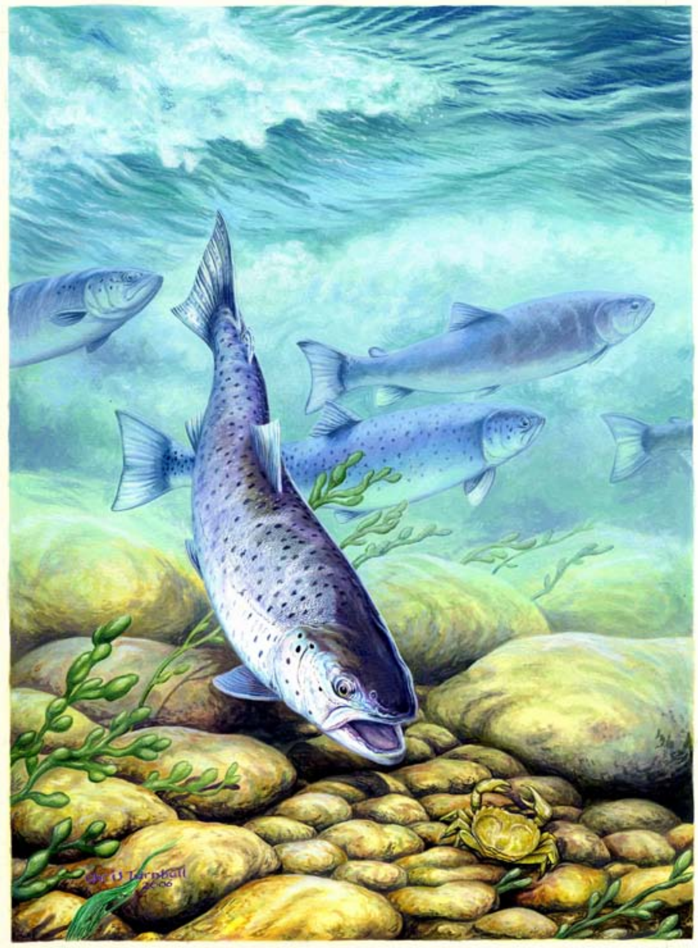

Anglian Rivers Sea Trout Project

Phase 1 Report

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Executive summary

The Anglian Rivers Sea Trout Project aims to use the collaborative efforts of many sectors of the angling, fishery science and management, conservation and landowning communities to identify actions required to facilitate conservation of sea trout stocks in four north Norfolk Rivers, the Glaven, Stiffkey, Burn and Nar, and the Great Eau in Lincolnshire, and to deliver a prioritised programme of sea trout conservation projects to improve production of sea trout through habitat management.

A key component of this project is to develop a better understanding of the status of both resident (brown trout) and migratory (sea trout) populations of *Salmo trutta* and the factors that may be limiting sea trout production in these five Anglian rivers (Phase 1). This is addressed in this report, which collates existing information on trout populations and identifies factors likely to constrain production of trout and sea trout in each river, in both a local and North Sea context, and identifies gaps in current knowledge as a basis for prioritising further work requirements to reduce these constraints.

It is important to recognise that, whilst some sea trout populations exhibit complete anadromy, i.e. they have juvenile stages in freshwater, but migrate as smolts (juveniles that undergo physiological adaptations for life in the sea) to grow and mature in the sea before returning as adults to freshwater to spawn, most are considered to be freely interbreeding elements of a single trout population that includes both anadromous and freshwater-resident components.

Though sea trout are known to enter all five Anglian rivers, a review of the scientific literature shows that the vast majority of sea trout inhabiting Anglian coastal waters probably originate in rivers such as the Esk, Wear, Coquet, Tyne and Tweed on the north-east coast of England and south-east Scotland. These fish migrate to the south as post-smolts and feed in the southern North Sea for a year or more before returning to their natal rivers to spawn. Licensed fisheries along the Anglian coast therefore exploit sea trout from a number of rivers (“mixed stocks”), which is why this fishery is being phased out in line with international policy to protect the most vulnerable stocks, which would most certainly include those originating in Anglian rivers. The relative conservation status of sea trout stocks exploited by the Anglian coastal fishery clearly merits further investigation.

The basic physical characteristics of the five Anglian rivers are similar, having headwaters flowing through wooded hills of glacial debris over chalk and then across low-lying former washlands to enter the sea via tidal sluices. Land-use adjoining the rivers consists of a mix of arable and woodland in the upper reaches, and grazing meadows in the middle and lower reaches. Like all Anglian rivers, the five rivers have been modified over the centuries through a combination of channelisation, drainage and clearance of the floodplain, and regulation of flow by mills, weirs and sluices. Together with on-stream lakes, these give the rivers a ‘stepped’ profile with slower flowing ‘ponded’ sections upstream of these structures and, in the case of the lower reaches of the Nar and Great Eau, flowing along carriers above the level of the valley bottom.

There are several sections in the upper rivers that flow quickly down a steep gradient (for East Anglia) and have natural bank formations, with bends and deep pools and riffle areas over a gravel bed: ideal characteristics for brown trout and their aquatic invertebrate food. In parts, the rivers are heavily shaded, and contain woody debris that adds to the quality of the habitat. The aquatic plant community generally has high species richness, with a well developed chalk-stream flora of water crowfoot, spiked water mill-foil, water starwort and horned pondweed.

