Ecology of the European Otter

Lutra lutra

Conserving Natura 2000 Rivers

Ecology Series No. 10

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Conserving Natura 2000 Rivers

This account of the ecological requirements of the European otter (*Lutra lutra*) has been produced as part of **Life in UK Rivers** – a project to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites. The project's focus has been the conservation of rivers identified as Special Areas of Conservation (SACs) and of relevant habitats and species listed in annexes I and II of the European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (the Habitats Directive).

One of the main products is a set of reports collating the best available information on the ecological requirements of each species and habitat, while a complementary series contains advice on monitoring and assessment techniques. Each report has been compiled by ecologists who are studying these species and habitats in the UK, and has been subject to peer review, including scrutiny by a Technical Advisory Group established by the project partners. In the case of the monitoring techniques, further refinement has been accomplished by field-testing and by workshops involving experts and conservation practitioners.

Life in UK Rivers is very much a demonstration project, and although the reports have no official status in the implementation of the directive, they are intended as a helpful source of information for organisations trying to set 'conservation objectives' and to monitor for 'favourable conservation status' for these habitats and species. They can also be used to help assess plans and projects affecting Natura 2000 sites, as required by Article 6.3 of the directive.

As part of the project, conservation strategies have been produced for seven different SAC rivers in the UK. In these, you can see how the statutory conservation and environment agencies have developed objectives for the conservation of the habitats and species, and drawn up action plans with their local partners for achieving 'favourable conservation status'.

Understanding the ecological requirements of river plants and animals is a prerequisite for setting conservation objectives, and for generating conservation strategies for SAC rivers under Article 6.1 of the European Habitats Directive. Thus, the questions these ecology reports try to answer include:

- What water quality does the species need to survive and reproduce successfully?
- Are there other physical conditions, such as substrate or flow, that favour these species or cause them to decline?
- What is the extent of interdependence with other species for food or breeding success?

For each of the 13 riverine species and for the *Ranunculus* habitat, the project has also published tables setting out what can be considered as 'favourable condition' for attributes such as water quality and nutrient levels, flow conditions, river channel and riparian habitat, substrate, access for migratory fish, and level of disturbance. 'Favourable condition' is taken to be the status required of Annex I habitats and Annex II species on each Natura 2000 site to contribute adequately to 'favourable conservation status' across their natural range.

Titles in the Conserving Natura 2000 Rivers ecology and monitoring series are listed inside the back cover of this report, and copies of these, together with other project publications, are available via the project website: www.riverlife.org.uk.

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Introduction

Over the last two decades the literature on the European (or Eurasian) otter appears to have increased at an exponential rate. There is a wealth of information on diet, distribution and levels of toxic chemicals in otters, their faeces and their prey. While these aspects of biology are relatively easy to study (though not necessarily to interpret), others, such as population dynamics, density, home ranges and movements, are more difficult to investigate in such a rare and elusive animal. Thus, a review of existing data reveals an abundance of information in some areas and a paucity in others.

Paul Glendell/English Nature

Although there is a lot of information available about the biology and distribution of the otter, a great deal still remains to be discovered about its general ecology, such as home range, density and population dynamics.

The principles of conservation management for otters were first established by the reports of the Joint Otter Group (O'Connor *et al.* 1977, 1979) and focused very strongly on perceived detrimental factors such as habitat destruction, disturbance by humans and lack of resting or breeding sites. The reports emphasised the experimental nature of these practices and it has become clear, as more has been learned about otters, that the animals are more resilient than had been previously supposed. Many people working in the field of otter conservation are aware of this fact but there is still a need to elucidate more clearly factors that are truly detrimental to otters so that activities can be focused most effectively.

As large, warm-blooded top predators, otters are insulated against many of the small-scale environmental factors that can have a marked impact on the survival of riparian invertebrates and plants (temperature, rates of flow, water chemistry, etc.). Since individual otters can have home ranges extending over tens of kilometres, populations depend on the conditions in catchments, or even groups of catchments, which may encompass a wide range of physical states in the riparian environment. For these reasons, determining 'favourable conditions' and setting targets for conservation-led management is not feasible in the way that it might be for smaller organisms.

This report consists of two sections:

1. A review of current knowledge about otters. The report attempts to evaluate such data, to highlight areas where there are disagreements and to indicate where long-held beliefs about the needs of otters are not supported by recent studies.
2. Four appendices reporting on short investigations into matters related to the review:

a) A summary of dietary studies.

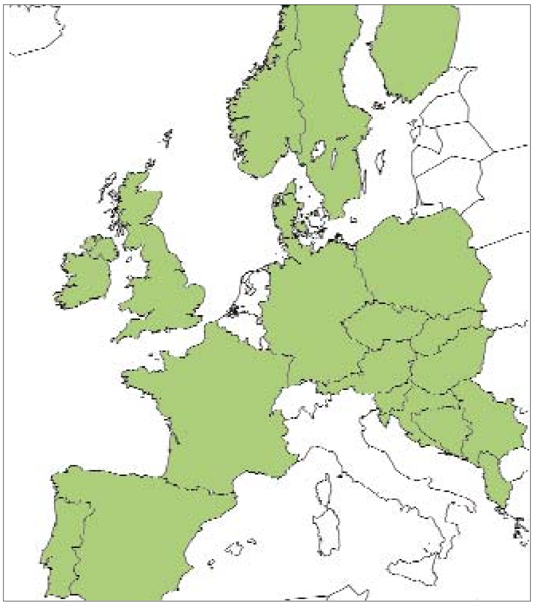
b) Changes in fish populations in a number of rivers in the Midlands and southern England over the last 30 years.

c) Changes in water quality in some of these rivers.

d) The work of the Otters and Rivers Project.

Status and distribution

The otter population of western Europe underwent a widespread decline during the 20th Century. The decline, and subsequent recovery, has been well documented in Britain (Chanin & Jefferies 1978; Andrews, Howell & Johnson 1993; Strachan & Jefferies 1996; Green & Green 1997), although less historical information is available for most other countries.



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Although the otter is rare or extinct in many European countries, it has recovered in others.

Macdonald & Mason (1994) reviewed the situation in western Europe at that time, showing that otters were rare or extinct in much of central Europe in a broad band extending from Italy across to central Spain in the south up to Sweden and southern Norway. 'Widespread' populations existed mainly in western areas (Portugal, Ireland, Scotland, and parts of Spain, France, Wales and England) or eastern areas (from Finland through to Greece).

A recent review (Conroy & Chanin 2001) found evidence of a recovery when comparing contemporary reports with those used by Macdonald & Mason on a country-by-country basis. It showed that, although European populations were still considered healthy and widespread in only a third of the 37 countries for which data were available, the number where they were believed to be increasing had gone up from 28% to 38%. The proportion where otters were believed to be threatened, declining, very rare or extinct had gone down from 40% to 22%.

UK distribution

Chanin & Jefferies (1978) identified a sudden and widespread decline in the success of otter hunts throughout much of England and Wales which corresponded closely with a perceived decline in the otter population from the mid-1950s. This was similar to changes observed in populations of various species of predatory birds and mammals, and led the authors to the conclusion that the decline in otters probably had the same cause – the introduction of cyclodiene pesticides (dieldrin and related compounds) in the mid-1950s.

Since 1977, as a result of a series of national otter surveys, substantial parts of England, Wales and Scotland have been surveyed three times, the whole of Ireland once and parts of it twice. In England and Ireland alternate 50km squares were searched; in Wales and Scotland the whole land area was covered. These surveys involved recording the presence or absence of otter signs (usually their faeces, known as spraints) according to a protocol that has been widely used in Europe (Reuther *et al.* 2000). In addition, the coast of Shetland has been surveyed twice by a different method involving the counting of active otter holts. Spraint surveys only provide information on distribution, while the holt surveys, which can only be used in certain coastal areas, provided estimates of the population.

The results of the spraint surveys are shown in Table 1, where it can be seen that the Irish otter population was widespread and abundant in the early 1980s, when in Britain the distribution was much more patchy.

Table 1. Results of National Surveys expressed as percentage of sites where signs were found.

	No. Sites[1]	1977-81[2]	1984-6	1991-4	2000-2
Ireland	2373	92%			
Scotland	2650	57%	65%	83%	
Wales	1102	20%	38%	53%	
England	2940	6%	10%	24%	34%

Data from Chapman & Chapman (1982); Green & Green (1997); Andrews, Howell & Johnson (1993); Strachan & Jefferies (1996), Crawford (2003). [1]Data selected only from sites which were surveyed in all three surveys. [2]Dates within which all surveys were completed. Irish survey was carried out in 1980–81, others in 1977–1979.

In the first survey of Scotland, otters were widespread throughout the islands, northern Strathclyde, the Highland Region north of the Great Glen fault, and Dumfries and Galloway. Here, for the most part, signs of otters were found at 90% or more of the sites searched. However, signs were much more difficult to find in the Central Region between the firths of Clyde and Forth, or in the Borders Region (under 25% of sites), while other areas were intermediate. By the time of the third survey, there had been a substantial increase in the number of positive sites – in most regions it exceeded 90% and was only below 80% in the Fife, Lothian and Borders regions (59%, 63% and 28%, respectively).

The first survey of Wales revealed a more patchy distribution, with otters present in most counties north or west of Glamorgan and Gwent, though at a much lower levels than in Scotland. Rather low numbers of positive sites were found in the Cambrian mountains and in Clwyd. By the third survey, the total number of positive sites had increased by more than two and a half times, and otters were present in every county and hydrometric area except Anglesey, where the population appeared to have become extinct between the first and second surveys. Otters have returned to Anglesey since the third survey (Ruth Warren, pers. comm.). The highest frequency of signs in this survey were in the Tywi (70%), Severn (74%), Cleddau (78%) and Wye (82%) catchments.

The first survey in England revealed a very low proportion of sites with signs of otters, which were found mainly in peripheral areas: the Southwest, the Welsh borders, north Norfolk and, more sparsely, in northern England. At this time, otters appeared to be close to extinction throughout much of central England. By the time of the third survey the number of positive sites had quadrupled, and in two areas (Welsh borders and the Southwest) more than 60% of sites were positive. The greatest increase between the first and third surveys was in western parts of England, but signs of otters were recorded in all regions, including Kent, and on all major catchments, including the Thames, Trent and Great Ouse.

The increase between the first and third surveys was not universal, and in East Anglia the number of positive sites decreased from 20 in the first survey to eight in the second (out of a total of 623). The increase from this to 52 sites by the time of the third survey is believed to be due, at least in part, to the reintroduction of otters by the Otter Trust.

A fourth survey of England was carried out between 2000 and 2002. The number of positives sites had increased to 34% over the whole country (Crawford 2003) and increases were recorded in all Environment Agency regions. Otters were recorded in 73% of the 105 Local Environment Agency Plan (LEAP) areas that correspond to individual river catchments (sub-catchments in the case of very large rivers or groups of catchments for very small ones). In some regions the increase in positive sites was less than expected. In the Severn Trent Region, re-colonisation of the lower reaches of the Severn and of the Warwickshire Avon was slow in contrast with the Trent catchment where the number of positive sites had tripled from 6% to 24%. In the Northwest, a modest increase from 29% to 34% included a substantial increase in the north on the Eden catchment (from 43% to 71%), as well as a slight increase in central areas (west Cumbria) and little change in the southern half of the region.

The fourth Welsh survey and a survey of Northern Ireland have also been completed and the results will be published later in 2003. The fourth Scottish survey will be completed by the end of 2004 and

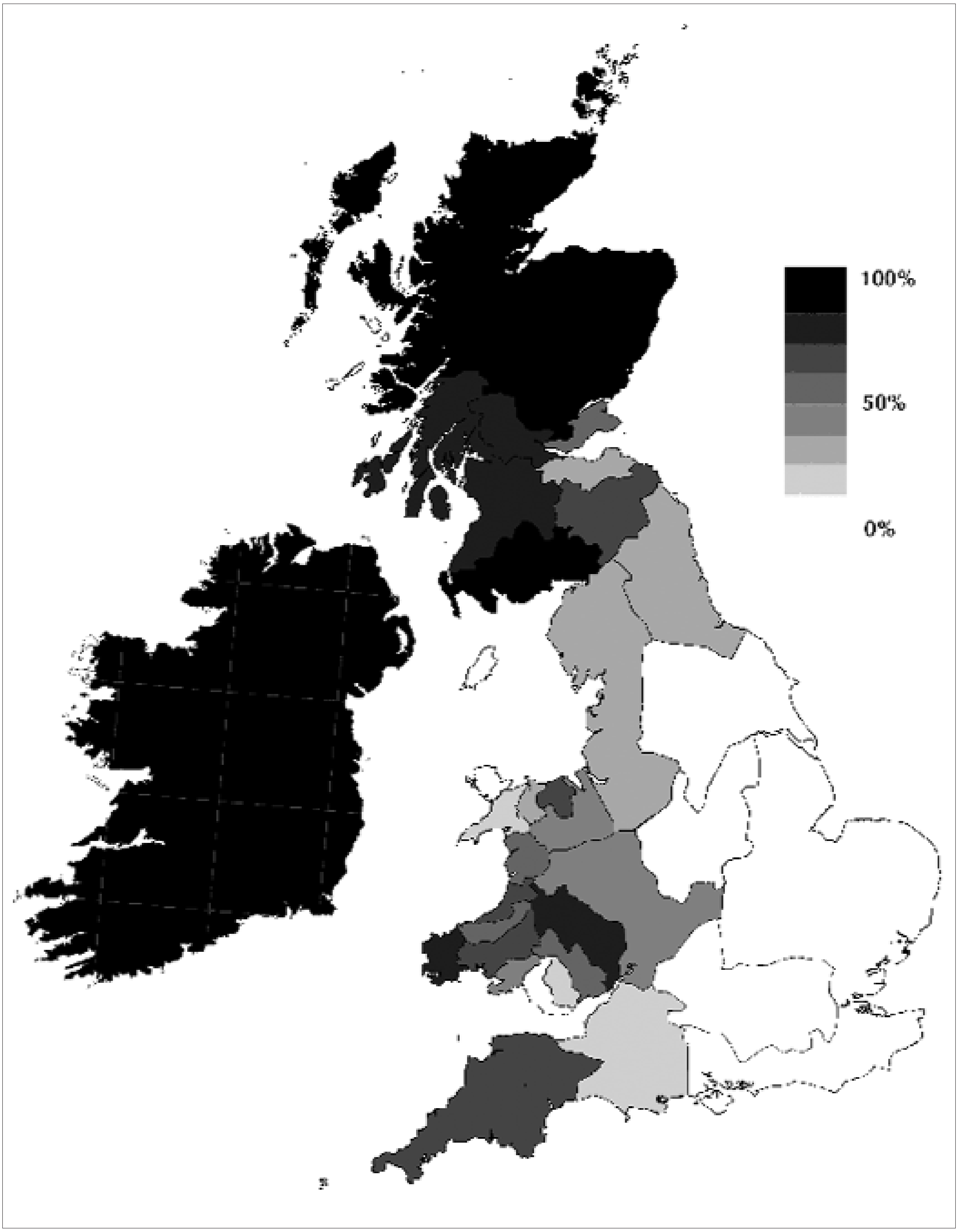

Figure 1. Distribution of otters in Britain based on the National Surveys of 1991-1994 (1980-81 for Ireland). English distribution based on Water Authority areas (with Severn and Trent catchments divided); Welsh distribution based on hydrometric areas; Scottish distribution based on administrative regions; Ireland by 100km square. Results for rivers on the border between England and Wales are combined for the whole catchment (Dee, Severn and Wye). Intensity of shading is directly proportional to percentage of sites with signs of otters.

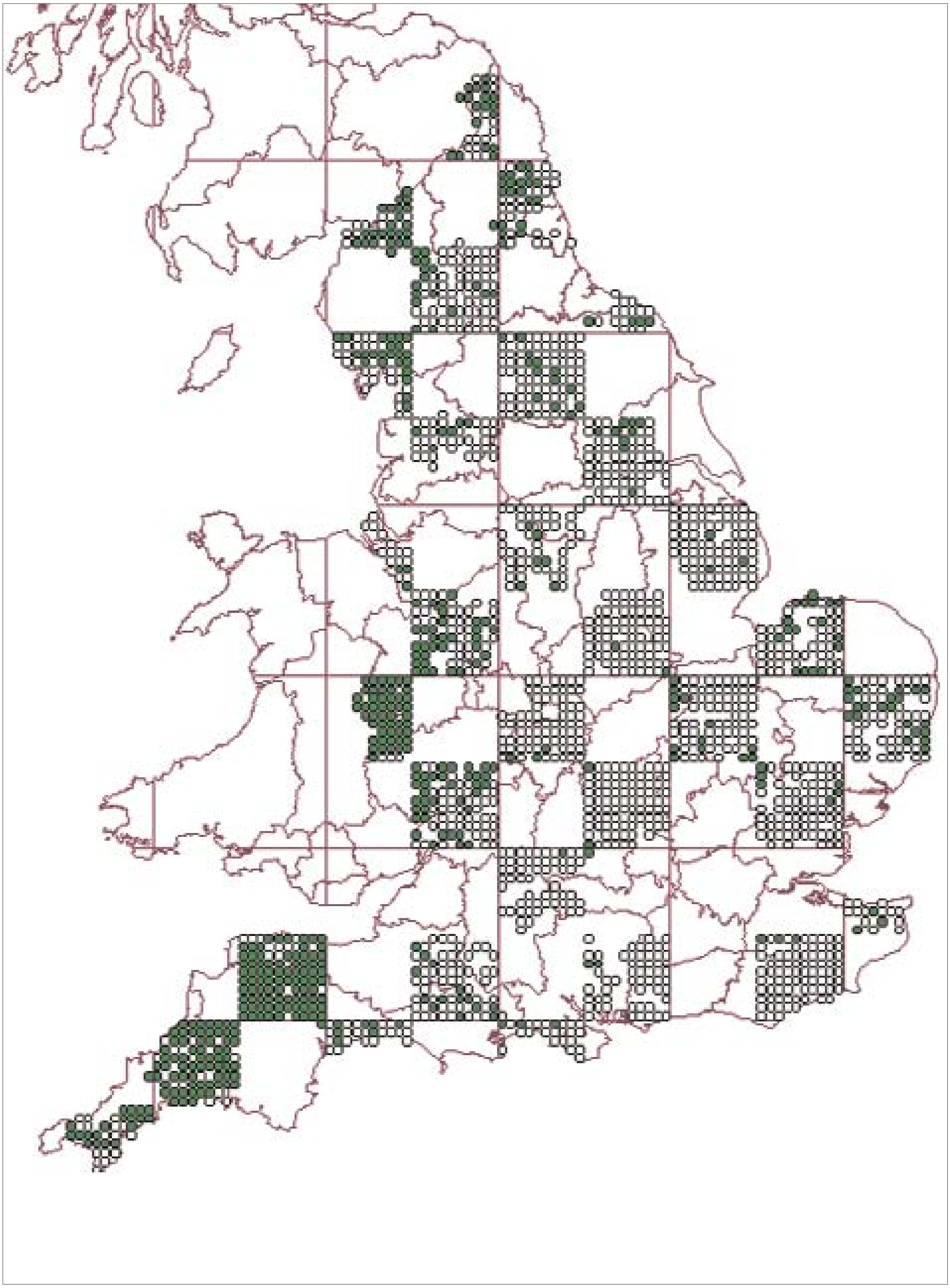

Figure 2. Distribution of otters in England – third National Survey 1991-94.
Each circle represents a 5km square where surveys were carried out. Closed circles indicate those where signs were found.

the results published during 2005. Figure 1 summarises the status of otters in Britain at the time of the third national survey, while Figure 2 shows the distribution in England at that time in more detail.

