in a region approximately 30 km east of Birmingham. The species did not appear to extend its range during 1977 but by the end of 1978 zander were found in the Ashby Canal and, during 1979, were taken by anglers from Wanlip Gravel Pits near Leicester. During the early 1980s, the species started to spread into the river systems of the catchment. It was first reported from the lower Severn in 1980, the lower Avon region and the River Teme confluence in 1981, the mid Avon and River Soar in 1982 and middle Severn in 1983. During 1984 isolated reports were received for the Stratford and Grand Union Canals. The distribution of zander in the catchment, together with dates of first recorded occurrence, is shown in figure 1; a summary of catches is given in table 1.

(*b*) *Coombe Abbey Lake*

This is a shallow (less than 2 m) man-made lake of approximately 35 ha. Roach and bream (*Abramis brama* (L.)) are numerically predominant, with pike (*Esox lucius* L.), perch (*Perca fluviatilis* L.), carp (*Cyprinus carpio* L.) and tench (*Tinca tinca* (L.)) also present; the fishery is generally regarded as one of high quality.

It is believed that 14 zander from East Anglia, up to 3 kg in weight, were illegally introduced into Coombe Abbey Lake during 1973 and 1974 (Fickling 1982). The first evidence of these introductions came when a 120 mm fish was caught during the Coventry City Angling Championship in August 1976. The lake is netted on a regular basis by STWA to monitor the status of the zander population. Results of a population estimate made in October 1984 (Hickley & Starkie 1985) are given in table 2, and show zander to have comprised 1.0% by weight at a density of 13.7 kg ha^{-1}.

(*c*) *Canals*

The canals containing zander are sections of the Oxford and Ashby-de-la-Zouch systems. They are heavily used by boat traffic, especially during the summer. Roach and bream occur

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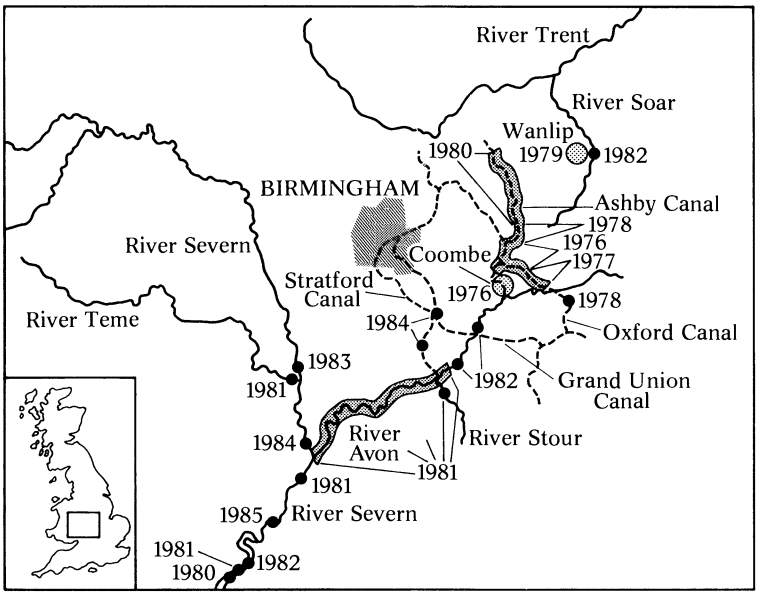

FIGURE 1. Map showing the distribution of zander in the Severn–Trent Water Authority area and dates of first reported occurrence. Stippling represents major colonization zones; solid points are for isolated reports.

TABLE 1. SUMMARY OF ZANDER CATCHES FOR THE CATCHMENT OF RIVERS SEVERN AND TRENT FROM 1976 TO THE END OF 1985

(Symbols: —, method not used; n.r., method used but catches not recorded.)

	number of zander caught	
location	survey	angling
Coombe Abbey Lake	1162	259
Wanlip Gravel Pits	11	418
Ashby Canal	39	31
Coventry Canal	37	n.r.
Grand Union Canal	4	1
Oxford Canal	635	n.r.
Stratford Canal	—	1
River Avon	—	109
Rivers Avon and Severn confluence	12	66
River Severn	—	12
Smite Brook (Coombe Outfall)	2	—
River Soar	—	1
River Stour (Warwickshire)	—	1
River Teme	—	1
total	1902	900

in reasonable numbers and provide adequate sport by canal standards. Other species present include pike, perch, gudgeon (*Gobio gobio* (L.)) and carp.