The diversity of habitats along many reaches of these rivers has been greatly modified in recent decades through changes in farming and land management practices, and in response to flood-risk policies. The most recent and pernicious impact on all the rivers has been where they were widened and dredged as part of flood defence schemes in the 1970s and 1980s, with a subsequent lowering of the river bed that lacks gravel and leads to a loss of riffle/pool habitat and bankside wetland habitat, and increased siltation, with consequential poor submerged plant growth and impoverished invertebrate communities.

Scrutiny of Environment Agency fisheries data, collected by standard electric-fishing surveys between 1987 and 2007, shows that, of the five Anglian rivers, the Burn has the lowest number of fish species (4), the Stiffkey 10, and the upper Nar, Great Eau and Glaven have 12, 13 and 15 species respectively (including the introduced alien rainbow trout). In all the Norfolk rivers, the European eel and brown trout have been the principal fish species in terms of population density and biomass, whereas coarse fish species (chiefly cyprinids) predominate in the Great Eau catchment as a whole, and probably in the Nar below Narborough. Other species of conservation importance are river lamprey, brook lamprey and bullhead.

Whilst it is thought that the sea sluices are the main barriers to sea trout migrating upstream, especially during periods of low water, sea trout have been reported in the lower reaches of all five rivers in recent years, usually between July and October. Good quality trout spawning habitat tends to be limited to the upper reaches and, on all but the Stiffkey, sea trout are prevented from accessing these areas due to impassable barriers at mills, usually those nearest the sea. There is no evidence that sea trout are spawning successfully in any of these rivers, nor that juvenile trout produced in these rivers migrate as smolts and return as sea trout (though outward-migrating trout smolts were recorded on the Stiffkey in 2007). Juvenile brown trout are sufficiently abundant in all five rivers to suggest that there are adequate natural spawning and feeding habitats at least in the upper reaches, though hatchery-reared adult fish are stocked in the Glaven, Nar and Great Eau to support angling fisheries.

The report provides an explanation for stakeholders of the most important physical and chemical qualities of a river's water that determine whether it can support a trout population. Water quality indices, developed by the Agency to assess the health of rivers and the impact of any discharges into them, show that the water quality in the five Anglian rivers is generally good to excellent, and that the upper reaches in particular are certainly capable of supporting trout, as evinced by the fish population data and by high macro-invertebrate quality indices. Impacts from sewage treatment works, fish farms and “industry” are generally negligible, whilst agricultural inputs appear to be the greatest threat, albeit a lessening one.

In order to better understand the ecology of trout in the Anglian rivers covered by this project, a review is presented of what is known about the habitat requirements of wild brown trout in small chalk streams, and how they use the available habitat. Juvenile trout show a preference for plant cover and tree roots in the stream margins, and may suffer increased mortality due to their relatively small size and increased vulnerability to predation under low flow conditions when these are lost (and after weed cutting or dredging). All trout show a preference for aquatic weed at night, possibly because the refuges offered by stones and boulders in their more normal rain-fed spate-river habitats are absent in these streams.

In relation to habitat management, a closed tree canopy and reduced in-stream weed growth due to shading diminish macro-invertebrate production, and canopy removal appears to have positive effects on the availability of potential prey for juvenile trout. The preference of juvenile trout for the cover afforded by the stream margins suggests that wild trout production might benefit from more sympathetic management of cover provided by riparian vegetation (which is enhanced by canopy removal, and establishment of buffer strips alongside the river). However, larger trout and sea trout appear to prefer areas that have shading and, with the additional impact of a predicted reduction of summer flows and higher temperatures due to climate change, this presents contradictory pressures on management to achieve a balance between canopy shading (cooling) and encouragement of bank-side and in-stream vegetation, noting especially that stream margins may be a critical habitat in low flow conditions. Riverine and floodplain habitat restoration schemes, including reinstatement of gravel riffles, re-profiling of the channel (including narrowing) and lowering of the flood-plain, have already been undertaken on the Glaven, Stiffkey, Nar and Great Eau.

One factor that is almost certainly limiting sea trout production in Anglian rivers is the availability of suitable spawning habitat within that part of the catchment that is accessible to adult sea trout. Because a wide range of microhabitats may be used by spawning sea trout, it is unlikely to be possible to analytically quantify the availability of sea trout spawning habitat within each of the rivers, but information is presented that will allow us to identify those areas of a catchment where spawning would not be expected (e.g. where the river flows over silt or sand) and those areas where spawning is limited or non-existent, but could be enhanced through restorative actions to improve habitat or enable sea trout to reach it.

A connected factor, siltation (the input of fine sediment from arable fields into rivers and estuaries), is a major cause of loss of ecological diversity and good habitat for spawning and juvenile trout (and sea trout), and is particularly important in many Anglian rivers where changes in farming practices have clearly influenced siltation rates. Whilst an assessment of the extent of this problem has not been attempted, the report presents a method of prioritising site visits to suspected silt sources, which suggests that cattle poaching (especially at drinks), fords in agricultural fields, deforestation near watercourses, and areas where banks have been denuded and are susceptible to erosion will all contribute silt to a water course, and should be considered for remediation measures. If siltation is mainly due to changes in farming practice that have resulted in increased soil runoff (i.e. diffuse siltation), however, then addressing point sources of siltation may have little or no remedial effect.