In the absence of recent data for Scotland and Wales, it is not possible to provide a comparable contemporary map, but shaded maps for all four English surveys are provided in Crawford (2003) which also includes a 'dot-map' at 10 km scale, together with detailed maps for each region.

Predicting the future

Strachan & Jefferies (1996) used data from the first three national surveys to calculate the rate of recovery for each region of England and for Wales, and predicted that by the time of the fourth survey 43% of sites in England and 70% of sites in Wales would have signs of otters.

The results for England proved to be lower than Strachan and Jeffries' predictions (36% for comparable sites). On a regional basis, predictions for Northumbria and the Wessex and Thames regions were close to the actual result, while the results for Severn-Trent, Anglia and the Southwest were higher than predicted (by approximately 33%, 25% and 14% respectively). In the North West and Yorkshire regions the results were approximately 30% lower than predicted.

Crawford (2003) did not discuss the discrepancy between predicted and actual results in Yorkshire but did comment on a perceived slowing down in the rate of recolonisation in the North West Region, pointing out that the recovery appeared to be proceeding better in the north than in the south of the region.

Summary of population changes in the UK

The otter population of the UK underwent a dramatic decline from the mid-1950s until at least the mid-1970s, when systematic surveys first began. The greatest declines were in England and Wales and although otters were generally widespread in Scotland in the 1970s, very low populations were recorded in lowland areas in south-central Scotland.

Since the first surveys the population has increased in most areas, but there have been some regional variations from this. Thus, otters appear to have declined to extinction in Anglesey by the time of the second survey (though they have returned since the third survey). In East Anglia the population continued to decline into the 1980s, though it has begun to recover since, probably as a result of the introduction of captive-bred animals.

The most recent survey shows a continuation of the recovery throughout England, although it appears to be slower than expected in some northern areas.

Life history

Births

Births in Britain have been recorded throughout the year and breeding has been considered to be aseasonal, at least on the mainland (Chanin 1991). However in a recent study in Scotland found that otters from the mainland tended to have their young in the winter (November to January) and a number of studies elsewhere in Europe have demonstrated that seasonal breeding can occur. The lack of evidence for it may in some places reflect insufficient data, or the pooling of data from large areas.

In many of these areas it has been possible to demonstrate seasonal changes in the availability of prey (Table 2), and that births occur at such a time as to maximise the abundance of prey when females are lactating (Beja 1996a; Kruuk 1995; Pikulik & Sidorovich 1996; Heggberget & Christensen 1994).

The evidence for a lack of seasonal breeding in mainland UK comes from data gathered by Harris (1968), which include a substantial dataset from Stephens (1957). This comprises 134 instances where the age of cubs was estimated by otter hunters or naturalists and the date of birth calculated. To this Harris has added a further 30 records from the literature. Curiously, while Stephens' data show approximately equal numbers of young born in each month, Harris' additional data are highly biased towards the colder months – 25 births estimated for the period October to March, five from April to

Table 2. Records of seasonal breeding.

Area	Habitat	Births	Authors
Sweden	Inland	Late winter	Erlinge 1967a
Portugal	Inland	January–March	Beja 1996a
Belarus	Inland	April and May	Sidorovich 1991
Shetland, UK	Coastal	May and June	Kruuk 1995
Denmark	Both	Summer	Elmeros & Madsen 1999
Norway	Coastal	Summer and autumn	Heggberget & Christensen 1994
Portugal	Coastal	October–December	Beja 1996a
Scotland	Inland	Winter	Conroy & Bacon in prep.

September. Whether this represents a biologically significant difference is difficult to determine. It is clear that many (perhaps most) of Stephens' records were based on sightings in the hunting field where the animals may not have been observed closely, while a high proportion of Harris' came from animals that had been handled and, in some cases, weighed.

A very limited set of data from southwest England, from which more accurate estimates of birth could be determined at autopsy, yielded information from six breeding females, each of which probably gave birth between September and February (Simpson 1998). Unfortunately, Bradshaw (1999), while reporting that 16 of the females in her sample were pregnant or lactating, provides no information on dates.

On the evidence currently available it would appear that while births have been recorded throughout the year in England and Wales, the possibility of seasonality should not yet be excluded.

Litter size and frequency

Kruuk, Conroy & Moorhouse (1987) have suggested that litters of otters recorded in fresh water are larger than those on the coast. Mean litter size ranged between 2.3 and 2.8 for four inland studies

Geoff Liles

An aerial view of a woodland and scrub otter breeding site in west Wales. The woodland and scrub is totally undisturbed, and largely impenetrable because of dense brambles.

Geoff Liles

A greater tussock sedge (*Carex paniculata*) natal den site within woodland on a small stream in Pembrokeshire, Wales.

(Mason & Macdonald 1986) and between 1.55 and 1.95 for three coastal studies (Kruuk *et al*. 1987).

These discrepancies may be partly explained by the ways in which observations were obtained. Heggberget & Christensen (1994) found that litter sizes of coastal otters at birth averaged 2.5 (based on autopsies), whereas litters that were observed when the young had become mobile, averaged 2.0 cubs. If, as seems likely, the coastal data referred to above are based on counting cubs and the inland observations on data from corpses, part of the difference may simply reflect mortality in the early stages of the otters' lives.

Other places where litter sizes have been estimated for the same population at different stages include Belarus (Sidorovich 1991) and Upper Lusatia in Germany (Ansorge, Schipke & Zinke 1997). Sidorovich recorded mean litter sizes of 2.7 from embryos (n=7), 2.6 at one month old (n=42) and 2.1 after leaving the den at about three months (n=133). Ansorge *et al*. recorded an average of 2.7 for counts of embryos and placental scars (n=14) and 2.1 for observations of cubs (n=48).

Kruuk (1995) reported annual births for some females but that not all adult females produced cubs each year. It was not possible to distinguish between females that failed to conceive and those that lost a litter of cubs at a very young age, before emergence from the natal den.

Geoff Liles

Orphaned otter cub being hand-raised. The litters of freshwater otters tend to be larger than those of otters that live in coastal areas.

Cub development and dispersal

Watt (1993) studied otters living on the coast of Mull and recorded the development of hunting abilities in cubs. He found that as they grew, not only did their reliance on their mother for food decrease, but their hunting ability increased and the proportion of the diet formed by unprofitable crabs declined. By 13 months old, young otters were entirely self-sufficient at foraging and became independent from their mothers but continued to catch a higher proportion of crabs than experienced adults. Watt concluded that this long period of dependence in his study area (about three months more than for otters in Shetland) reflected a lower abundance of prey.

In Sweden, Erlinge (1968) found that the distances covered by family groups of otters increased as the young developed, until by the age of one year, groups travelled up to 7 km in one night. He found that the young otters dispersed when they were about one year old.

Geoff Liles

High, sloping, wooded banks above flood level often provide good root-system holts for otters. This one has a well-used otter path from the stream up to the holt, and was used by a female with cubs. Depending on area and conditions, cubs become independent from their mothers at around one year old.

Jenkins (1980) followed the movements of one young male otter by injecting it with radioactive zinc (as Zn65Cl) and testing spraints with a Geiger counter. Up to the age of around eight months the animal's activities were confined to the loch on which it was raised, together with the inlet streams. It then began to exploit the nearby river Dee and extended its range on this river over the succeeding months. At the age of one year, it had been recorded along 68 km of the river, travelling distances of more than 20 km in one night.

A similar pattern of range expansion was reported for the North American river otter (*L. canadensis*) by Melquist & Hornocker (1983) who radio-tracked several young animals, some of which dispersed at 12–13 months of age. One young male travelled 104 km in 30 days and established a home range 32 km from its natal area. One female travelled 195 km in 50 days but then settled into a range adjacent to its mother's and partly overlapping it. Two other males had not dispersed from the natal range when contact was lost at 16 and 25 months old.

Population parameters

Reliable information on the demographic characteristics of otter populations is only available from the study of dead otters. Most of these have died as a result of human activity (road kills and those drowned in fishing apparatus), and in most studies relatively few died a 'natural' death. Most authors combine these data, although the two types of sample represent different parts of the population (see below).

The age of otters is usually determined from growth lines in teeth supplemented by cranial development in animals under two years of age (Heggberget, 1984).

Life expectancy

Gorman *et al*. (1998) analysed data from 391 otters from three areas in the UK (England and Wales, n=97; mainland Scotland, n=148; Shetland; n=146), separating the samples into violent deaths and natural or non-violent deaths. Life tables were constructed from each of these, taking the 'violent death' sample as an indicator of the age structure of the population and non-violent deaths as an indicator of the normal age at death. Estimates of the numbers of otters born were based on age-specific fecundity rates of animals in the sample.

No difference could be detected between males and females so the data were combined. There was, however, a significant difference in the median age at death between otters from Shetland (four years) and those from England and Wales (three years). The median age for mainland Scottish otters was four – not significantly different from either of the other samples. The maximum age at death in this sample was 16 years. Age-specific mortality for Scottish otters fluctuated between 0.1 and 0.4 up to the age of six, and then increased rapidly. Otters from England and Wales showed a higher mortality than Scotland in all age-classes greater than two, and mortality was higher than 0.5 at all ages greater than three. A smaller sample of otters from southwest England studied by Simpson (1998) also suggested a low life expectancy for otters in this region. Age was determined for 28 otters submitted between 1990 and 1993, and none was more than four years old.

Elsewhere in Europe, substantial samples of otters have been aged from three areas: the Iberian Peninsula (Ruiz-Olmo, Delibes & Zapata 1998; n=106), Norway (Heggberget, 1991; n=410) and eastern Germany (Hauer, Ansorge & Zinke 2000; n=1027). These authors all estimated age from growth lines in teeth, and their results are broadly similar, with median ages at death of three to four years, and the maximum age ranging between 12 and 16 years.

Age structure

Although the authors of the three studies referred to above estimated exact ages for the otters they sampled, they did not present their data in comparable ways, grouping them into differing categories. Hauer *et al*. used five categories, while the other authors used fewer. In order to compare data from the three areas (Figure 3), the data presented by the authors have been modified to fit in the following categories: Juvenile (less than one year); Sub-adult (animals in their second year); Adult (all others). There are no large datasets of a comparable nature from the UK.

Hauer *et al*. noted the very low proportion of animals less than two years old in their sample and suggested that this is probably an underestimate of the proportion of animals in these age classes. An analysis of a similar though smaller set of data from Germany by Ansorge *et al*. (1997) suggested that

Figure 3. Age structure of otter casualties from three European areas.

Sources: Germany, Hauer *et al*. (2000); Norway, Heggberget (1991); Iberia, Ruiz-Olmo *et al*. (1998).

the proportion of juveniles in this sample was underestimated by about 50%.

The only substantial set of data for England and Wales is provided by Bradshaw (1999) who estimated age on the basis of the animals' weight and reproductive condition. Bradshaw used different age-classes to those illustrated in Figure 3, and her assessment of juveniles was based on growth curves for two captive-reared otter cubs and should therefore be treated with some caution. Otters calculated to be under five months (males < 3.0 kg; females < 2.1 kg) were described as juveniles. Females larger than this were assumed to be sub-adults (6–18 months) if they showed no signs of reproduction (immature uterus and absence of nipples). Adult males were discriminated by possessing a baculum (penis bone) length >60mm. Only 3% of this sample consisted of juveniles, 23% were classified as sub-adult and 74% as adult.

Sex ratio

The proportion of male otters in the samples studied is normally in the range 50–60%. Bradshaw's study is at the extreme, with 61% of the sample being male otters. In her case the disparity was greatest in adult otters (65% male), whereas Hauer *et al*. found a greater disparity in the juvenile and sub-adult age classes (66% and 71% male, respectively).

Male-biased sex ratios in mortality samples from mustelid populations are not unusual and are frequently ascribed to differences in behaviours such as dispersal, territory size and distances travelled.

Population density

There are considerable difficulties in determining the density of otters. In part this relates to the difficulties of monitoring such rare and elusive animals, but even if the number is accurately known, there is no obvious solution to the problem of which spatial units to use. Otter territory sizes have most frequently been measured in terms of length of waterway, but this is not particularly useful in places where part or all of the range consists of lakes or ponds, or when comparing very large waterways with small ones.

This problem is clearly exemplified in data recorded by Durbin (1996) who found that in the case of a male and female otter with overlapping territories, the male had a home range encompassing 50 km of river, compared to 24 km for the female. However, when he calculated the area of water within each territory, the female otter had a 'larger' range than the male (34 ha compared to 29 ha).

A small number of values for population density have been calculated in Britain, in most cases on the basis of very small sample sizes. Harris *et al*. (1995) calculated otter densities in East Anglia and Perthshire from estimates of land area using data supplied by DJ Jefferies. They reported that an area of 75 km^2 in East Anglia contained three otters, while in Perthshire, 57 km^2 contained four otters. These values correspond to densities of one otter per 25 km^2 and one per 14 km^2, respectively. From this, together with average values for the lengths of waterway in England, Wales and Scotland respectively, Harris *et al*. (1995) calculated densities of one adult otter per 24 km of water in Scotland and one individual per 27 km in England and Wales. Clearly, the density of otters per unit of land area will vary with the proportion of it that is open water, and these average values conceal considerable local variation.

Kruuk *et al*. (1993) calculated otter density as ranging from 2–50 ha of water per otter, which was equivalent to one individual every 3–50 km of stream (median value of one otter per 15 km of stream).

A study of otters using DNA fingerprinting (Coxon e*t al*. 1999) revealed minimum numbers of otters present on the Tone and Itchen catchments during one year to be 23 and 13 otters, respectively. The area of the Itchen catchment is 473 km^2, while the Tone is approximately 400 km^2, corresponding to one otter per 36 km^2 and one individual per 17 km^2 respectively. These data include sub-adult, and possibly juvenile animals, which were excluded by Harris, and also transient as well as resident animals. They are also minimum estimates, since it is likely that not every otter present in the catchment during the year of the study was recorded.

These data not only demonstrate the difficulty of obtaining values for otter densities, but also that they can vary widely. The data from Kruuk *et al.* in particular varies by a factor of 17 from the lowest to the highest. It is evident that there is no basis at the moment for determining a 'normal or 'desirable' density of otters to set as a target.

One indication that the otter population may have reached a high level comes from observations by Simpson (1998) who found that 16% of otters received for *post mortem* analysis in southwest England suffered from bite wounds inflicted by other otters. These are found in both sexes, though more frequently in males. In this case, they had led to severe injury, infection and in some cases, probably, death. The pattern of wounding – lesions around the face and head or around the perineal area – suggested a stylised form of fighting, which suggests that this is the result of territorial behaviour, and that it was exacerbated by high densities of animals in the area. Although such fighting has been reported elsewhere (e.g. Erlinge 1968), it has not previously been recorded at this high a frequency during *post mortems*. Bradshaw (2001) has also observed wounds in the groins of male otters, including damaged bacula and one case of castration.

Genetic diversity

Studies of mitochondrial DNA in 30 wild otters from Denmark (Mucci *et al.* 1999) and 76 from Germany (Cassens *et al.* 2000) showed low levels of variability. Smaller samples from outside their own countries were analysed by these authors, and they had similarly low levels of variability with little or no basis for discriminating between populations. The authors consider that this may reflect the influence of a genetic bottleneck – but in the last Ice Age rather than in recent times, and possibly combined either with stabilising selection or an unusually low level of mutation.

By contrast, Dallas & Piertney (1998) investigating microsatellite polymorphism in the chromosomal DNA of 32 otters from Britain and Germany, found that variability at 13 loci was within the normal range for mammalian species. Using 10 of these loci, Dallas *et al.* (1999) investigated genetic diversity in otters from Scotland, comparing otters on the mainland with those from islands at different distances from the mainland. The results revealed a predictable decline in diversity from mainland populations to the more isolated island populations, with particularly low levels in the Shetland Islands.