A dead fish on the towpath and the sighting of three during a dewatering operation in 1976 were the first indications that zander were present in the canal system. Results of electric fishing surveys in March 1978 suggested that the species was confined to a 12 km section between Hawkesbury Locks at Coventry and Hillmorton Locks at Rugby. However, surveys in November 1978 resulted in the capture of zander 10 km north on the Ashby Canal. The species

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now occurs throughout the Ashby Canal (30 km) although significant spread south has still not been observed. A 5 km length of the Hawkesbury to Hillmorton section of the Oxford Canal carries the highest density of zander, and the results of a population estimate made in March 1984 are given in table 2, showing zander to have comprised 3.8% by weight at a density of 9.4 kg ha^{-1}.

Table 2. Population estimates for fish (exclusive of 0 group) as assessed for Coombe Abbey Lake by seine netting, October 1984, and for 1.3 km of the Oxford Canal by electric fishing, March 1984

	Coombe Abbey Lake				Oxford Canal			
species	percentage number	fish ha^{-1}	percentage mass	mass / kg ha^{-1}	percentage number	fish ha^{-1}	percentage mass	mass / kg ha^{-1}
roach	63.9	11868	39.1	556	72.0	1115	57.6	142.7
bream	35.4	6569	59.0	840	12.2	188	20.8	51.6
hybrid (roach × bream)	—	—	—	—	9.3	145	11.8	29.2
perch	0.53	98	0.2	3.5	1.8	29	0.8	2.0
pike	0.02	5	0.5	7.3	1.1	17	2.9	7.1
zander	0.1	19	1.0	13.7	3.2	50	3.8	9.4
others	0.01	1	0.2	2.1	0.3	5	2.35	5.7
all species	—	18560	—	1422	—	1549	—	247.7

(*d*) *River system*

Below its confluence with the River Avon, the Severn is a coarse fishery, providing only mediocre sport; bream, roach and chub (*Leuciscus cephalus* (L.)) are the main species present. The middle and lower reaches of the River Avon are rated as excellent coarse fisheries. Predominant species vary according to depth and flow; they include chub and dace (*Leuciscus leuciscus* (L.)) in shallower stretches and bream and roach in the deeper, slower lengths.

The earliest confirmed zander report for the River Severn was of two small fish (*ca.* 100 mm) taken during October 1980. One of these was trapped in an eel putcheon downstream of the River Avon confluence and the other found in a power station trash bin sited in the tidal Severn estuary. In the River Avon, the species was found to be present when a specimen was caught in an eel trap during February 1981. Anglers then started taking fish from popular fisheries on the middle reach of the River Avon and from the Severn–Avon confluence complex.

Mechanism of invasion

(*a*) *Coombe Abbey Lake*

Length–frequency histograms are given in figure 2 for zander caught in Coombe Abbey Lake. The results show a pattern whereby the progeny of the introduced fish have grown to maturity, subsequently producing strong year classes in 1981 and 1982 as the population started to exploit the new environment. By 1984, the population showed signs of becoming balanced, although the 1984 year class itself appeared to fail.

A zander cull was carried out in October 1984; the effect has been to return the zander population structure to the equivalent of its 1976 status. Numerical development is shown in figure 3; there was a rapid population increase from 1980 to 1982, whereupon the lake

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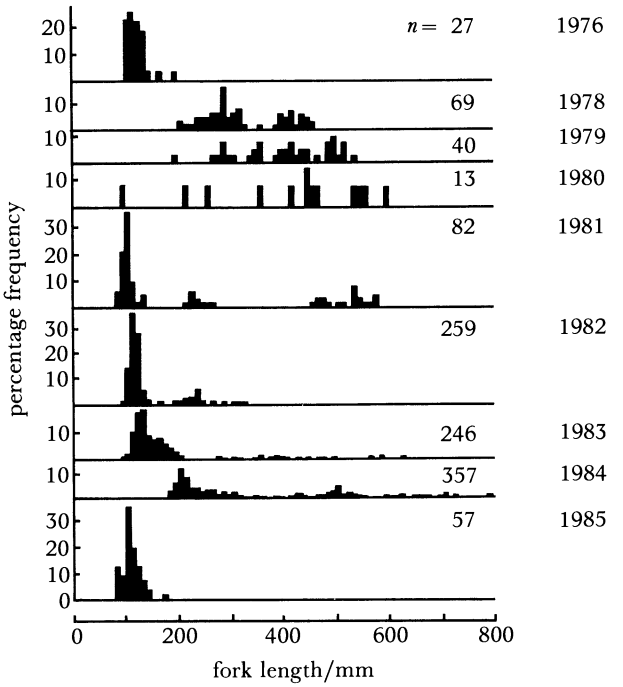

FIGURE 2. Length–frequency distributions for zander in Coombe Abbey Lake for the years 1976–1985; *n*, total number in sample.