Since one aim of the Anglian Rivers Sea Trout project is to ensure that sea trout stocks can be managed sustainably, it is necessary to be able to assess the status of sea trout populations and to establish targets against which the effects of management action can be judged. Although the fisheries associated with sea trout in the UK and Ireland have a considerable social, recreational and economic value, the specific management requirements of sea trout have until recently been largely ignored. It is suggested that the most promising approach is to consider the trout stock in a catchment as a whole, and focus monitoring efforts on that part of the stock that incorporates both freshwater-resident and anadromous components – the juveniles. This approach would assess the state of the juvenile trout population in a catchment in relation to potential freshwater production, and a mechanism is presented by which the potential average maximum abundance, the carrying capacity, of juvenile trout can be predicted for riverine parts of a catchment, against which to compare measured densities and set a management target.

Though it is not possible to predict the effects on adult sea trout numbers of either reducing or increasing juvenile abundance, the *a priori* assumption would be that, providing the juvenile abundance exceeded some predetermined level in relation to carrying capacity, the numbers of adult trout (anadromous and/or freshwater-resident) would be sufficient to meet the needs of stock conservation and associated fisheries. Other population characteristics, such as the size and age structure of the stocks, the relative abundance of repeat spawners, and the contributions of resident and migratory fish, should also be considered, since these may buffer recruitment against the impacts of short-term environmental change to habitats, and obscure the impact of habitat restoration on trout production.

The report concludes that one objective of Phase 1 of the Anglian Rivers Sea Trout project, to convince potential funders (of restoration actions to enhance sea trout populations) that the Rivers Glaven, Stiffkey, Burn and Nar, and the Great Eau have self-supporting trout populations and play host to sea trout, has been met, though evidence that these fish stay in the rivers to spawn and contribute to future generations is lacking. Clearly, more work needs to be done if we are to verify that sea trout complete their full life cycle in Anglian rivers, and to demonstrate that the remedial actions carried out under Phase 2 of this project have been successful. Approaches to provide the necessary evidence are discussed under three headings: entry; spawning; and smolt output. Whilst it would also be informative to know whether these rivers support distinct populations of sea trout, that is a secondary aim which could be pursued as part of a more wide-ranging study of sea trout in the North Sea (currently being developed).

For Phase 2 of this project, however, we need to identify those factors that potentially limit trout production and sea trout access in these rivers, and prioritise actions to reduce or remove these bottlenecks. The review of data and information presented in this report provides an insight as to why natural trout and/or sea trout production is limited in each of these five Anglian rivers, and a mechanism is presented that will provide a (subjective) analysis of the relative benefits of ameliorating factors that are expected to enhance sea trout production in (or at least sea trout entry to) each of these rivers, which can then be prioritised in light of associated costs and resource availability.

The combination, on most of these rivers, of the available spawning habitat being limited to the upper reaches and relatively good quality habitat for both juveniles and older resident trout throughout the rivers, suggests that there is little pressure for these trout populations to adopt an anadromous habit, and this could explain the current relatively low incidence of sea trout in Anglian rivers. If habitat restoration were to focus on extending spawning opportunities downstream, and easing upstream passage of potential anadromous spawners around barriers at mills in particular (it is not evident that sea gates and sluices are the main problem), the production of juveniles should improve and a greater proportion may adopt a sea-going habit. This would benefit both in-river availability of adult sea trout and production of sea trout smolts.

It is also suggested that the benefits of any actions to increase production of sea trout or their entry into Anglian rivers would be dissipated if netting were to continue unrestricted along the Anglian coast. At the very least, areas around the river mouths or in the estuaries of the Glaven, Stiffkey, Burn, Nar and Great Eau in which all netting is prohibited would help to protect sea trout running into these rivers, and promote and publicise the idea that Anglian rivers do harbour sea trout, a key action of Phase 2.

Acknowledgements

This report presents work carried out under Phase 1 of the Anglian Rivers Sea Trout project, which has relied heavily on input from many staff of the Environment Agency who provided data and access to reports, and I am especially grateful to Ros Wright (who co-ordinated their efforts) and to Charlotte Eade, Justin Mould, Reuben Page, Chris Randall, Jake Reeds, Ian Rees, Russell Robertson and Andy Sadler for unearthing factual information, showing me round rivers, and providing critical comments on earlier drafts of this report. This report also benefited greatly from the work of Alan Walker, Bill Riley and Ian Russell from the Centre for Environment, Fisheries and Aquaculture Science (Cefas) at Lowestoft, who gave me access to reports and papers and also provides critical comments on earlier drafts. I am indebted to Simon Johnson of the Wild Trout Trust, who instigated this project, and to stakeholders such as Carl Sayer, Ian Shepherd, Peter Suckling and David Mostyn (River Glaven Fishing Association), Nick Zoll (Holkham Syndicate, Stiffkey and Burn) and Robert Gibson-Bevan (Great Eau Flyfishing Syndicate), and staff of the Eastern Sea Fisheries Joint Committee, who have all shown enthusiasm for the project and taken time to show me around rivers, provided valuable reports and answered numerous questions.