Mainland otters were categorised as from northern or southern parts of the country and analysed separately since the southern population had undergone a significant decline and was believed to have been separated from the northern one for a period corresponding to several otter generations. Despite this, the loss of genetic diversity was small and the authors concluded that recovery would soon occur, now that the two populations are again in contact with one another.

Coxon *et al.* (1999) used the technique pioneered by Dallas and his colleagues in an attempt to carry out 'genetic fingerprinting' of DNA extracted from otter spraint from three rivers in south west England and one in southern England. They also analysed the tissues of 153 carcasses found in the region. This revealed a substantially lower level of genetic diversity in southern otters compared to those in Scotland, consistent with a significant bottleneck corresponding to the decline in the 20th Century.

Among the dead otters sampled (almost entirely from the Southwest) the number of alleles per locus for nine microsatellites ranged from four to six (mean 5.0) compared to 6–10 (mean 6.7) for Dallas & Piertney's original sample. The smaller number of individuals sampled by spraint analysis from the rivers yielded even lower diversity. Thus, for six loci on three rivers in Devon and Somerset, the number of alleles per locus ranged between two and five (mean 3.7, n=44). On the river Itchen in Hampshire there was a maximum of three alleles per locus (mean 2.3, n=13) and one was monomorphic.

The isolated Hampshire otters are thought to be derived from a founder population of only three animals released on to the river in 1993, and illustrate one consequence of small-scale reintroductions. However, the recolonisation of neighbouring catchments by natural spread is likely, in due course, to lead to this population being linked to a larger gene pool.

Paul Glendell/English Nature

Otters can be found in a variety of wetlands, including estuaries, although fewer individuals have been recorded in estuary sites in Britain than in other habitats.

Habitat requirements

Nature of waterway

Otters have been recorded as exploiting virtually all types of water and waterway in the UK. Although populations in England and Wales are confined mainly to fresh water, they readily exploit suitable coastal habitats in Scotland as well as elsewhere, such as Portugal (Beja 1995). The importance of estuaries to otters is more difficult to ascertain. In the third English survey, 25 estuarine sites were surveyed in Devon and Cornwall (where otters are widespread) and 40% of these had signs of otters, compared to 68% of non-estuarine sites in the area.

Otters have been recorded on still waters (canals, lakes, ponds and reservoirs) as well as rivers and streams of all sizes. Evidence from radiotracking (Jefferies *et al*. 1986) and from studies of the distribution of road casualties (Chanin 2001) shows that otters will use tiny streams and ditches including dry watercourses as regular routes. Jefferies (1988) reports one otter crossing a watershed by travelling 1.8 km overland in Norfolk.

Riparian habitat

Habitat destruction was first identified as a potential threat to otter populations by the Joint Otter Group (O'Connor *et al*. 1977), largely on the basis that there had been considerable changes to riparian habitats in the previous decade or so, which roughly coincided with the period in which otter populations had declined. Chanin & Jefferies (1978), while concluding that toxic chemicals had been responsible for the initial decline of the otter, suggested that one reason for the apparent slow recovery of the otter might be degradation of its habitat in subsequent years.

Early attempts to assess otter habitat requirements involved seeking correlations between the distribution of spraints and a range of habitat features, such as the presence or absence of trees and woodland, cover, potential den sites, human activities and various physical attributes of the waterways (Jenkins & Burrows 1980; Macdonald & Mason 1983; Bas, Jenkins & Rothery 1984). Macdonald & Mason's study was particularly influential, being based on surveys at over 50 sites in Wales and the Welsh borders, and using multivariate analysis of the distribution of otter signs plus 15 habitat variables. They concluded that the presence of ash and sycamore trees was particularly important, together with potential den sites, the majority of which were found under the roots of these two species as well as rhododendron bushes, oak and elm trees.

Both photos by Geoff Liles

Left: A typical mid-river boulder sprainting site with easy access for otters and spraint deposited on top.
Right: Fresh spraint (oily and dark with small fish bones) on a boulder.

Other studies based on spraints have pointed to the importance of the presence of trees and woodland or other cover, as well as the impact of human activities, while some have also demonstrated a relationship with food supply (e.g. O'Sullivan 1993; Prenda & Granado-Lorencio 1996; Thom 1997; White *et al*. in press).

Partly as a result of these studies and the Joint Otter Group Report, and possibly because it seemed natural, there has been a strong tendency for people concerned with otter conservation to put great emphasis on the importance to otters of bankside vegetation, particularly trees and scrub that might provide good cover or potential den sites. However, there is now considerable doubt as to whether this has any direct benefit to otters, not least because otters thrive in situations where there are no trees and little cover, such as Shetland.

Geoff Liles

A well-used path of otters through grass, with a surveyer checking a sprainting site.

A major problem with all such studies is in the use of spraint as an indicator of the preferences of otters. Most recent authors are careful to describe their studies in terms of predictions of, or correlations with, otter sprainting activity, but this begs the question of what 'sprainting activity' means. Many authors have used the numbers or density of spraints in a way that suggests it should correlate with the 'activity' of otters or perhaps the amount of time otters spend in particular places.

On inland waters otter spraints are not deposited at random on the waterside but at particular features of the riparian

Geoff Liles

Otter prints in mud on a lakeshore.

landscape such as the bases of large trees, boulders, bridges, confluences of streams, and so on. Spraint numbers are known to vary seasonally (e.g. Conroy & French 1985) and Thom (1997) found differences in the spatial distribution of signs between seasons as well as differences in numbers. In an unpublished study of a river in Devon with a well-established otter population, Hilary Marshall (pers. comm.) found considerable variation in spraint numbers between years. During the summer months when rainfall is low (June, July, August), the mean number of spraints found per month over a five-year period was 32.6, with a maximum of 60.0 and minimum of 4.7. Averaged over whole years there was still a five-fold difference between the year with the least spraints and the one with the most.

Thom (1997) used GIS techniques to investigate the spatial distribution of otter signs in the upper Tyne catchment. Attempts to predict the presence or absence of spraint using logistic regression models at various spatial scales did not lead to consistent results, but Thom concluded that models including altitude, the abundance of minnows and the presence of heavy metals in eel tissues were the most important determinants of spraint distribution.

Durbin (1998) obtained a much more precise measurement of habitat use from a study based on tracking five otters for periods of between three months and a year on the rivers Dee and Don in Scotland. He recorded more than 800 hours of otter activity within a three-year period. Durbin used the total amount of active time spent in a particular habitat as an indicator of use, and compared this with habitat availability as an index of preference. Separate indices were used for habitat length and habitat area. Although he found that all otters spent more of their time in relatively wide sections of river with large numbers of boulders and many trees, when he analysed his data on the basis of area, there was no preference for wide streams or trees, and most otters spent a disproportionate amount of their time in narrow, gravelly streams. Durbin found no evidence to suggest that otters actively avoided agricultural areas or areas of human activity, either when foraging or for resting.

In a review of otter habitat use and conservation, Kruuk *et al*. (1998) pointed out the difficulty of inferring 'habitat requirements' from studies of 'habitat preference'. Individual (or species) preferences for particular habitats do not necessarily have any significance in terms of survival. Using data collected by Durbin (1998) together with information from other radio-tracking studies they had undertaken, they concluded that the most significant determinant of otter usage of freshwater habitats was abundance of prey. Reedbeds and islands were also found to be important as they were frequently used as rest sites, while marshy areas were valuable as foraging areas for frogs. They found no evidence that the presence of trees, woodland or other forms of bankside cover influenced otter activity, and suggested that earlier emphasis on the importance of these may have been biased by patterns of otter sprainting activity. They also pointed out that otters thrive in areas where there is very little cover (such as Shetland).

Potential benefits of trees and woodland

Although it is now clear that otters do not 'need' trees or actively seek out wooded areas, there are a number of indirect benefits in allowing or encouraging tree and shrub growth beside waterways. Mason & Macdonald (1982) demonstrated that such riparian vegetation can significantly add to the availability of invertebrate prey for fish populations, which, in turn, will be of benefit to otters.

Potential harm

Encouraging the growth of trees and shrubs in riparian habitats undoubtedly benefits many organisms other than otters, including many species of invertebrates, fish and birds, but there may also be negative effects in some places. For example, water voles require dense growth of herbaceous bankside and emergent vegetation (Strachan 1998), and the promotion of scrub or planting of trees is detrimental to them. Some species of ground and water beetles of national importance depend on the presence of eroding riverbanks (Bielinski 1993), and it is important that these conditions should not be disturbed in the mistaken belief that it will benefit otters.

Dens, resting and breeding sites

Numerous words have been used to describe places where otters sleep, including, 'den', 'holt', 'couch' and 'resting site'. Holt and couch are words coined by hunters and refer respectively to covered and uncovered resting sites. However, the word holt is associated by many with the idea of a hole in the ground (usually under the roots of a bankside tree), and many people regard a couch as an uncovered nest-like structure. Kruuk and colleagues describe above-ground resting sites as couches. The terms 'rock holt' and 'stick-pile holt' are self explanatory, but some other structures do not fit easily into these two categories – bundles of reeds with a den in the centre, for example. A further problem with holts is that of finding them without the aid of a radio-tracked otter.

Many authors have recorded the presence of 'potential holts', which consist of tunnels, cavities or other covered structures that may be used by otters. It is not usually possible to determine how many of these are actually used, although spraints may be found beside some of them. Radio-tracking studies enable actual resting sites to be identified, and it is notable that a high proportion of these consist of places that would not be identified as potential holt sites in a survey (e.g. Green, Green & Jefferies 1984). So far, no-one has tried to compare the number of potential sites identified by a survey with the number of actual sites revealed by radio-tracking.

Both photos by Geoff Liles

A typical root system holt in a large sycamore on the River Clwyd, Wales.

In coastal areas such as Shetland and the Outer Hebrides, otter dens (holts) frequently consist of burrows in peat (Kruuk 1995). These may be substantial, conspicuous structures, some almost as large as a main badger sett, though without the large spoil heaps outside. Where females with cubs have been in residence, impressive piles of spraint may accumulate outside the entrance, sometimes up to 0.5 m across and 0.1 m high. Coastal holts are mostly within 100 m of the shore and may also be very frequent, with densities up to three or four per km in some areas (Conroy & Kruuk 1995).

In freshwater habitats, holts (in the form of tunnels) are less conspicuous and probably less numerous, though resting sites of other

Otters will use a variety of places as resting sites. Top: A cavity behind an old, collapsing wall in Pembroke town. Centre: The root plate of a fallen tree, with hole leading into a cavity, used by a radio-tracked otter. Bottom: Dense bramble scrub on the River Teifi used by radio-tracked otters for a daytime resting site.

All photos by Geoff Liles

kinds are much more common. Based on his experiences while otter hunting, Coghill (1980) summarised the types of resting site recorded in the upper reaches of the Severn catchment. He identified 256 sites, of which 42% were under the roots of trees (90% ash or sycamore). About 20% of sites were described as 'lying rough' in reed or osier beds, young forestry plantations, islands, rhododendron bushes, bracken, hedges, scrub, etc. Most of these were within 10 m of water but some were up to 50 m away. Stick heaps and rock holts formed 13% and 10% of sites, and various types of enclosed drain a further 11%. The remaining 'miscellaneous' category included badger setts, rabbit burrows, 'hollow islands', and a car body being used for bank protection.

Thom (1997) identified 212 potential holt sites in 200 km of the Tyne catchment, of which 58% were under trees (with half of these under ash or sycamore). A further third were in rocky banks, stone-filled gabions or caves, and the remainder consisted of piles of debris or holes in the bank. Thom pointed out that although the overall density was approximately one holt per km of stream, the distribution was very clumped, with 30% of 5 km stretches of river having none, and seven 5 km sections having more than 10 potential holt sites. There is no information on how many of these sites were used by otters or of the abundance of other potential resting sites.

In a radio-tracking study of otters in Perthshire, Green *et al*. (1984) found that individual otters used considerable numbers of resting sites and frequently lay up in relatively open areas. One male used 27 sites over a period of three months, and two-thirds of these were above ground, ranging from dense vegetation or under piles of sticks and branches (flood debris), to depressions in the bank where the vegetation was no more than 0.3 m high. They commented that fewer than 10% of the sites used for resting by otters would have been recognised as such without radiotracking.

Durbin (1993) found similar numbers of resting sites in his study of five otters, with the number recorded for individual otters depending on the length of time they were followed. Otters tracked for the longest periods had 27 and 30 holts corresponding to densities of 1.1 sites per km and 0.36 sites per km for a female and a male otter respectively. Durbin noted that many sites were only used on one or a few occasions and that otters had smaller numbers of sites that were frequently used.

Paul Glendell/English Nature

Woodland areas provide cover and forage for invertebrates that support the otter's fish prey. Otters sometimes use wooded areas as resting sites and for natal dens.

Kruuk *et al*. (1998) reported that four otters tracked for a total of 669 days spent 58% of their day-time resting periods in couches (29) and the remainder in holts (9). Most couches were in thick cover, in shrubs (9), reeds (3) or rushes (3). Three were on islands and the remainder under the bank, fallen trees, boulders, etc. Four holts were in artificial embankments formed by boulders, three in field drains and two in soil. None of these otters used a holt under tree roots while being radio-tracked.

Beja (1996b) located a total of 21 resting sites used by three coastal otters in Portugal and one living on an estuarine stream. None was underground and all were in thick vegetation such as brambles or among piles of boulders.

Unpublished observations by Kruuk and colleagues indicate that otters will rest under roads, in industrial buildings, close to quarries, and at other sites close to high levels of human activity. These observations clearly indicate that otters are very flexible in their use of resting sites and do not necessarily avoid 'disturbance' in terms of noise or proximity to human activity.

A common feature is that many of these resting sites are in places where the risk of direct physical disturbance is low (islands, reeds, dense scrub, culverts, piles of rocks, etc.). Although there is no evidence to suggest that the availability of such sites limits otter populations in the UK, some concern has been expressed that this may be the case in areas where riverbanks are completely devoid of natural cover. Where this occurs over very long lengths of river (kilometres rather than hundreds of metres) the provision of even small areas of dense scrub at intervals may be beneficial.

The construction of artificial dens may serve a similar purpose and there is evidence that these are readily used by otters. Cowell *et al*. (2001) found otter fur in 13 of 19 such 'log-pile holts' when they rebuilt them. On the whole, the benefits of dense scrub to wildlife other than otters are such that this should be a preferred option, although there is no reason why both should not be provided.

Natal dens

Studies on Shetland show that otters are born in natal holts that may not be the same as those used for rearing young or by adult otters (Moorhouse 1988). The piles of spraint, which are conspicuous at other holts, are not visible, and natal holts are difficult to find, with simple inconspicuous entrances and little evidence of the presence of otters. They are often some distance from the coast. On Lunna Ness, where Moorhouse carried out most of his observations, all were more than 150 m from the shore and one was 500 m from the coast.

Kruuk *et al*. (1998) have pointed out that three natal holts described by Harper (1981) were occupied by cubs that were several months old, which had probably not been born there. Thus there are only two descriptions of dens in which otters are known to have given birth. Taylor & Kruuk (1990) describe one they found in a reedbed on a Scottish loch. The den was a few centimetres above water level in a small clearing in the reeds close to a ditch 0.8 m wide and 0.7 m deep. It consisted of a mass of reeds 0.9 m by 0.75 m and about 0.4 m high, with a tunnel passing under it and a small side chamber. The authors believed that the reeds may have been bitten off.

Durbin (1996) located a natal holt in a narrow strip of deciduous woodland about 150 m from the main river (Don) and 3.5 m from a small tributary 0.7 m wide. The holt was under a pile of boulders 60 m^2 and 2.5 m high. Individual boulders ranged from 0.5 m to 1.5 m across. Five entrances were located, but it was not known whether they were connected within the pile. The pile had probably been formed during clearance of a nearby arable field, and had a covering of vegetation, suggesting that this had happened a while ago.

Location of natal holts during field surveys would appear to be extremely difficult, and the above observations suggest that they may be some distance from major rivers and areas frequently used by other otters. This might be a defence against cannibalism, which has been reliably recorded in one instance (Simpson & Coxon 2000).

There is no evidence as yet to suggest that the availability of natal holts limits the distribution of otters. Female otters seem to use sites well away from main watercourses and even appear willing to site them away from water altogether.

Food availability

There are probably more than a hundred reports on the food and feeding habits of the European otter in the literature. This is at least in part because this is one of the easiest aspects of otter biology to study, since otter spraints are relatively easy to find and collect, and the prey remains within them are relatively easy to identify. The technique of spraint analysis is not without problems, however, and the difficulties of extrapolating from the contents of spraints to the actual diet of otters have been widely discussed (see particularly Carss & Parkinson 1996; Carss & Elston 1996; Carss & Nelson 1998; Jacobsen & Hansen 1996).

The results of dietary studies may be presented in a variety of ways, and while early studies tended to report the frequency of occurrence or volume of prey remains in spraints, more recently, many workers have attempted to calculate the biomass or energy value of each prey type ingested. A consequence of this is that comparisons between studies are difficult to make other than in the broadest terms. In addition, many studies only cover part of the year or involve rather small sample sizes.

Freshwater prey

Appendix A lists the results of 15 studies from a range of freshwater sites in Europe where the sample size exceeded 300 spraints and the study covered all seasons. Table 3 summarises these data, which are all based on studies where frequency of occurrence was reported or could be calculated (full details of the calculations and sources are in the appendix). Although the results cannot be directly compared, a similar pattern emerges in studies based on percentage volume in the diet (e.g. Jacobsen & Hansen 1996; Taastrøm & Jacobsen 1999), estimated biomass of prey ingested (e.g. Beja 1996c, 1997), and energy value of prey ingested (e.g. Beja 1996c).