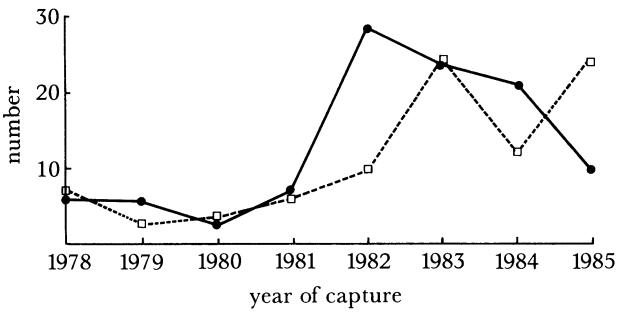

FIGURE 3. Solid line: numbers of zander caught per single seine net haul in Coombe Abbey Lake. Broken line: numbers of zander caught per kilometre per single electric fishing run in a 4.5 km repeat survey section of the Oxford Canal.

management team adopted new policies aimed at eliminating, or at least severely reducing, the zander population. It is now a rule of the fishery that all zander caught must be killed. Occasional 'zander only' competitions are held; some work has been carried out on the installation of habitat improvement devices, such as tyre reefs, to benefit the prey species.

(*b*) *Canals*

For the canal system, a length–frequency pattern similar to that for Coombe is apparent (figure 4) but interpretation is less clear because electric fishing gear tends to be biased against the capture of first-year zander, whereas seine netting is not. The change in numbers of zander removed from the study reach of the Oxford Canal is plotted in figure 3 and shows an increase

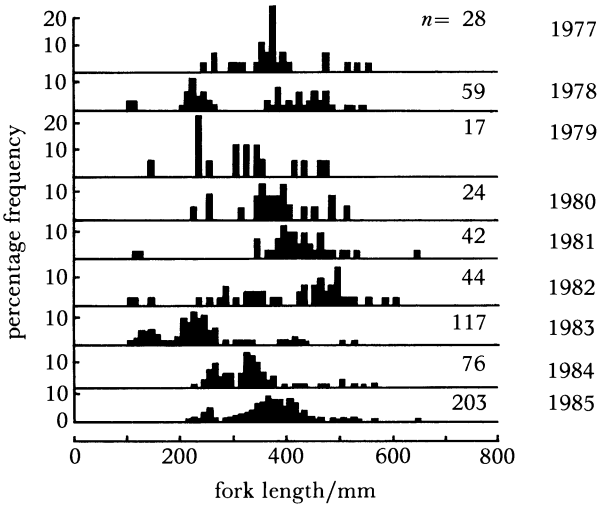

FIGURE 4. Length–frequency distributions for zander in the Oxford Canal for the years 1977–1985; *n*, total number in sample.

in population size since 1980. In the open-ended habitat of the canal system, management strategies are difficult to implement and whether or not zander numbers will continue to increase remains open to speculation.

(*c*) *River system*

Length–frequency histograms for zander caught in rivers, mainly by anglers, are shown in figure 5. Note that the pattern resembles the early stages of the invasions described above (figures 2 and 4). In 1984, the majority of zander were in a size group approximating to 500 mm in length, and thus sexually mature (Fickling 1982). It is possible that these fish are present in sufficient numbers to form the nucleus of a breeding population, as the frequency distribution for 1985 shows the entry of 0-group zander.