Whilst I have leant heavily on papers, reports and data that originated with the Environment Agency and Cefas, the interpretation of the information presented in this report and its conclusions are entirely my own.

Mike Pawson 30th July 2008

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1 Background and reasons for the project

The Anglian Rivers Sea Trout Project was initiated by the Wild Trout Trust (WTT) and aims to use the collaborative efforts of many sectors of the angling, fishery science and management, conservation and landowning communities within the Glaven, Stiffkey, Burn, Nar and Great Eau catchments to address the lack of information on trout (*Salmo trutta*) stocks in these five Anglian Rivers and to identify where further data and actions are required to improve production of sea trout through habitat management.

Sea trout are widely distributed throughout the UK, and are recognised as being of major economic, social and recreational importance (Harris, 2006). It is important at this juncture to recognise that, whilst some sea trout populations exhibit complete anadromy, i.e. they have juvenile stages in freshwater, but migrate as smolts (juveniles that undergo physiological adaptations for life in the sea) to grow and mature in the sea before returning as adults to freshwater to spawn (Milner *et al.*, 1993; Elliott, 1994), most are considered to be freely interbreeding fractions of a single trout population that includes both anadromous (hereafter “sea trout”) and freshwater-resident (hereafter “brown trout”) components. Progeny of sea trout and brown trout have been shown to become both forms (Frost & Brown, 1967; Jonsson, 1985; Walker, 1990) and, while genetic differences have been reported between trout populations both within and between catchments, no study of neutral markers has provided conclusive evidence of genetic divergence between brown trout and sea trout living in the same river (Ferguson *et al.*, 1995). Furthermore, the tendency to become anadromous often differs between the sexes, as evidenced by the female-biased sex ratios of sea trout during their spawning migrations (Le Cren, 1985; Solomon, 2006), although the ratios at spawning may approach unity when maturing brown trout are included (Sambrook, cited in Solomon, 1995).

Though many rivers in East Anglia are adjacent to an important coastal net fishery for sea trout, they are not themselves known as sea trout fisheries and there are few data available to assess the current status of sea trout stocks in these rivers. This is partly because of their small size, but chiefly because they have been greatly modified over the years, for energy supply (mills) and flood prevention, by agricultural and associated drainage and flow control practices, and by pollution of one form or another. These have led to access problems and habitat loss with a consequent impact on trout production within a river, but many do retain enough good habitat to support self-sustaining brown trout populations, and have the potential to produce sea trout. Supplementary stocking of brown trout has been carried out in some areas to ameliorate some of these effects and support angling fisheries, but there is no evidence that that this has been beneficial to natural brown or sea trout populations

Restoration projects on the Rivers Glaven and Stiffkey in North Norfolk have demonstrated the benefits of a co-ordinated approach to restoring brown trout habitat. The current project seeks to follow the same principles, by developing a management strategy for rivers in the Anglian area which can be implemented at a local level in partnership with Government and non-government agencies, charitable trusts, angling associations and other conservation organisations. To achieve this, the project will liaise closely with the local community to promote greater understanding of the freshwater ecology of brown trout and sea trout, encourage the sustainable use of the resource, and enhance the economic benefits of a sea trout fishery to local stakeholder groups.

A key component of this project will be developing a better understanding of the status of both brown trout and sea trout populations in Anglian rivers. The river stage of the sea trout life cycle is relatively easy to study, since it is essentially that of wild brown trout, but the brown trout/sea trout dynamic complicates matters considerably. Whilst management strategies developed for brown trout should apply equally to migratory trout in freshwater, little is known about the marine distribution and feeding habits of sea trout, nor the effects of predation in coastal waters. This is outside the scope of the present study, but it will be investigated through the Celtic Sea Trout Programme (a bid to the EU Cross-border Territorial Cooperation Programme, INTERREG IV) and a similar proposal for EU funded research on sea trout in the North Sea that, if successful, will start in the next 1-2 years.

The Anglian Rivers Sea Trout Project is designed as a phased programme, with each phase building on the success of the previous one. Phase 1 seeks to gather and collate existing information on brown trout populations and their associated sea trout in four North Norfolk Rivers, the Glaven, Stiffkey, Burn and Nar, and the Great Eau in Lincolnshire, to identify factors likely to constrain trout production in these rivers and provide a means of prioritising further data requirements and actions to reduce these constraints. Phase 2 seeks to address these actions, to publicise the work to the local communities and to gather wider support. Phase 3 will examine wider issues that may impact on local sea trout production, and address these issues where practicable.

This report presents work carried out by Dr Mike Pawson under Phase 1, working with scientists from the Centre for Environment, Fisheries and Aquaculture Science (Cefas), the Environment Agency (the Agency), the Wild Trout Trust (WTT) and stakeholders. It has involved collecting and collating historical data and published and “grey” literature from the Agency, Cefas, Eastern Sea Fisheries Joint Committee (ESFJC), and other organisations in the project area to identify likely production bottlenecks for sea trout in each of the five Anglian rivers, placed in both a local and North Sea context, and to identify gaps in current knowledge and further work requirements. Whilst this work does not include reached-based habitat assessments to identify areas of degraded habitat, which are the subject of separate work to be supervised by the WTT, the report will begin to identify the numerous structures and obstacles that currently block migration of trout, both resident within the river and to and from the sea.