Table 3. Summary of fifteen dietary studies carried out in Europe between the 1960s and 1990s.

	Minimum	Maximum	Median
Fish	49.8	94.0	67.7
Amphibia	0.5	36.7	13.4
Crayfish	0.0	34.8	3.0
Mammals	0.0	11.4	0.6
Birds	0.0	9.3	1.5
Reptiles	0.0	9.1	0.0

Not surprisingly, fish dominate the diets of otters in most places, and the only two other groups of prey that normally form a substantial proportion of the diet (>33%) are crayfish and amphibia (mostly frogs).

Occasionally, at certain times of the year, these two prey groups may occur more frequently in the spraints than fish, but this appears to be unusual (e.g. Erlinge 1967b for crayfish; Brzezinski, Jedrzejewski & Jedrzejewska 1993; Grigorev & Egorov 1969 and Weber 1990 for amphibia). Crayfish have rarely been recorded as prey of otters in the UK, but this is probably because most studies of the otter's diet in Britain have been undertaken in Scotland and southwest England where crayfish are scarce or absent (Holdich 2003).

Beja (1996c) has demonstrated that otters will readily take to preying on an introduced species, American red swamp crayfish (*Procambarus clarkii*), in Portugal and it seems likely that the same will happen in Britain as otters recolonise areas where crayfish are abundant. Beja found that the crayfish were taken more frequently than would have been predicted by their calorific value, and considered that this might be because they were frequently encountered when otters were foraging near the bottom where an energetically more valuable prey, the eel, was also to be found.

In Scotland, Weber (1990) found that amphibia (mainly frogs) formed 20% of the items identified in the diet through the year, with a peak in predation during late winter and spring. In one study area he reported that 55% of prey remains in the spring were amphibian.

It is probable, therefore, that in much of the UK, only fish and frogs make a significant contribution to the diet of otters in freshwater habitats at present, the latter on a seasonal basis. In some areas, crayfish may become seasonally important as the otter population recovers, and there may be other, locally important, food sources in certain areas, such as mountain hares in upland rivers of Scotland (Conroy & Calder 2000).

Fish species

A number of authors have attempted to assess the preferences of otters between fish species, but these studies are confounded by the difficulties of accurately assessing both the proportion of each fish species in the diet and the availability of each fish species.

It is generally the case that otters take most of the species that are present, and take a much higher proportion of abundant species than of scarce species. There is also a widely held belief that otters 'prefer' slower-moving species (or at least find them easier to catch), and that they therefore tend to prey disproportionately on cyprinids and other coarse fish compared to salmonids, and on eels in preference to all other fish. However, there is little unequivocal evidence from the wild to support this.

Geoff Liles

Above and below: Otters eat a wide range of fish, including perch, ruffe and minnows. They are also very fond of eels.

Geoff Liles

In two studies that involved very careful estimation of the numbers of each species of prey taken and the numbers present in the study area, Thom (1997) found no evidence for selection by species in his study area on the Tyne in Northumberland. Conversely, Taastrøm & Jacobsen (1999) found some evidence in their Danish study areas that otters preferred percids (perch and ruffe) and avoided cyprinids. This is the reverse of the situation reported by Wise (1978) who found that the ratio of perch to cyprinids in the diet was much lower than in the lake she was studying.

The fact that in one study area, Taastrøm & Jacobsen recorded cyprinids in the spraints of otters in January when none was caught by electro-fishing, clearly illustrates the difficulties of such studies. Otters can travel considerable distances (many kilometres) in the time it takes for food to travel through the gut. Although the minimum passage time for one meal is around three hours, the remains of a meal can still be detected 24 hours later (Jurisch & Geidezis 1997).

In addition, most studies assume that the proportion of prey available to the otter is the same as that recorded by electro-fishing. This is confounded by three factors:

- Electro-fishing does not sample all species and sizes of fish equally effectively. Eels are particularly difficult to sample (Knights *et al.* 2001).
- Differences in fish behaviour, both between species and through the year.
- Different foraging strategies by otters (hunting along the bottom versus hunting for mid-water species, or at the sides of streams, rather than in the middle).

Size of fish taken

Otters have been recorded feeding on a very wide range of fish from <50 mm in length and 1 g in weight (Kruuk *et al.* 1993), up to 900 mm in length and weighing 6.3 kg (Carss, Kruuk & Conroy 1990). Even larger specimens (20 kg+) have been reported by carp fishermen (Mitchell-Jones, pers. comm.). Where it has been possible to obtain accurate estimates of the sizes of prey available there is some evidence of selection. Both Kruuk *et al.* (1993) and Thom (1997) found that otters caught disproportionate numbers of salmonids between 70 and 90 mm long. However, when Thom looked at other species of fish, different sizes were favoured – eels between 150 and 200 mm, and minnows smaller than 50 mm were taken more frequently than expected from their abundance. In a Danish study where the diet was dominated by cyprinids, Taastrøm & Jacobsen (1999) found significant correlations between the size of prey in the diet and in the environment for most species in most of their study areas. However, there was evidence of size selection of cyprinids and percids in some areas. They noted that otters rarely took eels smaller than 180 mm or larger than 420 mm.

Carss *et al.* (1990) showed that some otters will concentrate their predation on adult salmon during the spawning season, particularly taking male salmon, which are more active and therefore more vulnerable to predation than females. Some otters obtained most of their daily food requirements by catching a single salmon each night. At the other end of the size scale, Weir & Bannister (1973) found that spraint collections from a small river in Norfolk consisted entirely of stickleback remains in April 1969 and March 1970 (monthly sample sizes not given; 1,200 spraints were collected from January 1969 to March 1970).

Summary

Throughout most of their range in Europe the diet of otters in fresh water is dominated by fish. Amphibia and crayfish may also form a substantial proportion of the diet in some areas, though their significance varies seasonally, crayfish being taken mainly in the summer and frogs usually in winter and spring.

Among fish species there is no evidence of strong avoidance for any species, and otters normally take each in approximate proportion to its abundance. Otters may take very small fish (sometimes in large numbers) or very large fish, sometimes concentrating on one of these extremes for short periods when availability is high. They do not appear to prey on extremely small fish (less than 30 mm in length), although the size of these prey makes it more difficult to recognise the remains and to discriminate them from prey ingested by larger fish that were subsequently consumed by otters.

Variations in the composition of the diet are more likely to be related to changes in the availability of different prey species than to preferences by otters.

In terms of conservation management there is no evidence that either the range of sizes or of species of fish are likely to have an impact on the ability of otters to exploit an area, and it is more likely that the abundance of fish will be a limiting factor. Thus, very small streams with dense populations of small fish may be as valuable to otters as larger rivers with large fish more sparsely distributed. However, because fish availability may vary through the year, where the number of prey species available is very small, there may be benefit in adopting habitat management strategies to promote the abundance of other species such as frogs.

Marine prey

The diet of otters living and feeding on the coast is also dominated by fish, but generally to a much greater extent than for those foraging in fresh water (see review in Appendix A). In these studies fish formed more than 90% of the diet in all but one area – Mull, where Watt (1995) found that crabs formed approximately 10% of the items recorded in spraints. He noted, however, that crabs were taken much more frequently by young otters than by adults, and that as the young otters developed and became more efficient at catching fish, the proportion of crabs in their diet declined. In Shetland, Kruuk (1995) found that crabs were taken rarely, and mainly by inexperienced otters, except in years when fish were scarce.

On Mull, Watt found that the size of fish taken by otters was similar to the size recorded in his fish traps. On Shetland, however, otters tended to take fewer of the very small fish (such as butterfish) in relation to their abundance and relatively more of the larger fish, such as eelpout.

Food availability and limits to otter populations

Studies by Hans Kruuk and colleagues (summarised in Kruuk 1995) have demonstrated that in some areas (Scottish rivers and islands, parts of Africa and Asia), otter populations are limited by their food supply. Ultimately, when otters have fully recolonised the areas in which they declined, this is likely to be the case throughout the range of the European otter in Britain. At the moment, however, the absence of otters from some areas is determined principally by historical events (the decline from the 1950s to 1970s), and the fact that they have not yet had time to recolonise the whole of their former range.

Strachan & Jefferies (1996) concluded that biomass was unlikely to limit otter populations throughout much of England since reports from regional offices of the National Rivers Authority indicated that most rivers reached targets of a sampling biomass of 15 g m^{-2} for salmonid fisheries and 20 g m^{-2} for cyprinid fisheries, with some exceptions in Wessex and the Thames catchment. Nevertheless, the availability of food should not be ignored either because a lack of food in some areas may prevent recolonisation by otters, or because, if there is more food available, otter populations will be higher. This has conservation benefits, since larger otter populations would be more resilient and less vulnerable to other deleterious factors (such as road casualties, short-term pollution events), and might also lead to more rapid recolonisation through enhanced recruitment.

Productivity

In an attempt to demonstrate that the otter populations in central England were not limited by food availability, Brazier & Mathias (2001) tried to estimate the minimum productivity required for an otter population to survive. Using data from a wide range of sources, they calculated averages for overnight distance travelled by otters, daily food consumption (by captive otters) and the proportion of fish in the diet. From these they calculated that each year, on average, each otter needed to harvest 5 g of fish per m^2 of its home range in order to survive. In other words, rivers with an annual productivity above 5 g m^{-2} $year^{-1}$ should support otters, but those with a lower level would not.

There are a number of problems with this approach, of which the greatest is in determining the area over which an otter forages. Brazier & Mathias used the average distance travelled per night multiplied by an 'average' stream width of 6.3 m. This overlooks the fact that a considerable part of an otter's travelling time is not spent hunting, but moving from one foraging site to another and also makes rather broad assumptions about the sizes of rivers involved in the various studies quoted from. A calculation based on home range sizes could have been more accurately determined for at least some of the studies but would not have been usable without accurate information on the numbers of otters foraging within each range.

More problematic was the fact that information on fish productivity could not be calculated from the contemporary records available to the authors, and they had to rely on estimates of productivity based on studies carried out 15 years previously. From these data they concluded that fish productivity was between 10 and 20 times greater than the requirements of otters, and that the absence of otters from areas of central and southern England was not due to lack of prey.

Biomass

Since biomass is strongly correlated with productivity,and is more easily calculated, and data are more readily available, it is probably more realistic to use this as an indicator of prey available for otters. One approach is to look at figures for biomass in places where otter populations are known to exist and try to determine a lower limit.

Kruuk *et al*. (1993) demonstrated that otters could successfully exploit oligotrophic streams populated mainly by salmonids with densities between 9 and 14 g per m^2. Calculations of the main prey of coastal otters in Shetland showed that the biomass varied mainly between 2.5 and 11 g per m^2 throughout most of the year (Kruuk, Nolet & French 1988) but with a dramatic increase during August (to 62 g per m^2). Otters in this population were shown to be in poor condition at times of year when fish biomass was low. They also tended to produce their young in summer so that when metabolic demands on breeding females were greatest (shortly before weaning) fish were most abundant.

Ruiz-Olmo (1998) carried out an investigation on the influence of altitude on otters in Spain, supplementing surveys of otter signs with systematic direct observation as a means of estimating the abundance of otters and detecting evidence of breeding. Fish populations were assessed by electro-fishing. Ruiz-Olmo demonstrated a decline in otter abundance with altitude, as well as a decline in fish biomass and number of fish species. From 300 to 800 m above sea level otters were recorded at between 20 and 30% of sites surveyed, fish biomass was between 20 and 280 g per m^2 and two to 10 species of fish were present. Thirty out of 36 'breeding events' were recorded in this zone.

Above this height, all values declined progressively. There was no evidence of breeding above 1000 m, only one species of fish was present at sites above 1200 m, and although signs of otters were recorded up to 1800 m, they were few in number. Biomass at these sites was much lower. Ruiz-Olmo noted that otters were present at sites with biomass values of 10–20 g per m^2 and quoted a study by Nores *et al.* (1990) in which signs of otters were not found at sites with 1.8–3.3 g fish per m^2 but were found where the biomass was between 18 and 60 g per m^2.

From these rather sparse data one may suggest a rule of thumb to the effect that otter populations can survive and breed where fish biomass exceeds 10 g per m^2. Where the fish biomass is below this figure throughout the year there is a possibility that they may not be able to do so.

Thus the UK Environment Agency targets for fish biomass (15 g per m^2 for salmonid fisheries and 20 g per m^2 for coarse fisheries) are well above the level considered to be required by otters, and where these targets are achieved, food supply is unlikely to prevent otters becoming established – although it will still determine carrying capacity.

Since the number of otters that can be supported by a river system will depend on the food available to them, any action that increases the productivity of fish will benefit the otter population. The logical extension of this is that the 'target' should be as high as possible while remaining appropriate to the nutrient status of the river. At the other end of the scale it is possible that biomass levels lower than 5 g m^{-2} may be so low as to prevent colonisation by otters.

Fish availability in seven rivers in England

In order to place these values in context, an attempt was made to summarise information held by the Environment Agency on the fish populations of seven rivers. These data were based on standard electro-fishing techniques, which tend to underestimate fish populations, particularly eels, and should thus be regarded as minima. Details of the findings are reported in Appendix B, and these may be summarised as follows:

- There have been changes in fish biomass over the past 30 years, with strong evidence of an increase in the southwest region.

- On some rivers in the past 30 years there may have been insufficient fish for otters to survive.
- There is no evidence from these rivers to suggest that otters will be prevented by lack of fish from re-colonising UK rivers .

Declines in fish populations

Over the final third of the 20th Century there was evidence that, in some places, fish populations increased (see Appendix B). Recently, however, concern has been expressed about declines in some species, notably salmon and eels. Declines in adult salmon have been taking place over a long period, but although these fish are taken by otters, and for short periods may form the staple diet of some individuals (Carss *et al.* 1990), they do not form a substantial part of the diet throughout the year. There is no evidence that declines in the number of salmon returning to spawn have any impact on otter numbers.

Declines in fry and parr could be much more significant, but only if they result in an overall decline in biomass. If declines in salmon fry and parr are compensated by an increase in trout, as on the River Otter (Appendix B), otters will be unaffected.

Concerned has also been expressed about declines in eel populations (Farr-Cox 1996). The recruitment of glass eels in Europe has declined since the 1970s, and there is also anecdotal evidence of declines in yellow and silver eel stocks (Knights *et al.* 2001). Knights *et al.* reviewed the historical evidence for this and carried out surveys on the rivers Severn, Dee, Piddle and Frome at sites where there was verifiable information on the historic abundance of eels. The authors concluded that, although there had been a decline in recruitment of glass eels, the apparent decline in yellow and silver eels was more likely to be due to changes in fishing effort. This was a result of competition from farmed eels leading to lower prices and resulting in lower yields from the wild fisheries.

They found that most rivers flowing west had higher populations of eels extending further up river than those discharging into the North Sea, and concluded that naturally lower recruitment in the eastern rivers (further from Atlantic currents) had led to lower populations in these rivers. The density of eels declined from sea to source in all rivers, but upstream lower densities led to faster growth so biomass did not decline to the same degree, particularly in western rivers.

One significant conclusion of this study is that conventional multi-species electro-fishing techniques result in eel densities being under-recorded by a factor of two to five times. Thus, where eels form a significant part of the fish population, biomass estimates from normal fish sampling may be well below the actual level. The effect will be correspondingly small where eels are relatively scarce.

Physical and chemical attributes

Although it is possible to demonstrate that some physical attributes of rivers, such as width, correlate with occupation of sites by otters (Chanin unpubl.), it is most likely that the reasons for this are consequences of otter behaviour and the availability of food, rather than direct effects. The fact that stream width is negatively correlated with biomass of fish, at least in some areas (Kruuk *et al.* 1993; Appendix B), suggests that any apparent preference for stream size is likely to be influenced by food availability. Since stream width is correlated with a number of other variables (depth, altitude, current speed) any apparent relationships between these and otter spraint distribution may be due to the same factor.

Thom (1997) found that altitude was a significant predictor of the distribution of otter signs and suggested that this might be a consequence of thermo-regulatory effects. However, otters successfully forage in Spanish streams at heights exceeding 1000 m (Ruiz-Olmo 1998) and live in areas of northern Europe where snow cover lasts for many months of the year, which suggests that some other factor may be involved.

Accidental captures of otters in lobster pots show that they are capable of diving to depths of 15 m

(Twelves 1983), but observations in Shetland showed that 98% of dives were in water less than 7 m deep (and more than half of these in water less than 2 m deep). In most rivers throughout Britain, therefore, otters are capable of foraging throughout the water column. In very deep rivers, lakes and possibly estuaries, they may be unable to hunt bottom-dwelling fish, apart from close to the shore. Fish swimming in mid-water would still be available to them, however.

In general, it seems likely that most physical attributes of waterways only affect otters if they have an impact on food availability, or if obstructions such as weirs or dams prevent otters moving along a stream. A significant threat may be posed where otters are forced to leave the waterside and cross a busy road. Generally, otters travelling upstream are more likely to be impeded than those moving down.

There are three circumstances that might prevent upstream travel:

- Where there is a permanent physical barrier with no opportunity for otters to leave the water to bypass it (for example, a weir under a road where the waterway has no banks or it is not possible for an otter to clamber on to the bank).
- Where the waterway is constricted so that the water velocity prevents otters swimming upstream and there is no bypass route.
- When there is a temporarily high rate of flow (for example, during floods) and no bypass route.

Upstream and downstream travel might be prevented:

- Where a waterway is piped and there is no headroom.
- When there are temporarily high water levels and no headroom.