The change in numbers of zander reported is shown in figure 6. There is an apparent decline in numbers taken at the Severn–Avon confluence during 1984 and in the rest of the river system during 1985 compared to the previous steady increase. Although this may reflect a real decrease in population size, experience suggests that fishermen are good at volunteering information on

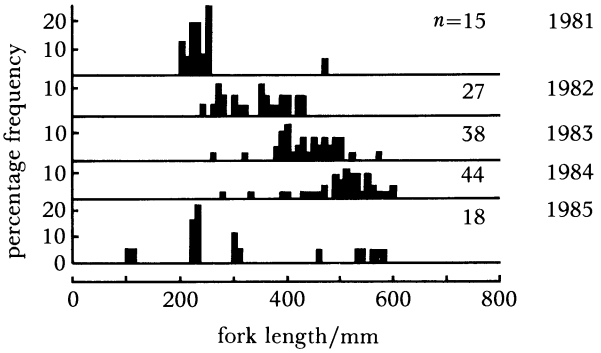

FIGURE 5. Length–frequency distributions for zander in the Rivers Avon and Severn for the years 1981–1985; *n*, total number in sample.

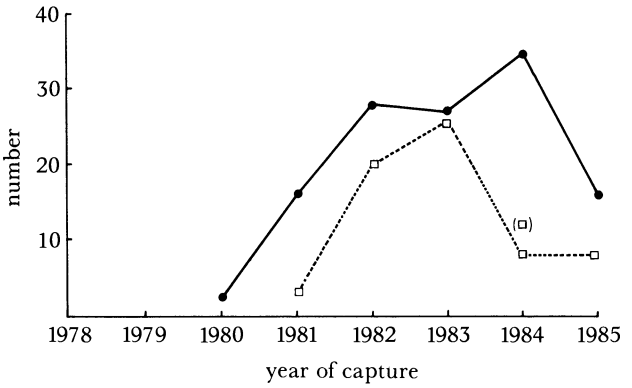

FIGURE 6. Change in number of zander caught by angling, eel traps and power station intakes in the Rivers Avon and Severn. The broken line shows data for the confluence complex; the solid line, for all other sites combined. The symbol in parenthesis indicates catches from electric fishing at the confluence.

first appearances of zander at new venues, but as catches become more commonplace a considerable shortfall on reporting normally occurs.

CONSEQUENCES

The effect of zander on the fisheries in the Severn–Trent catchment in which they occur will depend on the rate of expansion of the populations and the ability of the resident fish communities to withstand the presence of an additional predator. At present it is not possible to produce a sophisticated mathematical model with which to make an assessment, but some insight into the dynamics of the ecosystem, particularly for the enclosed population at Coombe, can be derived from simple calculations.

The biomass estimates given in table 2 show that in October 1984 zander composed 1% and 3.8% respectively by mass of the Coombe Abbey Lake and Oxford Canal fish populations. However, once they become piscivorous (after the first few months of life) zander feed almost exclusively on roach, which make up 97% (Coombe) and 71% (Oxford Canal) by number of prey fish ingested. Also, zander of all age groups consume fish of small size; roach larger than 120 mm fork length are rarely taken.

The significance of this can be seen by comparing the biomass density of zander with that of roach of the sizes vulnerable to predation (i.e. ages I and II) in table 3. As the annual food ration required by zander is approximately 250% of body weight (Popova & Sytina 1977; Leah & Kell 1986) such ratios of zander to roach may indicate an imbalance in the predator–prey relationships of these waters.

TABLE 3. BIOMASS (kg ha^{-1}) OF ZANDER AND ROACH IN TWO SURVEYS

	zander	group I and II roach	zander/ roach
Coombe Abbey Lake	13.7	51.3	37%
Oxford Canal...			
sample site	9.4		70%
full range	5.6	13.4	42%

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Theoretical values for annual production (P) were calculated for the roach population of Coombe Abbey Lake (see methods). Table 4 shows that, for a 1 kg mean biomass of juvenile roach, the net production lost through mortality is 802.1 g, compared with an increase in biomass of 643.5 g for survivors. From these values, together with a 250% food requirement, it can be calculated that, if all net production were available for consumption, 1 kg of zander

TABLE 4. SELECTED VALUES FROM THE CALCULATION OF THEORETICAL ANNUAL PRODUCTION FOR ROACH IN COOMBE ABBEY LAKE

(Abbreviations: G, instantaneous rate of weight increase; B, biomass; P, production.)

age group	G	mean B (g)	increase in B (g)	P (g)	net P (g)
0–I	2.102	91	116.8	191.3	74.5
I–II	1.971	308	359.8	607.1	247.3
II–III	1.077	601	166.9	647.2	480.3
totals		1000	643.5	1445.6	802.1

would require 3.1 kg of small roach to sustain it. To apply the converse, the density of zander would be 32% of prey biomass. This must be an absolute maximum figure; in practice it is highly improbable that all roach mortality would be due to predation. Nevertheless, this hypothetical figure serves to put the observations in table 3 into perspective.