2 Work programme for Phase 1

The programme of work under Phase 1 has four main Actions.

Action 1: *Collate existing data on trout populations in the Rivers Burn, Stiffkey, Glaven, Nar and Great Eau.*

The Agency, landowners and local anglers have been approached to provide information about brown trout populations and angling catches on each river, stocking records and evidence for sea trout being present. Whilst some historic information has been used to seek evidence for natural breeding of brown trout and anadromy, the emphasis has been on the last 10-20 years, since this will provide the best baseline for the remainder of the project. Most importantly, the Agency has been able to provide overviews and data from fishery surveys, environmental sampling and river characteristics, and extracts from the Section 30 fish movements consent data base to identify trout stocking activities on these rivers. Local sources of information and data for each of the rivers Glaven, Stiffkey, Burn, Nar and Great Eau were contacted and visited to see the rivers at first hand (see Acknowledgements), though less so on the River Nar for which a number of comprehensive reports have recently been produced. The ESFJC has been contacted for information on the Anglian coastal sea trout fishery, and angling books and articles have been used to flesh out the picture, as appropriate.

This information has been used to provide an historical background of trout populations and fisheries in each of the five rivers, stocking records (origin, where and when), and evidence of sea trout in the rivers.

Action 2: *Collate information to convince potential funders (for remedial measures) that the rivers support sea trout populations*

The information produced under Action 1 focusses particularly on the current situation on each river, since the success of any remedial action on access or habitat will have to be judged against changes to the in-river sea trout population in the relatively short term (1-5 years). Methods to collect information from anglers likely to or already catching sea trout in the rivers, including photographs and scale samples from candidate sea trout, and for a redd monitoring scheme, are described.

Action 3: *design a programme that would provide evidence as to whether different sea trout populations use each of these rivers, and on the relationship between these fish and those taken in the Anglian coastal fishery.*

A summary has been prepared of tagging data that link sea trout smolts originating in the rivers of the north-east English/Scottish coast (between the Yorkshire Esk and the Tweed) and those caught in the Anglian coastal fishery, which provides an outline design for a programme for obtaining similar data for Anglian rivers (should it be considered useful). Though it may be possible to use genetics or scale characteristics (pattern and/or chemical signatures) to identify stocks to which these fish belong, this is an expensive approach to a question that may not be immediately relevant, and I suggest that any investigations along these lines are left until we know the outcome of plans for a “North Sea sea trout” project.

Action 4: *Scope factors potentially limiting trout production in these rivers and prioritise actions to reduce or remove these bottlenecks.*

The information compiled under Action 1 provides a good insight as to why brown trout and/or sea trout production may be unnaturally limited in each of these rivers, and a mechanism is provided that will enable the project to weight these factors in relation to the benefits of enhanced sea trout production, which can then be prioritised in light of associated costs and resources available for remedial measures. It should be noted that habitat surveys (by the Agency/WTT) should enable the limiting factors to be identified, reach by reach, and a pre- and post-restoration monitoring programme will be designed by Dr Andrew Gill.

Structure of report

The information compiled during Phase 1 of this project has been used to present what is known about the origins and demography of sea trout that are taken in fisheries along the Anglian coast, the characteristics of the Rivers Glaven, Stiffkey, Burn and Nar in Norfolk and the River Great Eau in Lincolnshire, and of the trout populations in these rivers. This is presented in sections 3-5 of this report. The next three sections deal with the factors that are likely to affect the production of brown trout and sea trout in Anglian rivers, specifically from the perspective of environmental quality and habitat availability for the various life stages of *Salmo trutta*, and opportunities for management of detrimental impacts; section 9 addresses the need to quantitatively assess sea trout populations (so as to know if they are failing, or increasing); and section 10 outlines monitoring programmes and a means to prioritise the river restoration and management actions required to increase the abundance of sea trout in Anglian rivers.

References to scientific papers and technical reports are provided as appropriate, but for an up-to-date account of what is known about the biology, conservation and management of sea trout, the reader is referred to Harris and Milner (2006), the Proceedings of the First International Sea Trout Symposium, held in Cardiff in July 2004.

3 The origins and characteristics of sea trout exploited in fisheries along the East Anglian coast

3.1 Sea trout fisheries

There are at least one hundred rivers in England and Wales that contain sea trout populations (Solomon, 1995; Evans and Greest, 2006), all of which support rod fisheries and around 34 that support commercial (net and trap) fisheries (Anon, 2007). The largest commercial fishery taking sea trout operates on the north-east coast of England and employs both drift nets and fixed, trap nets known locally as 'T' and 'J' nets operated close to the shore. The drift net fishery exploits mainly Atlantic salmon (*Salmo salar*) from a variety of river stocks in eastern Scotland and north-east England (Anon., 1991), and has been subject to a phase out since 1993, accelerated through a buy-out agreement in 2003, when 16 drift net licences operated (an overall reduction of 89% since 1992). The fixed nets, which are set to target sea trout, took an average of 34,375 sea trout between 1994 and 2003, representing between 75% and 86% of the total declared England and Wales net catch of sea trout over that period. Peak catches of sea trout generally occur in June and July, whilst anglers' catches in local rivers tend to peak between August and October.