Recommendations for minimising the risks to otters when designing new roads are included in the *Design Manual for Roads and Bridges* (Highways Agency, Vol 10, Section 1, Part 9).

Paul Glendell/English Nature

Otters need natural riverbanks with places where they can easily clamber in and out of the water.

Substrate

Substate characteristics are only likely to affect otters if they affect food supply, and it is possible that siltation in particular may have a significant impact.

Changing farming practices have led to concern about the impact of soil erosion. In particular, increases in winter cereal cropping, reseeding of pasture, the use of tramlines, removal of hedges and the planting of maize have all added to the amount of topsoil being lost from fields and carried into ditches and streams (MAFF 1999a). Excessive poaching by cattle along unfenced river banks is a further cause of erosion.

Extreme levels of input to streams can cause the blanketing and loss of a wide range of plants and animals, leading ultimately to decline in fish stocks. Lower levels of very fine sediment may have a less obvious but equally serious effect by infiltrating gravel spawning grounds of salmonid fish and preventing the inflow of oxygenated water to the eggs. Run-off is greatest during the winter at the time when the eggs are developing, thereby exacerbating the effect (Environment Agency undated a).

The impact of this on the otter population is difficult to predict, but there are extensive areas in England at risk from this form of pollution (MAFF 1999b), and since the food supply of the otter may be affected, its potential significance should not be ignored.

Channel structure and management

In the past, the simplification of the channel often involved in flood prevention and drainage works inevitably led to a loss of structural diversity and a reduction in biological diversity and biomass. Brooker (1985) reported declines in fish biomass of more than 80% in some schemes, as well as declines in fish diversity.

This has been recognised as an issue in otter conservation management, and *Otters and River Habitat Management* (Environment Agency 1999) addresses the point clearly. *The Water Vole Conservation Handbook* (Strachan 1998) also provides advice on management of channel structure, and since much of this has the potential to lead to an increase in food availability, it is therefore of benefit to otters. The Environment Agency has published a series of case studies of river restoration, which clearly illustrate what can be done to rehabilitate rivers that have been degraded by over-engineering (Environment Agency undated b). Significant benefits could accrue from such schemes where they increase the food supply for otters.

Man-made structures associated with highly regulated rivers, such as weirs, bridges and bank reinforcements, are not avoided by otters and may be used as sprainting sites. There are also many instances of otters finding suitable resting sites among boulders and stone-filled gabions used in bank reinforcement.

Water quality requirements

Within the range of natural values, water chemistry has little impact on otters other than by affecting food supply. For example, moderate eutrophication may benefit otters by leading to an increase in the abundance of certain fish, although excessive eutrophication is detrimental when it leads to the reverse effect. Otters are not directly affected by pH values within normal ranges, but where acid rain leads to excessive acidity in watercourses, it can have an adverse effect on food supply. The impacts of toxic pollutants on otters are potentially extremely serious, and are considered in the following section.

Toxic chemicals

Overview

The first evidence that toxic chemicals might be responsible for the decline of otter populations in Britain came from an analysis of hunting records (Chanin & Jefferies 1978). The authors concluded from the timing of the decline that the introduction of dieldrin and related pesticides was the most likely cause.

During the 1980s and 1990s there were a substantial number of reports on pollutants in otters, their spraints and their prey in the UK and Europe (Mason 1989; Kruuk & Conroy 1996; Kruuk, Conroy & Webb 1997; Simpson 1998; Bradshaw 1999; and Jefferies & Hanson 2001). Smit *et al*. (1994, 1996) undertook a major investigation into otters and polychlorinated biphenyl compounds (PCBs) in The Netherlands – *Development of Otter-based Quality Objectives for PCBs* (DOQOP).

Mason (1995) provided a detailed overview of otters and pollutants and this is updated in Mason & Wren (2001), a review the ecotoxicology in carnivores that includes a substantial section on otters. Publications by Smit *et al*., (1994, 1996) summarise their work on the DOQOP project and the Proceedings of the International Conference on Otter Toxicology held on Skye in 2000 (Conroy, Yoxon and Gutleb, 2002) includes a number of relevant review papers.

Types of pollutant

Mason (1989) categorised contaminants that might have an effect on otters as:

Those having an indirect effects (mainly on food supply)

- Organic pollution from sewage treatment works, farms and the brewing, food and dairying industries.
- Eutrophication as a result of run-off from farms and sewage treatment works.
- Acidification mainly in the form of acid rain.
- Acid mine waste.

Those with mainly direct effects

- Oil spillage, mainly in coastal areas.
- Radioactivity.

Those with effects as a result of bioaccumulation:

- Metals, particularly mercury, but also cadmium and lead.
- Pesticides and PCBs.

Mason concluded that PCBs have been the most important factor in limiting otter populations in Europe, while heavy metals may have had local effects but were not responsible for declines on a wide scale. This view is widely held in Europe, but there are some who consider that the situation in Britain is not so simple (Kruuk & Conroy 1996; Kruuk 1997; Jefferies & Hanson 2001).

In the following review, attention is focused on bioaccumulating compounds, particularly organochlorine.

Significance of PCBs

PCBs are normally used (and found in the environment) as mixtures of several components (congeners) with differing levels of toxicity. Mason has argued repeatedly and persuasively for the importance of these compounds both as a cause of the decline of otters in Britain (and elsewhere) and in hindering its recovery (Mason 1997). In particular, he has pointed out that:

- Concentrations of PCBs tend to be lower in countries or regions where otter populations are thriving or widespread, and vice versa.
- Otter populations have declined in countries where PCB production has occurred and in areas downwind of production sources.
- PCB levels in fish correlate with those in spraints.
- In Britain the highest occupancy of sites in the national surveys occurs where PCBs in spraints are lowest.

- At a local level, both in Wales and around Glasgow, sprainting intensity was negatively correlated with PCBs.

The toxic effects of PCBs are mediated particularly by their effect on vitamin A metabolism (Smit *et al*.,1996; Murk *et al*., 1998). Simpson *et al*. (2000) has shown a strong negative correlation between the levels of Vitamin A in otters and the levels of PCBs in road casualties from southwest Britain.

An alternative view was presented by Strachan & Jefferies (1996) who pointed to evidence implicating dieldrin (and related compounds), at least in the initial phases of the otter's decline. This has subsequently been amplified by Jefferies & Hanson (2001) who presented data to support their contention that the introduction of dieldrin was responsible for the decline of the otter in Britain from the mid-1950s, and that PCBs were not implicated, either in the initial decline or in slowing the otter's recovery. Jefferies analysed otter tissues from as early as 1962 and pointed out that concentrations of dieldrin were much higher in the 1960s than subsequently, with many otters having concentrations exceeding the critical level for foxes (1 mg per kg wet weight). By the mid-1970s, concentrations in all otters analysed had declined below this. In contrast, although PCBs were first used in the 1930s, they were only found at trace levels in otters during the 1960s and early 1970s, increasing in concentration after that time.

Jefferies & Hanson pointed out that there was a close link in time between the introduction of dieldrin and related compounds in 1955 and the recorded onset of the otter's decline in 1957. In addition, the very marked coincidence in time with declines in predatory birds such as peregrine falcon and sparrowhawk is very convincing. Ornithologists using much more substantial databases were unable to detect any effect of PCBs on populations, whereas the evidence against dieldrin is almost overwhelming.

The most difficult observation to reconcile with the PCB hypothesis is that levels of PCBs in otters in Shetland are considerably higher than elsewhere (Kruuk & Conroy 1996) despite the fact that this population of otters is known to be thriving. Kruuk & Conroy also pointed out that individual otters (in Shetland and elsewhere in Scotland) with high levels of PCBs were in good condition and breeding successfully.

The evidence that PCBs can have an adverse effect on the physiology of mammals is clear (Leonards *et al*. 1994) but Kruuk (1997) has pointed out that it is important not to confuse effects on individuals with effects on populations. He also observed that by using inappropriate 'environmental standards' we might condemn as unsuitable areas that are, in fact, good otter habitat. Thus, otters in Shetland have a relatively high concentration of PCBs but the population is thriving and increased from the 1980s to the 1990s (Kruuk & Conroy 1996). The geometric mean for a sample of 14 animals from Shetland was 64% higher than the value at which reproductive failure occurs in mink, a frequently quoted 'level of concern' in otters. Kruuk & Conroy reported levels between 10 and 20 times higher than this in apparently healthy animals, one of which was lactating.

Mason reported in 1998 that, following a decline of 8% per year in PCB concentrations in otters over the period 1983–1992, he no longer considered that PCBs were a threat to otters in Britain.

It is clear that there have been disagreements over the significance of PCBs in the decline and recovery of the otter population in Britain. Mason believes PCBs may have been responsible for the initial decline and limited the population during the 1980s and early 1990s, but no longer do so. Jefferies believes that organochlorine pesticides were responsible for the initial decline of otters in Britain. Kruuk questions whether the levels of contamination that Mason has put forward as having an adverse impact on individual otters have had significant impacts on populations. The only consensus would appear to be that at the beginning of the 21st Century, PCBs are not limiting otter populations in the UK.

Elsewhere in Europe there is a more general consensus that PCBs have had a significant impact on otter populations, but despite this, the evidence is not clear-cut. In Scandinavia, Christensen (1995) found no evidence of PCB stress or reproductive failure in the coastal Norwegian otter population, and concluded that the lower densities of otters on the western coast could not be explained by PCBs. However, she noted that high levels of PCBs in fish from southern and central coasts might be a cause for concern and that the disappearance of otters in southern Norway could be caused by PCBs. Roos *et al*. (2001) reported that changes in PCB levels correlated closely with changes in Swedish otter populations, and suggested that the recovery of the otter population in southern Sweden may be prevented by the high levels of PCBs in that area.

Pesticides

Mason, Ford & Last (1986) recorded the presence of one or more of lindane (HCH), dieldrin and DDT (and its metabolites) in the tissues of 23 otters collected over a wide area of Britain. Levels of these compounds were low in otters from Orkney and Shetland, but elsewhere the pattern was variable. Lindane was generally found in low concentrations (below 20 mg per kg of lipid in muscle tissue), but dieldrin and DDT reached higher levels (up to 66 and 116 mg per kg, respectively).

Similar values to these, though a little lower, were recorded 10 years later by Kruuk & Conroy (1996) for otters in Scotland. Meanwhile, in southwest England, Simpson (1998) found Dieldrin and DDT in all otters analysed (56) but in most cases at low levels and with a significant decline from 1989–96. Lindane was not detectable in 75% of Simpson's samples and was at very low levels in the remainder.

The sample of 122 otters analysed by Jefferies & Hanson (2001) included animals that died over the period 1965–89. They were able to demonstrate a decline in residues of dieldrin over this period, but noted that high values were recorded in the period 1965–69, long after the start of the decline of otters and following bans on its use for seed dressings in 1962 and sheep dip in 1966.

Roos *et al*. (2001) reported a decline in concentrations of DDT of more than 70% between the 1970s and early 1990s in Sweden, but concluded that these changes did not explain changes in otter populations as well as spatial and temporal changes in PCBs. They also detected a decline in concentrations of DDT in fish of more than 80% in most areas.

The Environment Agency's review of its pesticide monitoring programme (Environment Agency undated c) shows that Environmental Quality Standards (EQS) for both Aldrin and HCH were breached in 1998 (one and eight times, respectively). All these failures were close to the Thames Estuary (rivers Medway and Blackwater), with four of the HCH failures in estuarine sites, the remainder in fresh water. All were at concentrations below 0.1 g l^{-1}. Otters are currently scarce or absent in this area, but this is probably because they have not yet had time to recolonise it.

No other pesticides have been directly linked to otter declines, but there were over 200 EQS failures for organophosphate and synthetic pyrethroid compounds used in sheep dips in 1998 (Environment Agency undated c). Many of these were scattered throughout the sheep farming areas of Wales, Northumbria and Cumbria, but there was a substantial concentration of sites in the Yorkshire area associated with the textile industry. Biological surveys in Wales revealed a loss of invertebrates at 9% of sites visited.

Sheep dips were the origin of 24% of pollution incidents recorded in 1998, and that number had increased markedly since 1996. This reflects a shift from the use of organophosphates to synthetic pyrethroids, which are safer for humans but more toxic to aquatic organisms. The impact on otters is likely to be indirect, resulting from a reduction in fish that have lost their invertebrate food supply.

Heavy metals

Mercury may be a more serious contaminant of otters than other heavy metals, along with cadmium and lead.

Mason, Last & Macdonald (1986) found relatively low levels of mercury, cadmium and lead in tissue from 36 otters that died between 1982 and 1985, mainly in Wales and Scotland. They concluded that these contaminants did not generally reach levels that might cause mortality, but were close to levels that led to sublethal effects in other mammals.

Kruuk, Conroy & Webb (1997) found mean concentrations of mercury in 112 otters that died between 1986 and 1992 in Scotland to be similar to those recorded by Mason *et al*. (1986). They noted that a small proportion of animals had concentrations of mercury sufficiently high to pose a risk to their survival (for example at times of food stress). Nevertheless, they concluded that this was not likely to have an impact on the population.

An indirect effect of heavy metal pollution was suggested by Thom (1997). He considered that otter populations on the South Tyne River might be limited by the availability of minnows, whose distribution was negatively correlated with the concentrations of lead in eels.

Local incidents

While nationally there is a downward trend in concentrations of most pollutants in water, a number of incidents over the years demonstrate that local effects can have at least temporary effects on otter populations. In southwest England there have been a few examples of accidental releases of insecticides from the textile industry and damage to pesticide dumps. These have had short-term and dramatic effects. Similarly, sudden influxes of highly enriched water (from sewage, slurry or silage effluent) leading to excessive eutrophication may have a serious, if short-term, impact on the food supply. Over longer periods the possibility of leaching from unregulated pesticide dumps cannot be ignored.

In Sweden, Olsson, Jensen & Reutergårdh (1978) demonstrated seasonal fluctuations in PCB levels in fish in lakes. These increased by two to five times in April when high flows brought in sediments from rivers. Similar effects might be expected where high levels of toxic chemicals trapped in sediments are released during dredging or other river management work.

Standards

PCBs

Given the unresolved controversy as to whether PCBs have been a significant threat to otter populations in Britain, it is difficult to make firm recommendations on water quality standards for these and other toxic chemicals. Two principal approaches have been used to set such standards.

Mason used information on the toxicity of PCBs to mink to set standards for otter tissues, and from these calculated appropriate levels for spraints using a mathematical model. This has been criticised on two grounds. Firstly, that the use of mink was inappropriate since the mink are much more sensitive to PCBs than otters (Kruuk 1997). Secondly, that experimental tests to corroborate the relationship between body burden of PCBs and concentrations in spraint did not yield predicted results (Smit *et al.* 1994; Gutleb & Kranz 1998; Conroy & Carss 2001).

Standards for levels in spraints from Mason & Macdonald (1994)

Critical levels

- Concentrations in spraints >16 mg per kg of PCB and dieldrin singly or combined

or

- Concentrations in spraints of total organochlorines >20 mg per kg

Levels of concern

- Concentrations in spraints: 9–16 mg per kg of PCB and dieldrin singly or combined

or

- Concentrations in spraints of total organochlorines: 16–20 mg per kg

Maximum allowable concentrations

- Concentrations less than the level of concern but greater than the no effects level

'No effects' levels

- Less than 4 mg per kg for all individual contaminants as described above.

The second approach, adopted by the DOQOP project, relied on an assay for the physiological effects of PCBs on vitamin A metabolism (Smit *et al*. 1996). Rather than calculate the effects of individual components of the toxic burden, these authors used a method to directly detect toxic effects at the cellular level. This CALUX assay (Chemically activated luciferase gene expression) measures the effects of the compounds on stages in the production of vitamin A as changes in luciferase activity. Assay results are expressed as TEQs (TCDD (dioxin) Equivalents).

This method has the benefit of measuring one toxic effect directly and does not suffer the disadvantage of requiring separate assays and calculations for each compound in a sample. In addition, very small samples can be used. The questions still arise as to how to extrapolate from effects at the cellular level to impacts on the whole organism or on a population.

Smit *et al*. used these data to provide quality objectives for PCBs both as TEQs and as concentrations of the sum of seven standard PCB congeners in otters, fish and sediments. They did not attempt to relate these to concentrations in spraints. They used two levels: a 'safe' level corresponding to a 1% reduction in hepatic retinoid levels (EC1), and a 'critical' level corresponding to a 90% reduction (EC90).

Standards from Smit *et al*. (1996)

a. Expressed as TEQs (nanograms per g or kg)

		Level:	
Sample	**Measurement** endpoint vitamin A deficiency	**Safe** EC_1	**Critical** EC_{90}
Otter	lipid wt (ng g^{-1})	2	5
Fish	fresh wt (ng kg^{-1})	0.7	1.8
	lipid wt (ng kg^{-1})	11	29
Sediment	organic carbon (ng kg^{-1})	3	7
	dry wt (ng kg^{-1})	0.2	0.4

b. Expressed as sum of seven standard congeners (nanograms per g or kg)

		Level:	
Sample	**Measurement** endpoint vitamin A deficiency	**Safe** EC_1	**Critical** EC_{90}
Otter	lipid wt (ng g^{-1})	4	11
Fish	fresh wt (ng kg^{-1})	6	14
	lipid wt (ng kg^{-1})	88	233
Sediment	organic carbon (ng kg^{-1})	17	39
	dry wt (ng kg^{-1})	1.0	2.2

Organochlorine pesticides

No specific independent targets have been set for other organochlorines, although they are incorporated in the above standards. The US National Academy of Science states that concentrations greater than 0.1mg per kg wet weight (ww) should not occur in fish (Mason 1989). However, mean concentrations of dieldrin exceeded this value in 53% of 62 rivers in Britain surveyed by MAFF (the Ministry of Agriculture Fisheries and Food), and high concentrations of dieldrin were reported from a river in southwest England with a thriving otter population (Mason 1989).