There are signs that the increase of zander in Coombe Abbey Lake may have depleted the roach population, but confirmatory evidence is so far lacking.

DISCUSSION

The ideal zander habitat has been described (Deedler & Willemsen 1964) as eutrophic, turbid, well oxygenated and of low mean depth, and, if a river, slow-flowing rather than turbulent. The success of species throughout East Anglia has generally been in accordance with these criteria (Leah & Kell 1986). The area within the Severn–Trent catchment where zander are most likely to expand their geographical range is the canal system, although this expansion may not be particularly rapid. Fickling (1982), studying movement of tagged zander in East Anglia, found that over 50% of fish stayed within 1 km of the release point; movements in excess of 10 km were seldom noted. Such a behaviour pattern could explain why the main zander population is confined to a 12 km reach of the Oxford Canal, with thinly distributed outliers. Similarly, in the rivers Severn and Avon, zander are generally caught close to sites most likely to have been the ones used for illegal stocking. In the river system, numbers are expected to increase. If the pattern of population development seen in the canals occurs in the river system, the growth of the 1985 year class and their subsequent spawning could firmly establish the species in the river system from about 1990. However, further geographical expansion is likely to be limited by water velocity. Further colonization of enclosed waters should not occur but, of course, some anglers may stock zander illegally in new locations.

In mainland Europe, the zander is a fish of considerable economic importance and, in view of its rapid growth and palatability to man, is often used to enrich native fish fauna and control small fish species of little value (Popova & Sytina 1977). Consequently, the effects of introduced zander on recipient resident fish stocks have been studied extensively in central European waters

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

but nevertheless remain unpredictable (Fickling & Lee 1983). The abundance and diversity of prey species and the presence or absence of other predators are among the major factors determining outcome (Aksiray 1961; Dahl 1962; Willemsen 1969). It would appear that the zander may have a considerable effect when diversity of prey species is low. Unfortunately, in comparison with the mainland fauna, all British waters containing zander have a low diversity of species. In particular, they lack the smelt (*Osmerus eperlanus* L.), which, when available, is a preferred food and may constitute up to 100% of zander diet (Willemsen 1969).

Linfield (1984) investigated zander, pike and cyprinid stocks for 35 river fisheries in East Anglia and found predator–prey imbalances to be clearly evident. The extent of imbalance and degree to which cyprinid biomass had become reduced was loosely correlated with the length of time that zander had been present. Further research in Anglian fisheries by Leah & Kell (1986) revealed that the zander has a much larger relative effect on prey species than does the pike. First, the effect of any pike cohort is greatest in the year after spawning, whereas for zander it is in the third year of life, with the consequential higher individual biomass of predator. Secondly, as confirmed by this study, zander feed disproportionately on prey of small size; this means that the species causes much higher mortality among young age groups of prey fish than would an equivalent biomass of pike. This is the mechanism by which a zander population may cause a collapse in resident prey fish stocks. From the records for Coombe Abbey Lake, it seems that the species has a potential for considerable detrimental impact if not carefully managed. The October 1984 survey (table 2) showed the highest zander and lowest juvenile roach biomasses recorded to date. Had a cull not been carried out at that time, the roach population might well not have withstood the predation pressure. In the canals and rivers forming the open ended watercourses of the catchment, both piscivores and prey have a degree of geographical flexibility with respect to recruitment and maintenance of populations which, although tending to buffer change in stock levels, makes it difficult to monitor predator–prey imbalances and to implement management procedures. A straightforward and perhaps fail-safe approach would be to try and ensure that zander populations are never allowed to exceed a biomass of 5 kg ha^{-1}. This figure is recommended by Leah & Kell (1986) as the maximum density to ensure stability in East Anglian fisheries, but already the population in the Oxford Canal exceeds this value in places (9.4 kg ha^{-1}; March 1984).

In many parts of Europe, extensive commercial fisheries exist for zander; this keeps populations under control. To ensure good numbers of cyprinid fish, especially roach, for anglers in the U.K., it is imperative that these same anglers be encouraged to crop zander in the affected waters during all phases of invasion.