The second largest commercial fishery for sea trout in England and Wales is that licensed to take salmon and sea trout along the Anglian coast, which is managed by the ESFJC, three of whose Fishery Officers (FO) carry Environment Agency warrants to enforce the Salmon and Freshwater Fisheries Act 1975 across the area from Sutton Bridge to Felixstowe. Because there are negligible catches of salmon, and the sea trout fisheries are part of a complex inshore and beach netting fishery that also takes sea bass *Dicentrarchus labrax*, grey mullet *Chelon labrosus*, herring *Clupea harengus*, mackerel *Scomber scombrus*, and a variety of flatfish in season, which the ESFJC FOs cover, the Agency does not have dedicated fishery officers in this area. The FOs complete inspection returns and forward them to the Agency, which keeps all details on the licence holders and their returns which they submit directly to the Agency each year.

A comprehensive review of the Anglian coastal fishery was prepared for the National Rivers Authority (forerunner of the Agency) in 1992, with a view to developing a management plan for the fishery in light of legislation introduced under the Salmon Act 1986 to phase out drift netting for salmon and sea trout in Yorkshire and Northumberland and to prohibit the use of fixed nets within the 6-mile coastal zone unless otherwise authorised. This report (Champion, 1992) concluded that drift netting for salmon and sea trout should be banned between Grimsby and Cromer, and that licences to fish with fixed or seine nets could be introduced between Grimsby and Kings Lynn to ease enforcement costs of those who landed sea trout as a by-catch. It also suggested that, in the area presently covered by the Anglian coastal fishery, a byelaw authorising the use of fixed nets may be required, as would one defining the permitted type and length of net together with a Net Limitation Order (NLO) to "preserve the *status quo*" in terms of the number of licences that may be issued. In relation to the present project, it is significant that Champion did not envisage any gains to be made from providing protected areas around river mouths along the Anglian coast in which fishing for sea trout would be prohibited. This is a long established conservation measure in most areas where salmon and sea trout are vulnerable to netting fisheries.

In 2006, there were 36 salmon and sea trout netting licences issued for the Anglian Region, and the fishery is subject to a reducing NLO introduced in 1996 as part of a phase-out, so that this number declines as licensees leave the fishery and are not replaced (Anon, 2007). The open season extends from 1 April to 30 September, and licensed drift nets tend to be 200-500 m in length and have 80-90 mm meshes. A quarter of the licences are for "other" nets that take sea trout, bass, mullet and flatfish, and sea trout are also taken in unlicensed nets set for bass and mullet throughout the Anglian Region. In 2005, a total of 50 boats were using fixed or drifted gill nets and 45 individuals set nets along the shoreline in Lincolnshire, Norfolk and Suffolk (including the licensees mentioned above: Cefas unpublished data). The most active part of the fishery is along the north Norfolk and north Suffolk beaches, and much of the fishing activity is by seasonal part-time "hobby" rather than full-time commercial fishermen. The main activity in this fishery is in April and May, September and October, and sea trout catches tend to be highest from June onwards.

There is no licensed sea trout fishing on the Lincolnshire coast. Between King's Lynn and Blakeney, around twenty licensees fish for sea trout, bass, mullet and flatfish: three use fixed nets from longshore boats between Wootton and Hunstanton; four or five set stake nets at Thornham and Titchwell; two vessels use drift nets and eight individuals set fixed nets on the beach at Wells; whilst two vessels at Morston and Blakeney may set fixed nets and two individuals set fixed nets on the beach.

Five vessels operate from the beaches at Mundsley, Bacton, Happisburgh and Sea Palling, using gill nets to target sole *Solea solea*, bass and sea trout, whilst the five to seven longshore boats from Hopton and Corton use drift nets for sea trout and bass.

There is a similar fishery along the Suffolk coast, mainly using drift nets to target bass, mullet, herring, mackerel and sea trout: approximately ten <10 m vessels at Lowestoft; three part-time longshore boats fishing off Pakefield and Kessingland beaches; three vessels from the mouth of the river Blyth at Southwold and Walberswick; and two or three small single-handed vessels who fish part-time at Orford and Hollesley Bay.

An annual average of 1635 sea trout were declared caught in this fishery between 1996 and 2006, with highs of over 2400 fish in 2001 and 2003, and lows at around 900 fish in 1998 and 2006, but with no discernible trend. This far exceeds any known or suspected production of sea trout from Anglian rivers (only one sea trout was reported caught in Anglian Region in the last ten years; Anon, 2007), and it has long been suspected that the majority of these fish originate elsewhere. Nall (1930) suggested that the home rivers of sea trout taken in this fishery are in north-east England and/or south-east Scotland, and this has been demonstrated by the results of tagging programmes summarised below (Potter, 1990).