Heavy metals

There is no experimental evidence on which to base safe levels of contamination for otters, although some data on toxic effects are presented in Mason (1989). Mason, Macdonald & Aspden (1982) suggest that a safe level for mercury in fish might be 0.3 ppm (ww), while Hovens (1992, in Kruuk *et al*. 1997) calculated that a mean level of 0.1ppm would be tolerable. Otters in Shetland feed on prey with mean levels up to 0.14 ppm mercury without evidence of significant effects.

Kruuk *et al*. (1997) illustrate the difficulty of extrapolating safe levels for humans to otters by calculating that otters in Shetland have an annual intake of mercury approximately 40 times higher than that recommended for people.

Monitoring

Even if there is no agreed basis on which to set targets or standards for levels of pollutants, there is agreement that high levels of PCBs, organochlorine pesticides and heavy metals are all potentially detrimental to otters, and it is therefore important to monitor the levels of these in otter populations and their environments.

Simpson (1998) and Bradshaw (1999) demonstrated the benefits of carrying out large-scale, long-term monitoring of dead otters (killed mainly in road accidents) although these can only provide useful samples when looked at over a relatively large area. Sampling of prey or water (via the Environment Agency's monitoring schemes) provides much more detailed information at the catchment or even stream level, though this may not provide a good indication of impact on otter populations.

The use of spraints for monitoring pollutant levels in otters is still controversial, and at the International Conference on Otter Toxicology held on Skye in 2000, it was agreed that further work is necessary before a full understanding of this will be possible. Mason & Macdonald's (1994) calculations of safe and critical levels were based on a mathematical model, and some attempts to test this experimentally have led to unpredicted results (Smit *et al*. 1994; Gutleb & Kranz 1998). For example, it is not clear whether the concentrations of pollutants in spraints reflect the most recent meal consumed by an otter, or are influenced by food consumed over a longer period of time.

Until these issues are resolved, the use of spraints as a monitoring tool should be undertaken with caution. High levels of contaminants in spraints should certainly give cause for concern, since they indicate that the otters have been exposed to the pollutants. However, the standards set by Mason may not be appropriate. Further work is needed to confirm this.

Conclusions

Further information on levels of toxic chemicals in several river catchments is set out in Appendix C.

From these data and the reports cited above some conclusions can be drawn:

- In the UK and parts of Europe levels of toxic chemicals in otters, their prey and in fresh water are declining. This has taken place alongside a recovery in the otter population, but there is no agreement as to how the two phenomena are linked.
- It is possible, perhaps likely, that different pollutants have affected otter populations in different areas and at different times.
- The possibility of new pollutants (such as synthetic pyrethroids) having an impact on otter populations either directly, or via their prey, cannot be ignored, and vigilance for future contaminants is essential.
- While various standards have been set, some on a firm physiological basis, there is not universal agreement that these are appropriate. Effects on individuals do not necessarily mean that there will be effects on populations, and there is evidence that populations can thrive when otters carry pollutant burdens higher than some of the standards that have been suggested.
- Ultimately, the most desirable objective is to eliminate toxic chemicals from waterways entirely, and the only logical target is zero or at least as low as possible. In practice, as otter populations recover and contamination of waterways by many pollutants declines, the most important conservation objective should be to continue monitoring to ensure that known pollutants continue to decline and to detect the appearance of new ones.
- The possibility of local, possibly temporary, high levels of pollutants having a significant effect on otters or their prey should not be ignored.

- On these grounds, monitoring of pollutant levels in otters and their environment is essential and it would be desirable to agree a national strategy for doing this.
- It is clear that the volume and complexity of the literature on otters and toxic chemicals is such that a full review is beyond the scope of this project. With the publication of Jefferies' data on toxic chemicals in otters dating back to the 1960s (Jefferies & Hanson 2001), it may be timely to consider a full review of studies of pollutants and British otter populations, incorporating the published literature and using data on watercourses held by the Environment Agency.

Summary of the effects of physical and chemical attributes

Although there is no evidence to suggest that either physical or chemical attributes of waterways are inhibiting the continued spread of otters, both of these have the potential to limit the ultimate size of the population by their effects on the food supply.

Currently, the effects are most likely to be mediated by the impacts of siltation, inappropriate channel structure and the use of certain pesticides. There are regional variations in the extent of these but it is probable that, nationally, significant efforts to remedy or mitigate them could have a substantial impact of the ultimate size of the otter population rather than its distribution.

Disturbance

Anthropogenic disturbance

As with habitat destruction, the suggestion that human activity might cause significant disturbance to otters dates back to the report of the Joint Otter Group. In the UK this appeared to be supported by the fact that the otter population declined most in the central, southern and southeastern parts of Britain where the human population is highest, while otters survived well in Scotland and, to a lesser extent, in southwest England where human densities are lower. Despite the fact that there is increasing evidence that otters habituate readily to many forms of human disturbance, there is still a widespread belief that disturbance is detrimental to otters.

Jefferies (1987) reviewed much of the anecdotal evidence available at the time and demonstrated that otter activity was not significantly affected by various forms of anthropogenic disturbance (including walkers, anglers and dogs), though he noted that there was less evidence available for female otters with cubs and suggested that these might have more stringent requirements. Since then, further evidence has accrued.

A common response to the sounds of anglers or walkers with dogs is for radio-tracked otters to move to a position where they can see the origin of the disturbance, then dive and swim underwater for 50 m or so before surfacing and resting on the bank for five to 30 minutes, then resuming their previous activity (Durbin 1993).

Perhaps the most dramatic demonstration of the ability of otters to live in highly disturbed areas is the recolonisation of Glasgow. During the first survey of Scotland, few sites within the conurbation of Glasgow had signs of otter, but this had increased to 12% by the time of the second. In the third survey, 63% of sites within the conurbation had signs of otters and breeding had been recorded at four urban sites (Green & Green 1997).

In England, officers of the Otters and Rivers Project (OARP) have reported the presence of otters in 80 cities and towns, and they are described as being frequent or resident in 49 of these. There was evidence of otters breeding in nine towns and near several others.

In Shetland, where the otter population is considered to be healthy, otters regularly breed under the islands' ferry terminals and under the jetties of Europe's largest oil terminal at Sullom Voe.

From these reports it seems safe to conclude that the recovery of the otter population is not being impeded by human disturbance.

Introduced species

The fact that feral American mink first began breeding in Britain at the start of the otter's decline led to it being suspected as a causal factor – through competition, predation of otter cubs or as a carrier of disease.

The best evidence for a significant interaction between mink and otter comes from the analysis of distribution records collected during the national otter surveys of England (Strachan & Jefferies 1996). They demonstrated that in southwest England where otters had a high level of site occupancy in 1991–94, mink occupancy had declined. In East Anglia, where otters were scarce, mink occupancy had remained stable or increased. The Severn-Trent region was intermediate in both respects. The authors concluded that the most likely cause of this decline in mink was aggression and possibly predation by otters.

Substantive threats in different areas of the UK

The evidence pointing to a substantial recovery of the otter population is irrefutable (Strachan & Jefferies 1996), and the most important factor leading to the continued absence of otters from many areas is almost certainly time. Strachan & Jefferies pointed out that, although otters can travel considerable distances and could cross central England in less than two weeks, they have a low breeding rate and recolonisation is slow. They calculated that it took 14 years for the 'rolling front' of recolonisation to travel a distance of 50 km from the Welsh borders into the East Midlands, and estimated that even by 2020, signs of otters will be found at only about 72% of survey sites in England.

Reviewing a wide range of factors that might threaten the recovery of the otter population, Strachan & Jefferies (1996) concluded that only road deaths and the possible spread of contagious diseases from captive and feral mustelids gave them cause for concern. One further factor that may have a regional effect is the acidification of waters, which occurs mainly in Wales and Scotland.

Disease

Post mortem examinations of over 200 otters reported by Bradshaw (1999) and Simpson (1998) reveal remarkably few infectious diseases. However, there was a single report of a dying otter found in

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Otters are at risk from the acidification of waters, which mainly occurs in Wales and Scotland.

Norfolk with symptoms and lesions very similar to those of Aleutian disease, an immune deficiency virus associated with captive mink (Wells, Keymer & Barnett 1989). DNA from this virus was isolated from a single otter in Spain, though the pathogenicity of the strain identified was unknown (Mañas *et al*. 2001).

Road casualties

Investigations

Concern about the increasing numbers of otters found dead on roads led the Highways Agency to commission research into this phenomenon (Philcox, Grogan & Macdonald 1999; Grogan, Philcox & Macdonald in prep). Philcox *et al*. obtained data on 673 casualties over the whole of Britain between 1971 and 1996, and noted a marked increase in numbers from the mid-1980s. Part of this could be attributed to an increasing awareness of the need to report and collect otter casualties, but it was not possible to determine the extent to which increases in road length, traffic and otter numbers influenced this trend. A high proportion of these casualties (22%) occurred in southwest England. Apart from the Scottish Islands, Philcox *et al*. found that this region had the highest number of casualties per unit area.

In Wales, Liles & Colley (2000, 2001) undertook a study of road deaths for the Environment Agency Wales, Welsh Water and the Wildlife Trusts. The first report identified sites where mitigation should be carried out and established priorities, while the second described procedures for implementing these measures. Information on adjacent habitat and the nature of each mortality site was recorded and a preliminary effort was made to identify factors that could be used in a predictive model, but none was presented. However, 58% of casualties occurred away from bridges or culverts at sites described by the authors as 'watersheds', 'short cuts' or 'enigmas'.

Two further studies on road casualties have been commissioned by the Highways Agency – one regional, in southwest England carried out in 2000, and one national, carried out during 2001 and 2002.

An investigation into otter mortality on the trunk roads and motorways in Devon and Cornwall identified over 200 actual or potential casualty sites along 320 km of the A30, A38 and M5 (Chanin 2001). Potential sites were places where the road crossed or ran adjacent to a river, but seven of the 30 sites where casualties had occurred were away from water. Thirty-seven casualties were recorded on these roads between 1990 and 2000, a disproportionate number occurring on the A30 in Cornwall where it ran along the watersheds between rivers draining to the north and to the south of the peninsula. Apart from crossings where the passage of otters was permanently blocked (by impassable weirs, for example), it was not possible to predict where otters were most likely to be killed. A unique feature of this study was that sites where otters had not been killed were examined, as well as those where they had. It was therefore possible to compare the frequency of casualties at particular types of structure with the 'abundance' of those structures along the roads. It was notable that, although otters were unlikely to be killed at high viaducts, there was no relationship between size or type of structure and the likelihood of casualties occurring.

Following this, a national project to identify sites for mitigation on trunk roads was carried out during 2001 and 2002. The project was managed by Halcrow and guided by an advisory panel, including representatives from statutory and non-statutory organisations involved in otter conservation, as well as knowledgeable individuals.

Impact on otter populations

Since 1992 the Southwest Region of the Environment Agency has arranged for otter carcasses to be collected and subjected to *post mortem* examination (Simpson 1998) and has maintained records of all casualties reported to it. From 1990 to 2000, more than 250 otters have been killed on the roads of the Southwest (Figure 4), and the increase in numbers over this time has given some cause for anxiety, with a total of 50 animals recorded in 1999. However, these data include animals killed in areas where otters are still recolonising (notably Somerset, Dorset and Hampshire), and if only otters reported in Devon and Cornwall are included there is some evidence to suggest that the annual kill is levelling off (Figure 4).

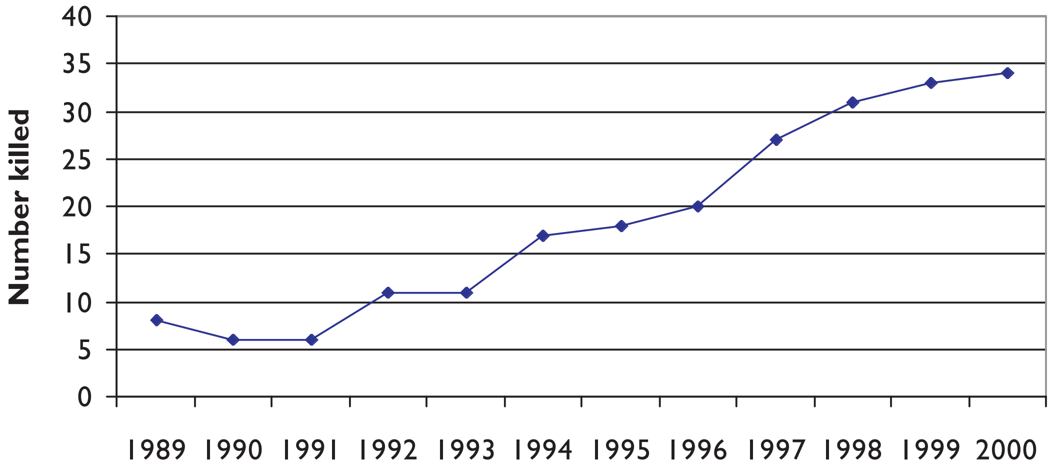

Figure 4. Reports of otter road casualties in Devon and Cornwall recorded by the Environment Agency Southwest Region.

Whether this reflects a serious regional threat to otters is open to question. The use of DNA fingerprinting enabled a total of 23 otters to be identified on the River Tone catchment (Coxon *et al.* 1999). These were recorded over one year in an area 400 km^2 (<4% of the area of Devon and Cornwall combined), which suggests that the proportion of otters killed on the road each year may not be so high as to have a serious impact on the resident population. Clearly, each otter killed is one less to take part in the expansion of the population, but this is of decreasing consequence as recolonisation extends eastwards away from Devon and Cornwall.

Elsewhere the impact may be more serious. Tim Sykes (pers. comm.) reports six road and rail casualties on the River Itchen in 2000. This is a relatively small river, only 37 km from source to sea and with a catchment of nearly 480 km^2. The mortality equates to one casualty per 80 km^2 per year, compared with one per 200 km^2 per year in Devon and Cornwall. It is not known whether this high rate relates to the nature of the river and its relationship to the roads and railways, or to traffic density, but it is a cause for concern.

Acidification

Mason & Macdonald (1988) reported that otters were not resident on Welsh streams draining through conifer plantations where pH fell below 5.5 at times, but were present on nearby streams draining moorland areas where the pH was higher. They attributed differences in otter use to low populations of fish. In a further study in Scotland (Macdonald & Mason 1989), they reported that otters were present at all of 72 sites searched, but that the intensity of marking correlated with both pH and conductivity, pH being more influential. They concluded that acidification might have a local impact on otter populations if it reduces the fish population, particularly in headwaters, but that it would not lead to a decrease in the otter's distribution at the levels encountered in their study.

Recommendations for further work

This section includes suggestions for further research, as well as areas where it would be beneficial to otter conservation if national policies and procedures could be agreed.

Population biology

There are two areas where further research could directly advance the cause of otter conservation:

- The assessment of population size.
- Population ecology in lowland areas.

Population size

Barring further large-scale changes in the environment, it seems likely that otters will continue to colonise those parts of Britain where they declined to extinction during the third quarter of the 20th Century. Long-term monitoring by national surveys will enable this recovery to be charted, but whether the population densities in those areas recover to former levels will be more difficult to ascertain.

National long-term conservation objectives for otters tend to be set on the basis of their distribution; that by a certain date otters should be found over a particular area, rather than on the basis of population size or density. However, judging from recent correspondence, there is also a need to obtain information on numbers of otters inhabiting particular areas, Special Areas of Conservation (SACs) and National Parks, for example.

Good estimates of the population of otters in Shetland (with defined confidence limits) have been determined by Kruuk *et al*. (1989) and Conroy & Kruuk (1995), but other estimates of otter numbers and density in Britain are based on inadequate data and should be treated with considerable caution.

Determining the population in freshwater habitats is only likely to be practical in the near future by the use of DNA fingerprinting of otter spraints, a technology that is promising but still in its infancy. If there is a need to know numbers of otters for conservation purposes, a higher priority should be given to developing this technique, and serious consideration should be given to seeking funding and commissioning further research.

Population ecology in lowland areas

To date, all studies of otter movements, social organisation and habitat use in the UK (other than those using spraints) have been undertaken in Scotland. While there is no reason to believe that otters in lowland areas of England would behave differently, comparative data are lacking and there is considerable scope for studies using radiotelemetry and DNA fingerprinting to investigate otter biology in these areas as the population recovers. There are substantial difficulties in carrying out such work in terms of resources, development of techniques (DNA fingerprinting) and catching the animals (radiotelemetry). Nevertheless, consideration should be given to promoting such research, particularly in areas where preliminary studies have been carried out, such as parts of Yorkshire and the Itchen catchment in Hampshire.

Diet in lowland areas

In reviewing the literature on otter diet it has become clear that, although numerous studies have been carried out in Europe as a whole, there are remarkably few from lowland Britain. Apart from two projects on a eutrophic lake in south Devon in the 1970s (Chanin 1981; Wise, Linn & Kennedy 1981), most substantial studies of the diet of otters in Britain have been undertaken on the coast or on upland rivers and streams in Scotland.

As otters return to central and southern England, the opportunities for such a study continue to increase and although it is unlikely to have a major impact on otter conservation, there would be value in promoting such work. One situation where such information may usefully support conservation measures is where otters come into conflict with still-water fisheries and consideration should be given to commissioning research on this topic.