The author thanks his colleagues for both advice and assistance in field work. The views expressed are those of the author and not necessarily those of the Severn–Trent Water Authority.

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Discussion

M. H. Williamson (*Department of Biology, University of York, U.K.*). On the European mainland, zander feed on smelt. Why not introduce smelt to the United Kingdom?

P. Hickley. Smelt cannot survive in highly eutrophic waters, whereas zander can. In Britain, the latter are colonizing waters where smelt would be unlikely to establish themselves.

R. M. May, F.R.S. (*Department of Biology, Princeton University, New Jersey, U.S.A.*). If no attempt was made to control zander and the system was left to develop, how would the impact of their predation be likely to modify it?

P. Hickley. In Coombe Abbey Lake roach populations were already reduced, and without zander control they would crash. Another species would then bear the brunt of the predation. Ultimately the zander would become the only abundant species and would prey on themselves. A long-term cycle of oscillation extending over some 30 years would probably develop. Ecologically, this might be acceptable, but anglers want a multi-species fishery.

G. Edwards-Jones (*Imperial College Field Centre, Silwood Park, Ascot, Berks., U.K.*). The initial colonization was in the Coombe Abbey Lake area. The fish then next appeared in the Lower Severn, and subsequently colonized upstream, back towards Coombe Abbey Lake. Why did it only colonize upstream, and was this colonization brought about by man?

P. Hickley. The role of man has been very significant in promoting colonization of watercourses by zander. Judging from the reports of captures, I believe that the sequential upstream distribution, referred to in the question, reflects a pattern of illegal stocking at new locations rather than movement of fish within the river system.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

J. H. Lawton (*Department of Biology, University of York, U.K.*). What is the effect of zander on other predatory fish like pike and perch?

P. Hickley. Zander predation falls mainly on fry of the year. Pike are likely to be affected only if too few young roach survive to the fourth- or fifth-year age classes, which they take.

A. M. Young (21 *Southwood Court, Bigwood Road, London, U.K.*). If zander deprive pike of their prey, why cannot the pike eat the zander?

P. Hickley. Zander do not necessarily deprive pike of their prey, as those specimens of a prey fish cohort that survive to grow beyond 120 mm in length will be available to pike but not to zander. Although pike can, and occasionally do, take zander, the latter grow fast and are not generally susceptible to predation for very long; their spiny nature increases the complexity of dealing with them as prey and the mode of pike predation reduces the chance of suitable encounters.

R. J. O'Connor (*British Trust for Ornithology, Beech Grove, Station Road, Tring, Hertfordshire, U.K.*). Dr Hickley mentioned the establishment of tyre reefs as refuges. Could the habitat be modified so as to favour roach?

P. Hickley. This was the reason for establishing the tyre reefs at Coombe, which do seem to work. It is necessary to manage species when they are co-existing in a closed environment.

R. M. May, F.R.S. Why does the author suppose that the fry of the species now being taken as prey have lacked predators for all these years? They appear to have been an unexploited resource.

P. Hickley. There are data on the survival of roach before the introduction of zander. The latter has an impact as a new element in the system. Roach fry production has increased as the predation load has intensified.

A. J. Gray (*Institute of Terrestrial Ecology, Furzebrook Research Station, Wareham, Dorset*). I am interested in the very slow spread of zander. Dr Hickley's marking experiments revealed that 50 % of the population did not move very far, but I noticed that two or three animals dispersed more than 10 km. In the context of invasions, these are the important ones. Why do they not act as foci of infection for faster spread?

P. Hickley. Only two- or three-year-old zander are mobile; the adults appear not to disperse. Hence the young colonists have no effect as founders of a sub-population until they mature, and this slows the colonization process.

M. W. Holdgate (*Department of the Environment, 2 Marsham Street, London, U.K.*). What is the national picture of zander distribution? How typical are the experiences in the Severn–Trent region when compared, for example, with the situation in East Anglia?

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P. Hickley. A local introduction was made in the Fens but not monitored. Fish populations were then found to be disappearing and some 35 fisheries in the area were surveyed. There was found to be a correlation between the length of time zander were known to have been present in a water and the standing crop of the prey species. Data from under 5-, 5–10, and over 10-year-old populations show proportional decrease in roach biomass. There appears to have been a slow outward spread from introduction points, but also carriage by fishermen.

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