3.2 Tagging studies

Sea trout caught in the Anglian Coastal fishery are either fish in their first year at sea at between 24 and 33 cm in length, or adult fish of 40 – 70 cm that have spawned at least once (but note that later data indicate relatively few previously spawned sea trout in this fishery). Some 85% of the 1311 fish caught in seine nets there between 1949 and 1955, tagged with Einar Lea hydrostatic tags just below the dorsal fin and released, were in the former category, and most of the recaptures reported were from local fisheries soon after release (as is common with most fish tagging exercises). However, 6 of the larger fish tagged were reported from fisheries on the Yorkshire coast and two in the River Coquet (Northumberland) later in the year of tagging, whilst tagged fish were recovered on the Northumberland coast (4) and in the Rivers Esk, Aln and Tweed (4) in the year after they were tagged.

Sea trout smolts were trapped on their seaward migration in April and May on the River Coquet in 1951 and 1952 (over 39 thousand fish), and on the River Tweed between 1951 and 1954 (18,500 fish), and in both cases tagged with small plate tags made of darkened silver or celluloid (Anon, 1953). Overall recapture rates were low (around 1% of the fish tagged), but the patterns of recaptures of fish from the two rivers were similar. In the first year, prior to spending their first winter at sea, the majority (~85%) of post-smolts recaptured were reported from the Anglian coastal fishery, with the remainder spread along the coasts of Northumberland and Yorkshire and around the eastern North Sea between The Netherlands and Norway. Recaptures of tagged fish after their first sea winter were mainly (~83%) back along the Northumberland coast or in their home rivers, with far fewer fish in the Anglian fishery or along the eastern North Sea coasts.

Nearly 4,000 sea trout kelts (recently spawned fish) were also trapped and tagged (with Einar Lea hydrostatic tags) in late winter and spring on the River Coquet between 1951 and 1956, of which 15% were reported recaptured. Very few fish were recaptured in the 2 months after leaving the river: 9 up to the end of June in the Northumberland and Yorkshire coastal fisheries and three on the Anglian coast; and the majority of recaptures were made on the Northumberland coast in July and August or in the estuary of the River Coquet. Only 15 of a total of 565 recaptures were reported from the Anglian coastal fishery, and a similar number were reported from offshore in the southern North Sea.

In 1983, a national micro-tagging programme was initiated by Cefas (as the then MAFF Directorate of Fisheries Research) to evaluate the impact of high seas fisheries on salmon stocks in English and Welsh rivers. In one particular study, carried out in Northumbria and Yorkshire in the period 1985 – 1995 to evaluate the effects of the North-east coast fishery on the region's salmon and sea trout stocks, sea trout smolts were tagged on the rivers Coquet, Wear and Yorkshire Esk. The Wear had previously been impacted by water quality problems, and sea trout rod catches rose steadily from under 200 fish per year prior to 1985 to at least 1,000 fish from 1998 onwards. Rod catches on the Esk had also increased, from an average of around 190 fish before 1993 to a mean of 350 fish in 1994 to 1997, while Coquet rod catches fluctuated around an average of some 400 fish with no real trend. In 2006, declared rod catches of sea trout on the Wear, Esk and Coquet were 1298, 552 and 325 respectively. Although there were no direct measures of run size, the sea trout populations in these rivers were considered to be either recovering (Wear and Esk) or of reasonably favourable status in the late 1980s and 1990s.

The results of this study were presented in a paper at the 2005 International Sea Trout Symposium (Russell *et al.*, unpublished), and provide a useful description of a modern sea trout tagging and tag-recovery programme that could be used in Phase 2 of this project to identify the origin of sea trout that are found in the lower reaches of Anglian rivers. The results obtained also describe the stock characteristics (maturation patterns at age, marine growth and mortality) of the sea trout that frequent Anglian coastal waters, which are discussed below in relation to future studies on migration patterns and stock demography of sea trout that frequent Anglian coastal waters and in the context of evidence for local river stocks.

In Russell's study, around 80,000 wild sea trout smolts were trapped during their spring-time seaward migration and marked with coded wire microtags (Jefferts *et. al.,* 1963): 7,000 on the Coquet in 1985-88 and 1993-94, over 57,000 on the Wear between 1985 and 1996, and over 15,000 on the Esk in 1994-95. Each smolt had its adipose fin clipped to facilitate subsequent identification of tagged fish by netsmen, anglers or scientists, and thus aid tag recovery, and a sample of fish was usually measured each day to provide a length frequency distribution accompanied by scale samples from a small (<10) size-stratified sample of fish for ageing purposes.

Adult sea trout caught in the north-east coast net fishery usually pass through fish merchants' premises, which were visited throughout each of the 1986 - 1997 fishing seasons, daily in most cases, to check for adipose fin-clipped fish. It was not possible to operate a similar catch-screening programme in the rod fishery, or in the Anglian coastal net fishery. Instead, fishermen were rewarded for reporting the capture of fin-clipped fish, from which the whole head was usually collected for tag removal (micro-tags are injected into the nasal cartilage), plus a scale sample, and details of the length and weight of the fish as well as the date and place of capture were recorded, where possible. Scales were read according to the procedures recommended by Elliot & Chambers (1996) for interpreting annual growth bands and spawning marks in sea trout.