Review of toxic chemicals in otters

Considerable numbers of otters and spraints have been analysed for toxic chemicals. Reports are scattered through the literature and it is very difficult to obtain an overview of the data. The longest-term study, dating back to the 1960s and carried out by DJ Jefferies, is now approaching publication (Jefferies & Hanson 2001). The Centre for Ecology and Hydrology at Banchory, Aberdeenshire, holds a large number of unanalysed samples dating back to the early 1990s and covering much of Scotland (James Conroy, pers. comm.).

The data on water quality obtained for this report and described briefly in Appendix D demonstrate that there is information available to provide a background to the pollutant burdens of otters. A review of these data covering the whole of Britain over the past 40 years and describing changes in space and time would make it possible to provide a coherent picture of the impact of toxic chemicals on the UK otter population in the second half of the 20th Century. This would also provide a valuable foundation for evaluating future changes.

Monitoring

National Surveys

The repeated surveys of otters in Britain provide a unique record of changes in the distribution of a threatened species over a period of nearly 25 years. The fact that there is not yet a policy for the future of these surveys is a serious cause for concern.

There is an urgent need for a review of the method and approach to otter surveys and data storage as a basis for determining a policy for their future. Such a review should not only take into account the need for continuity, but also national arrangements for monitoring mammals, should these be agreed, and the proposed scheme for monitoring otters throughout Europe (Reuther *et al.* 2000).

Road casualties and postmortems

The current system of collecting and recording otter road casualties has developed on an *ad hoc* basis in the three main regions where otters are abundant: southwest England, Wales and Scotland. There is no formalised scheme for Northern Ireland (Conroy & Carss 2001). There is a need to develop a national policy on dealing with road casualties, ideally with regional mechanisms for collecting carcasses and forwarding them for postmortem examination. There should also be nationally agreed protocols for data recording and for carrying out postmortem examinations. Data from postmortems should be regularly reviewed as a means of monitoring changes in the health of the otter population in terms of condition, clinical diseases and pollutant burdens.

Data from road casualty sites should be regularly reviewed in order to identify places where mitigation might usefully be carried out. The Highways Agency has put considerable resources into investigating otter road casualties, revised its *Design Manual for Roads and Bridges* to incorporate the needs of otters and undertaken to carry out mitigation where appropriate. However, its responsibilities only extend to trunk roads and motorways, and there is an additional need to involve local authorities with responsibility for roads in monitoring and mitigation schemes. Local and regional offices of the Environment Agency would form a useful focus for such work.

Priorities for action

High priority

- Population monitoring schemes (National Surveys).
- Monitoring of road casualties (postmortems).
- Monitoring of road casualties for purposes of mitigation.
- Dietary studies where there are conflicts with still-water fisheries.

Medium priority

- Review of the impact of toxic chemicals.
- Development of DNA fingerprinting.

Low priority

- Studies of otter population biology in lowland areas of England and Wales.
- Dietary studies in lowland areas of England and Wales.

Conclusions

This review has shown that, at present, there is no evidence to suggest that the recolonisation of Britain by otters will not continue. The impact of some factors that had previously been considered to impose constraints on otters' ability to exploit some waterways may have been over-estimated – anthropogenic disturbance and the availability of suitable resting sites, for example. While the actual effects of toxic chemicals in the past are only now being elucidated, there is a general consensus that all the likely candidates for causing the decline in otter populations are now present at low levels and that they are unlikely to inhibit recolonisation in much of Britain.

There is scope for further clarification of the biology of otters, particularly in lowland areas, and it is important to ensure that the population continues to be monitored, both in terms of its distribution and various aspects of the health of individuals (disease, pollutants, etc.).

The greatest potential for enhancing the long-term conservation status of otters lies in tackling factors that reduce the food supply below its natural level. One of these, the effects of pollution by sheep dips, is being undertaken by the Environment Agency, which has promoted a Sheep Dip Strategy involving the production of a code of practice under the Groundwater Regulations 1998 (Environment Agency undated c). The agency is also aware of, and addressing the issues of, siltation and channel management, but significant improvements in these areas will involve a wide range of interests, such as the construction and road-building industries, agriculture, forestry and flood prevention. English Nature has produced position papers on managing floodplains to reduce flood risk and enhance biodiversity, and on reducing pollution from diffuse agricultural sources, the latter focusing particularly on SACs and SSSIs (Sites of Special Scientific Interest).

In the past the otter has been used as a 'flagship' species for conservation activities on a relatively small scale. Whether it can be used to promote long-term, sustainable strategies for management of waterways at the catchment level is unclear, but there is no doubt that if it can, there would be significant benefits to the otter population, as well as the aquatic and riparian environment generally.

Steve Chadd/English Nature

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Appendix A: The diet of the European otter

The following tables summarise the diets of otters, determined by a wide range of studies throughout Europe. Criteria for inclusion in the list were that the study had to cover the whole year, include more than 300 spraints (or observations) and be compatible with other data.

In each case the values used were recalculated to express the diet in the form of percentage occurrence of items, excluding non-significant matter (plant material, insects, small crustaceans or molluscs). Summaries of the data are provided (and included in the main text).

All studies in fresh water are based on analysis of spraints. Some studies in coastal areas are based on spraint analysis; others on direct observation.

Table A1. Diets of otters in freshwater habitats, expressed as frequency of occurrence (%).

Country	N	Fish	Mammal	Bird	Reptile	Amphibia	Crayfish
Ireland	1709	62.6	0.2	1.5	0.0	10.1	25.6
Poland	379	80.0	0.3	0.0	0.0	18.3	1.3
Spain	367	57.0	5.5	1.3	0.9	0.5	34.8
Spain	598	66.2	0.6	0.3	2.2	12.3	18.3
Sweden	14615	67.7	0.6	9.3	0.0	8.1	14.3
England	353	94.0	4.3	1.1	0.0	0.6	0.0
England	607	91.4	7.1	1.0	0.0	0.5	0.0
England	858	86.6	0.4	4.9	0.0	8.1	0.0
Scotland	1180	74.9	3.0	1.8	0.0	20.3	0.0
Spain	2145	70.4	0.4	6.7	9.1	13.4	0.0
Ireland	2349	51.1	0.0	2.0	0.0	15.9	20.9
Portugal	2883	53.2	0.0	0.5	1.4	16.4	28.6
Hungary	873	76.5	1.5	7.2	0.8	14.0	0.0
Finland	1506	65.2	11.4	3.2	0.0	17.1	3.0
Belarus	641	49.8	0.2	1.4	0.0	36.7	11.8

N = sample size

See list at end of appendix for sources of data

Table A2. Summaries for freshwater habitats.

	Fish	Mammal	Bird	Reptile	Amphibia	Crayfish
Maximum	94.0	11.4	9.3	9.1	36.7	34.8
Minimum	49.8	0.0	0.0	0.0	0.5	0.0
Mean	69.8	2.4	2.8	1.0	12.8	10.6
Median	67.7	0.6	1.5	0.0	13.4	3.0

Table A3. Diets of otters in coastal areas expressed as frequency of occurrence (%).

Country	Type	N	Fish	Mammals	Birds	Reptile	Amphibia	Crab
Portugal	Spr	2267	91.7	0.1	0.3	0.5	5.3	2.1
Norway	Spr	1074	97.9	0.0	0.9	0.0	0.0	1.3
Ireland	Spr	1026	97.3	0.0	1.2	0.0	1.2	0.4
Scotland	Obs	2030	96.8	0.1	0.0	0.0	0.0	3.0
Scotland	Spr	948	86.8	0.0	1.0	0.0	0.9	11.3

Type: Spr = based on spraint analysis; Obs = based on direct observation.

See list at end of appendix for sources of data

Table A4. Summaries for coastal habitats.

	Fish	Mammals	Birds	Reptile	Amphibia	Crab
Maximum	97.9	0.1	1.2	0.5	5.3	11.3
Minimum	86.8	0.0	0.0	0.0	0.0	0.4
Mean	94.1	0.0	0.7	0.1	1.5	3.6
Median	96.8	0.0	0.9	0.0	0.9	2.1

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Appendix B: Fish population changes

A small survey was carried out to collate information on fish populations from a number of rivers in England and part of Wales. There were three principal objectives:

- To provide a brief overview of the nature of data available.
- To investigate changes in fish populations through time.
- To compare biomass values in these rivers with those obtained from areas where otters were known to be present.

Requests for information were made to fisheries staff in three Environment Agency regions for records from the 1970s to the present. Table B1 lists the regions and rivers with information on otter surveys where appropriate, and comments on the status of otters. Information on pollutants in these rivers was also sought, and the results are presented in Appendix C.

Information was obtained from all rivers except the Teme. In addition, while collecting data for the River Kennet, some records for the Kennet and Avon Canal were also obtained. Records were sent mainly as spreadsheets or copies of reports. For one region, a visit was made to the office where paper reports were held.

Table B1. Rivers selected for analysis showing number of sites searched during national otter surveys, number positive at each survey and brief notes on otter presence.

Midland	Teme	52	12, 18, 41	
	Avon	64	0, 0, 4	Present in early 1970s*.
Thames	Windrush	0		Sporadic records, no otters resident up to 1999*.
	Kennet	22	0, 0, 0	Sporadic reports from 1990s. No resident otters.
Southwest	Camel	14	8, 9, 11	Serious pollution incident in 1988
	Teign	0		Present in early 1970s but signs much less frequent than mink**. Signs much more frequent than mink in 1998*.
	Otter	9	0, 1, 4	Absent in early 1970s*.

* personal records; ** Chanin 1976.

Nature of records

Most early surveys were carried out with fishing interests in mind. There was therefore a tendency to focus on target species such as salmonids in the Southwest and salmonids plus coarse fish in the other areas. Fish numbers (and, in many cases, sizes) were recorded in most instances, but estimates of biomass were much less frequent. For three rivers a time series showing changes in numbers over a period of about 30 years can be presented. Biomass data are usually limited to one or two sampling sessions for each river, and much of this was obtained after 1985.

Extraction of data from the written reports is not always easy, and it is noticeable that there is considerable variation in the comparability of the data. On some rivers there are records over a large period from the same sampling sites. Elsewhere, sampling was carried out on a more *ad hoc* basis, with different sites used at different times. Despite this, the records form a valuable resource, and the trend for extracting data and recording it in spreadsheets or databases for ease of access should be encouraged.

Summary of information received

A full analysis of these data is beyond the scope of this report and the information is therefore presented in a series of illustrative tables and graphs.

Biomass

There were no cases were biomass could be compared for more than three sampling years, and it was not always possible to compare large numbers of identical sites. For the rivers Kennet and Windrush, and the Kennet and Avon Canal, comparable data were obtained from enough sites for statistical tests to be carried out, but analyses of variance revealed no significant differences between samples taken at different times.

Table B2. Mean fish biomass on rivers and the Kennet and Avon Canal.

			-2
Upper Avon	1985	23	7.8
	1992	20	9.8
	1996	11	14.9
Lower Avon	1993	27	11.6
River Windrush	1986	10	24.7
	1993	10	29.2
River Kennet	1986/7	18	31.8
	1993/4	18	27.6
Kennet & Avon Canal	1986/9	21	34.4
	1993/4	21	31.7
River Teign	1979	15	10.1
River Otter	1978	12	23.4

While most rivers mostly had a biomass in excess of 20 g per m^2, it is noticeable that the Teign (an oligotrophic moorland stream) had a mean value of only 10 g m^{-2} in 1979, and the potentially more productive River Avon was below 8 g m^{-2} in its upper reaches in the mid-1980s.

Kruuk *et al.* ((1993) demonstrated that fish biomass and productivity was strongly correlated with stream width in a river dominated by salmonids. A similar picture is found on the river Teign (Figure B1) where the biomass of salmonids was 10 g m^{-2} or less in sections of stream greater than 7 m wide, and 10 g m^{-2} or higher in all but one section greater than 7 m wide.

On the River Otter there were similar differences for salmonids, but coarse fish were distributed more evenly (Table B3). Since the proportion of eels varied between parts of the river, and these are known to be under-recorded by multi-species electro-fishing, the estimates for non-salmonid fish on this river are likely to be low.

Table B3. Biomass (g m^{-2}) of different types of fish in the main river Otter with that in the upper reaches and tributaries.

Salmonid	3.43	13.36	15.57
Non-salmonid	10.58	10.01	17.28
Total	14.01	23.37	32.85

On tributaries of the River Kennet there was no correlation between width and biomass. On the River Windrush there was a tendency for smaller streams to have a higher biomass, but this was much less pronounced than on the River Teign. Figure B2 illustrates this for 1986. A similar situation prevailed in 1993, though with higher values.

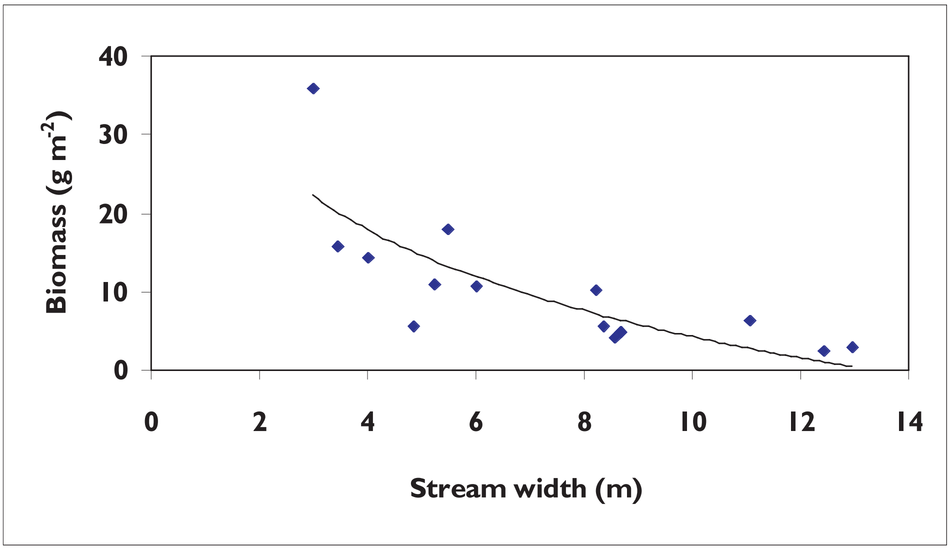


Figure B1. The relationship between fish biomass and stream width on the River Teign in 1979.

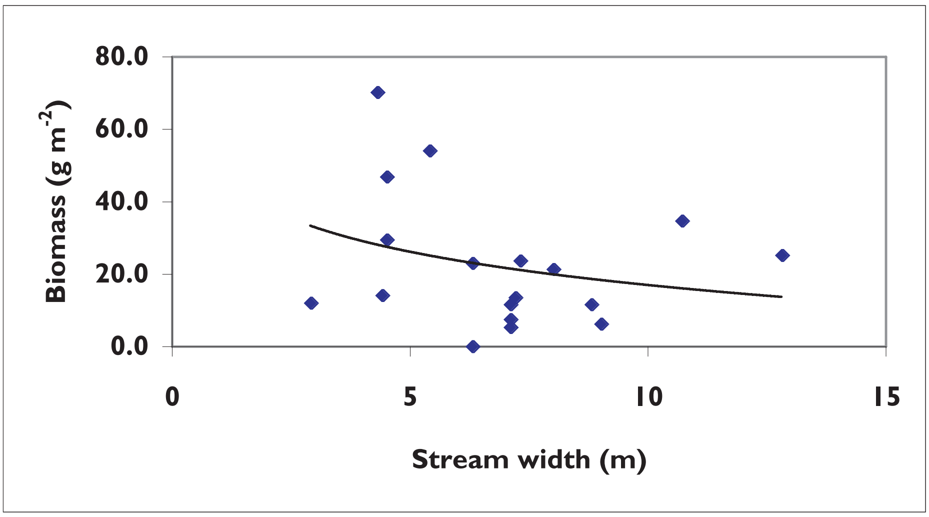


Figure B2. The relationship between fish biomass and stream width on the River Windrush in 1986.

The maximum biomass recorded during these surveys was (195 g per m^2 on the River Kennet, but values below 10 g per m^2 were frequently recorded, and there were also significant numbers of sites with less than 5 g per m^2. The proportion of these varied, but in some places may have been sufficient to have had an impact on otters, had they been present at the time. For example, otters were known to have been present on the River Teign when a third of sites had a biomass of less than 5 g per m^2.

Table B4 illustrates these data, and incorporates a small sample from the Upper Nene from an unpublished Anglian Water Authority report.

Interpretation of these data requires some caution, since conditions in the River Avon, a slow-moving deep river, are very different to those of the mainly shallow, fast-flowing Teign. Nevertheless, it is interesting to note that, as recently as the early 1990s, a high proportion of sites on the Avon had low values for biomass, and the Nene in the 1970s was in an even poorer condition.

Table B4. Proportion of sites where biomass estimates were below 5 and 10 g m^{-2}.

	Date	Sites	Biomass <5 g m^{-2}	Biomass <10 g m^{-2}
Upper Avon	1992	20	45%	65%
Upper Avon	1996	11	0%	27%
Lower Avon	1993	27	63%	78%
River Windrush	1986	18	6%	22%
River Windrush	1993	21	5%	33%
River Kennet	1986/7	20	0%	10%
River Kennet	1993/4	29	10%	17%
Kennet & Avon Canal	1986/9	23	4%	13%
Kennet & Avon Canal	1993/4	25	0%	15%
River Teign	1979	15	33%	53%
River Otter	1978	12	0%	0%
River Nene	1979	12	50%	83%

Fish density

Information on changes in fish numbers over a long period of time were only available for salmonids in the southwest region, and these are illustrated in Figure B3, which shows an increase in all three rivers from the 1970s to the 1990s. The increase is most marked on the River Otter, where there were no salmon recorded. On the Teign there was a change in fish composition, with trout increasing substantially over the period and salmon decreasing (Figure B4). Fish density on the River Camel increased up to the early 1990s, but appeared to decline after that date.

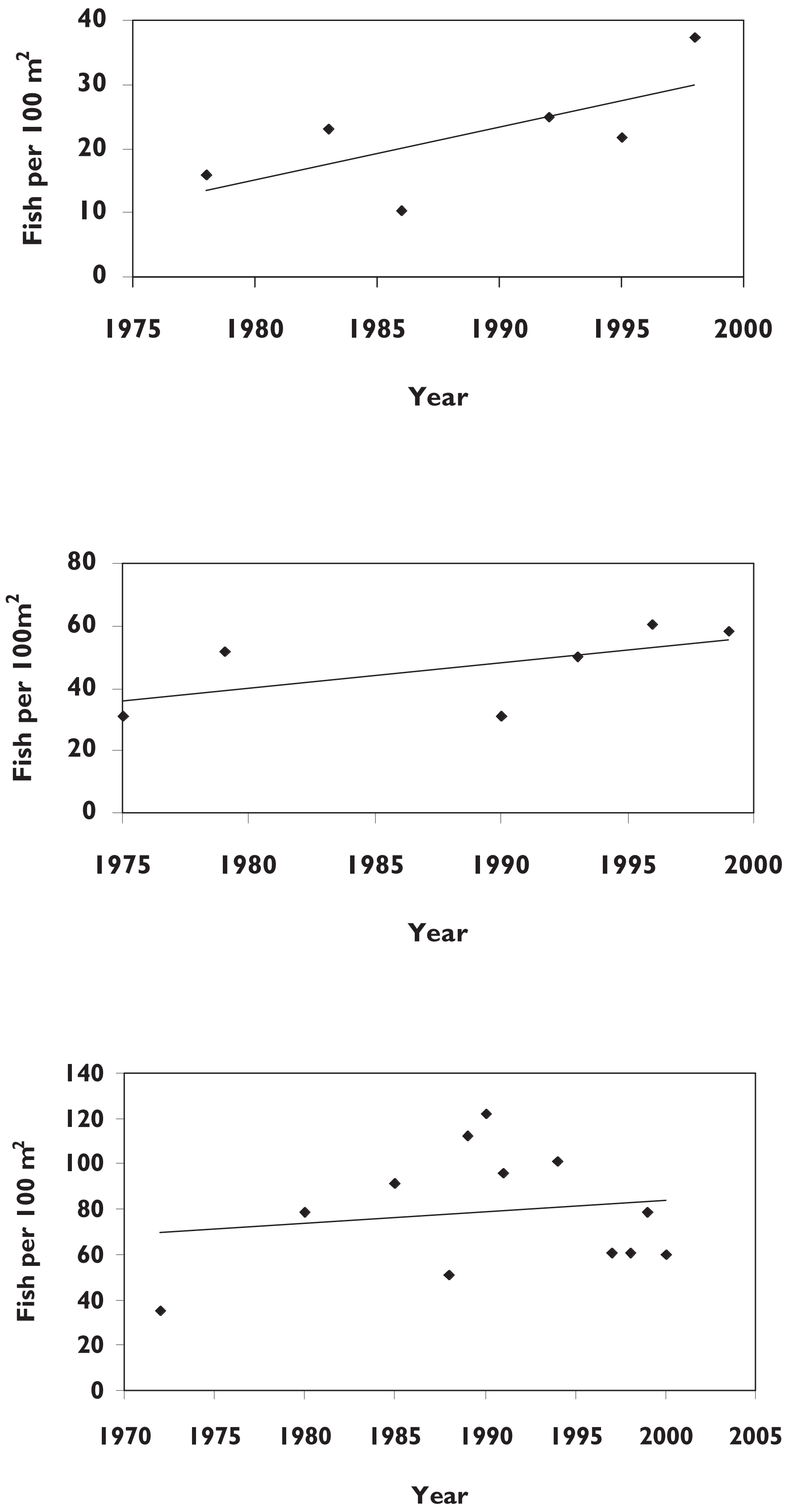


Figure B3. Changes in salmonid density on the rivers Otter (top), Teign (centre) and Camel (bottom).

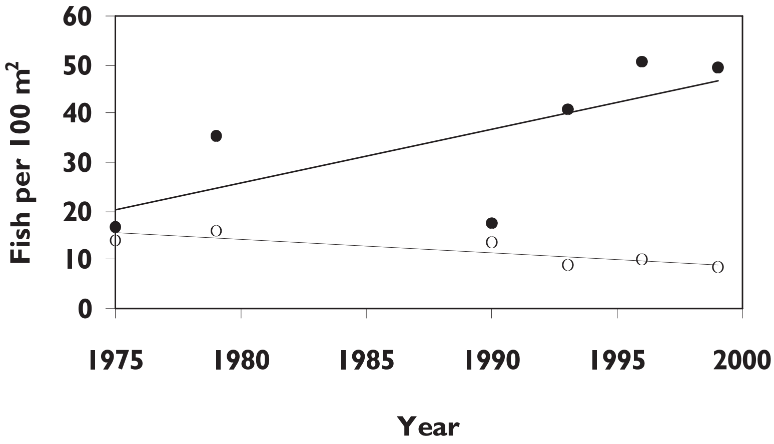


Figure B4. Change in species composition on the River Teign. Open circles = salmon. Closed circles = trout.

It is notable that the absolute densities of salmonids on these streams vary widely, being lowest on the River Otter and highest on the River Camel. These differences are independent of differences in biomass (potential food for the otter), and are due to the presence of larger fish on the Teign and, particularly, the River Otter. Trout on the River Otter grow much faster than those on the Teign, with the result that the mean sizes for 1+ trout on the Otter ranged between 16 and 25 cm at different sample sites, while the means for 2+ trout on the Teign ranged between 16 and 19cm.

Overview

These data show that the biomass of fish in the rivers investigated varied widely. There is clear evidence of an increase in fish densities in southwestern rivers, and possibly an increase in biomass over time elsewhere. It would appear that in the past 30 years there have been places where fish populations have been so sparse that otters may have found it difficult to successfully exploit them, although there is no firm evidence that this is the case now.

Sources of information

Information was obtained from unpublished records held by the Environment Agency in its local and regional offices. Assistance in obtaining records was provided by the following:

Southwest Region: Simon Steel and Rob Wood.
Thames Region: Darren Bedworth and Paul Lidgett.
Midland Region: Jo Mosley.

References

Chanin PRF (1976). *The ecology of the feral mink* (Mustela vison *Scheber) in Devon*. Unpublished PhD thesis, University of Exeter.

Kruuk H, Carss DN, Conroy JWH & Durbin L (1993). Otter (*Lutra lutra* L.) numbers and fish productivity in rivers in northeast Scotland. In: Dunstone N & Gorman ML (eds). *Mammals as Predators*. Oxford Scientific Publications, Oxford, 171–191.

Appendix C: Changes in water quality in rivers

Background

Information on water quality in the rivers Camel, Teign, Otter, Kennet, Windrush, Avon and Teme was sought from Environment Agency offices in the Southwest, Thames and Midland regions.

The amount of information available on this topic is immense, and it soon became clear that only the most superficial analysis would be possible. The most complete information came from the Midland Region and constituted 114,000 analyses from the River Avon, covering 209 sites and 2126 sampling dates between 1974 and 2001. A similar listing from the River Teme was about a quarter of the size. These data included analyses of the effects of pesticides on otters, but not of PCBs.

For the River Windrush, annual summary sheets were obtained for a number of sampling stations that reported mean, minima and maxima for a range of organic and inorganic compounds, together with other water quality data (turbidity, dissolved oxygen, etc.). These included a wide range of organochlorine pesticides and PCBs. No data were obtained for the Kennet.

Summary data were obtained from the Southwest Region for 1974–2001 for various pesticides and PCBs at selected sampling stations on the three rivers. These included mean, minima and maxima.

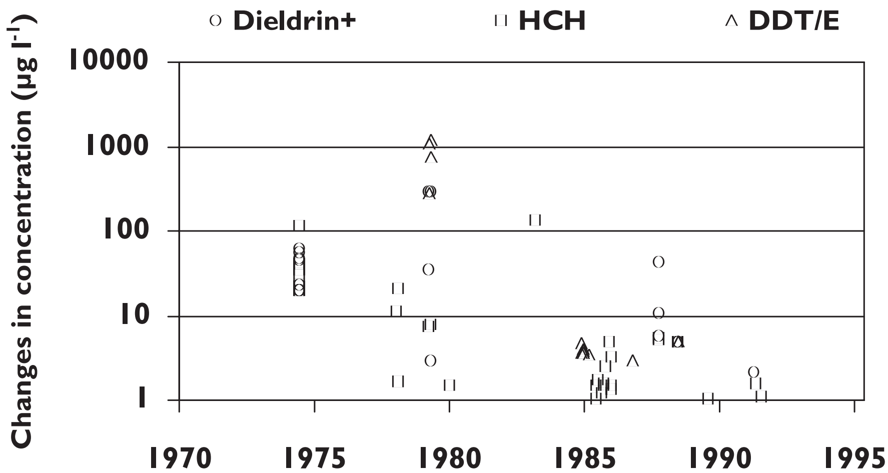
Values

The summarised data for the three southwestern rivers show low levels of PCBs (when measured) and organochlorine pesticides throughout the period. Maximum yearly values of PCBs and pesticides are all below 0.01mg l^{-1}, except for lindane (HCH), for which all values fall within the range 0.01 to 0.15 mg per litre. Similar maximum values are found for the Windrush, and although there appear to be declines in concentrations over the periods for which data are available, many measurements are at the lower limit of detection, and this has decreased with time, rendering analysis impossible.

The most comprehensive set of data came from the Avon and the Teme. Here, too, there was a decline in concentrations with time, also confounded by changes in sensitivity of the analyses. It is also clear that on the Avon there is at least one ‘hot spot’ – a heavily polluted site where samples are taken from a borehole. At this site, a maximum value for lindane of 3.7 mg per litre was recorded in 1986, and a value of over 1 mg per litre was obtained for DDT in the same year. In order to illustrate changes that have taken place, and particularly to demonstrate that high levels of toxic chemicals were present in both rivers over an extended period, figures E1 and E2 include only samples where concentrations exceeded 1.0 mg per litre. Data from boreholes are also excluded, and toxic compounds are grouped to clarify the picture.

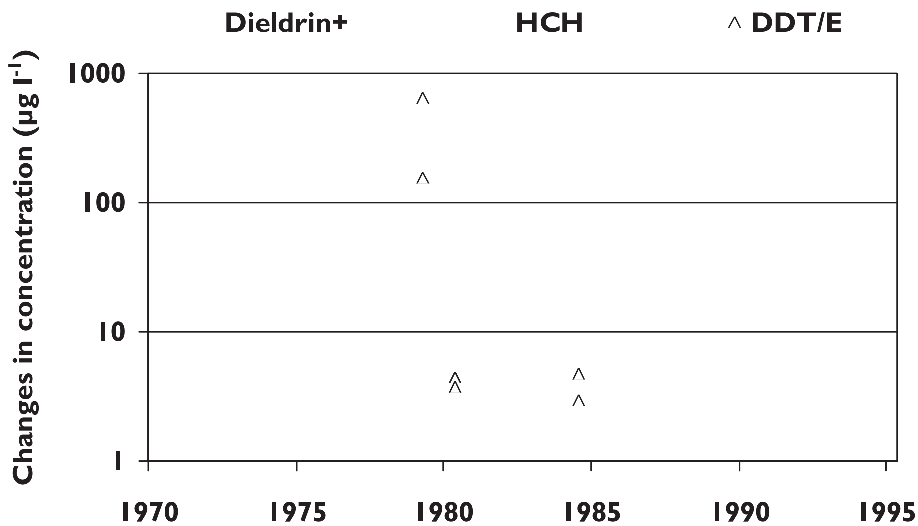
Note that the broad patterns of high levels are similar in the two catchments, and although it may appear that pollution on the Avon was more severe, approximately four times as many records were received for this river.

A clear trend of declining values is not unexpected, but it is perhaps significant that values in excess of 100 mg per l of several pollutants were recorded in these rivers more than 20 years after the start of the decline of the otter.



'Dieldrin+' includes values for Dieldrin, Aldrin and Endrin
'HCH' includes all isomers of HCH
'DDT/E' includes all isomers of DDT and DDE

Figure C1. Changes in concentrations (mg l^{-1}) of some organochlorine pollutants in the River Avon between the 1970s and the 1990s.



'Dieldrin+' includes values for Dieldrin, Aldrin and Endrin

'HCH' includes all isomers of HCH

'DDT/E' includes all isomers of DDT and DDE

Figure C2. Changes in concentrations (mg l-1) of some organochlorine pollutants in the River Teme between the 1970s and the 1990s.

Sources of data

Thanks are due to the following for permission to use the data and for extracting them:

Southwest Region: Rob Moore and Nigel Morris
Thames Region: Jason Gash and John Eastwood
Midland Region: Andrew Sayer and Sue Stocks.

Appendix D: The Otters and Rivers Project

Brief questionnaires were sent to all project officers in the Otters and Rivers Project, with a view to assessing:

- The extent to which records of habitat management and holt construction have been kept.
- Local knowledge of any studies of otters in progress or completed.
- The number of distribution surveys carried out and the extent to which the results are published or recorded in local (or other) recording centres.
- Knowledge of the use of towns by otters.

Seventeen of the 24 officers responded.

Monitoring conservation work on otters

All respondents stated that records of current conservation activities (including holt construction) were being kept. In most cases, information is stored by the local Wildlife Trust, although this is not universal, and several respondents stated that information was kept as 'personal records'. In three areas, records are maintained by the Environment Agency, and in one, information is kept at the local Record Centre. Only five areas have complete records of management, though for some of the others, data may be available in the Vincent Wildlife Trust archives. Nine had full records of holts constructed in their areas.

Monitoring distribution

Fifty-seven local distribution surveys were reported, all but seven of these taking place since the beginning of 1995. Several were large-scale, taking in whole counties (13 surveys) or other large geographical areas (for example, the Lake District National Park). Most of the remainder were river- or catchment-based.

To date, records from only 12 surveys had been sent to a recording centre, though in several cases there was no suitable centre available. Only 15 reports were published, either by the local Wildlife Trust as internal documents, or as reports to sponsoring organisations.

Otters in towns

Otters were reported from 80 cities and towns and described as resident, frequent or regularly occurring at 49 of these. The status was unknown at three and occasional or rare at the remaining 28.

There was evidence of breeding in nine towns, and 'just outside' a further four. Breeding was considered probable at two other towns, and females with cubs were recorded in three others.

Comments

There is clearly a great deal of work being done by the Otters and Rivers Project. With a history of otter conservation work extending back over more than 20 years in some areas, much has been achieved. It is important to ensure that records are maintained, and particularly to make sure that survey data are adequately recorded and used appropriately. The OARP is devising an appropriate recording system for surveys and other work carried out under the project and its antecedents (Lisa Schneidau pers. comm.). The survey work has the potential to complement and significantly add to the monitoring undertaken by the National Surveys, and every effort should be made to support this initiative.

It would be beneficial to ensure that distribution records are integrated into the National Biodiversity Network.

Areas from which responses were received:

Devon
Yorkshire
Northumberland
Cheshire
Cornwall
Derbyshire
Dorset
Norfolk and North Suffolk
Nottinghamshire
South Suffolk, Essex
Somerset
Staffordshire
Warwickshire
Worcestershire
Sussex and Kent

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1 Ecology of the White-clawed Crayfish, *Austropotamobius pallipes*
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4 Ecology of the Bullhead, *Cottus gobio*
5 Ecology of the River, Brook and Sea Lamprey, *Lampetra fluviatilis*, *L. planeri* and *Petromyzon marinus*
6 Ecology of Desmoulin's Whorl Snail, *Vertigo moulinsiana*
7 Ecology of the Atlantic Salmon, *Salmo salar*
8 Ecology of the Southern Damselfly, *Coenagrion mercuriale*
9 Ecology of the Floating Water-plantain, *Luronium natans*
10 Ecology of the European Otter, *Lutra lutra*
11 Ecology of Watercourses Characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* Vegetation

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2 A Monitoring Protocol for the Freshwater Pearl Mussel, *Margaritifera margaritifera*
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4 A Monitoring Protocol for the Bullhead, *Cottus gobio*
5 A Monitoring Protocol for the River, Brook and Sea Lamprey, *Lampetra fluviatilis*, *L. planeri* and *Petromyzon marinus*
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11 A Monitoring Protocol for Watercourses Characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* Vegetation

These publications can be obtained from:

The Enquiry Service
English Nature
Northminster House
Peterborough
PE1 1UA
Email: enquiries@english-nature.org.uk
Tel: +44 (0) 1733 455100
Fax: +44 (0) 1733 455103

They can also be downloaded from the project website: www.riverlife.org.uk

Life in UK Rivers was established to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites.

Set up by the UK statutory conservation bodies and the European Commission's LIFE Nature programme, the project has sought to identify the ecological requirements of key plants and animals supported by river Special Areas of Conservation.

In addition, monitoring techniques and conservation strategies have been developed as practical tools for assessing and maintaining these internationally important species and habitats.

The European otter is a top predator and important in maintaining the equilibrium of a freshwater ecosystem. It declined dramatically over most of the UK after the 1950s with the introduction of pesticides. However, it is gradually making a comeback, and can now be found over much of its former range.

The otter is an important indicator of the environmental quality of its habitat. This report describes the ecological requirements of the otter in a bid to assist the development of monitoring programmes and conservation strategies that are vital for its future.

Information on Conserving Natura 2000 Rivers and Life in UK Rivers can be found at
www.riverlife.org.uk

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