3.2.1 Tag recovery

A total of 3,101 micro-tagged sea trout (3.9% of the smolts tagged) were recovered between 1986 and 1997: 2669 fish from around a quarter of a million sea trout sea trout checked for adipose fin clips and the presence of microtags in the north-east coast fishery; 406 reported by anglers (none from Anglian rivers); and 26 from the Anglian coastal fishery. The number recovered by nets varied considerably between years, reflecting the numbers of smolts tagged in each river each year and the duration of their stay at sea before returning as maturing or previously spawned fish.

Though mark-recapture experiments have suggested very low loss rates of microtags from wild salmon smolts, estimates of tag loss for sea trout recaptured in this study appear to have been substantial (Russell *et al.*, unpublished). This would serve to underestimate the apparent exploitation rate in net fisheries (and rod fisheries), or losses due to other mortality at sea, but does not invalidate interpretations of the spatial distribution of these recaptures.

The reward scheme for anglers reporting the capture of fin-clipped fish appears to have been of limited value, judging from the proportion of fin-clipped fish reported in commercial and angling catches on the north-east coast. However, there was a notable increase in the number of recoveries from the rod fishery between 1992 and 1996, possibly due to anglers' increased awareness of the tagging scheme. Russell suggested that it may be possible to improve estimates of tagged fish caught by anglers by issuing log books to a number of anglers to record details of all fish captured, and thus provide better information on the proportion of a stock that is tagged. Alternatively, the proportion of tagged fish in the upstream run could be estimated using a fish trap, or by identifying adipose fin-clipped fish by lateral-view cameras in automatic fish counters.

3.2.2 Smolt characteristics

Sea trout stocks demonstrate a considerable variety in life history patterns. Within England and Wales, such variations include smolt age (1-4 years), age at first spawning (0-2 years), spawning frequency (once to several), growth rate at sea and pattern and timing of return to freshwater (Solomon, 1995; Harris, 2002). In many studies, information on length and age distributions of smolts is derived from scale reading of adult returners, which has the potential of inconsistent interpretation of smolt ages and may be biased by age/size-related mortality. Similarly, there is often little information on smolt lengths, mainly due to scale-reading studies not undertaking back-calculations of length-at-age from adult scales. As a consequence, a direct analysis of smolt age structure in the population is available for relatively few sea trout stocks (but see Harris, 2006). In Russell's study, two year-olds (S2) predominated in the sea trout smolt runs on all three rivers, comprising, on average, 87% of the run on the Coquet, 74% on the Wear and 90% on the Esk. One year-old (S1) smolts contributed around 10% of the run on the Coquet and Wear, but were relatively uncommon on the Esk (<0.5%). Three year-old (S3) smolts made up the remainder of the run on the Coquet and Esk, but a small proportion of four year-old (S4) smolts were also recorded on the Wear in some years. This is a common pattern for smolt age in sea trout stocks in English and Welsh rivers, which are predominately S2 or S3, with S2's representing more than half the stocks, and very few S1's and S4's recorded (Harris, 2006).

The median date of smolt migration on each river occurred around the middle of May, though it was a little later on the Coquet and earlier on the Esk. There was considerable variability in the size of sampled smolts at different ages and a large overlap in size range between smolt age groups. For example, on the Wear, S1 smolts ranged from 10 to 18 cm in length, S2 smolts from 11 to 28 cm and S3 smolts from 14 to 30 cm. This information will be important in comparisons with smolts and adult sea trout recorded in Anglian rivers in relation to their probable origin, but only if Anglian sea trout smolts have characteristics that differ from those originating in north-east coast rivers.

3.2.3 Sea age

There are distinct patterns in the sea age at which sea trout mature, or return to freshwater without having spent a winter at sea (as whitling). Scale samples were used to elucidate the spawning history of 2830 individual sea trout recovered from net and rod fisheries between 1986 and 1997. Out of a total of 1950 maiden sea trout (fish without spawning marks on their scales), 94.3% were 1 sea winter (1SW) fish, 5.6% were 2SW's and there was one 3SW fish. Of the 880 sea trout that had spawning marks at recapture, the vast majority (96 – 99%) had first spawned after 1 SW, whilst very few fish were found to have spawned for the first time after 2 SW, and none after 3 SW. The age structures and length distributions of all sea trout measured in Russell's study and caught in nets off the north-east coast, by rods or as kelts (fish that have spawned) in downstream traps, were similar, which suggests that the rod catch fairly represents the river-run populations (as evidenced by kelts), and confirmed the very low incidence of whitling.

These results suggest that some 95% of sea trout originating from the Coquet, Wear and Esk return to spawn for the first time after 1 SW, a characteristic of sea trout from the rivers extending from the Tweed on the Scottish Border south through north-east England, which generally have a low proportion of maturing whitling (Harris, 2006). Sea trout from rivers along the south English coast, on the other hand, have a much higher level of maturing whitling. Although there is no data for sea trout from Anglian rivers, anecdotal information suggests that whitling are seldom if ever reported to be caught in them (i.e. all sea trout reported are >40 cm in length). Of the 26 tagged fish reported from the Anglian coastal fishery (between July and September), 11 were captured at 27-30 cm in the same summer as they emigrated as smolts ("post-smolts"), 13 were 1 SW fish averaging 46-48 cm, and two fish of 62 cm has spawned previously.

3.2.4 Mortality

Because there is little evidence of whitling in the north-east coast rivers, and the temporal pattern of recaptures of particular smolt year groups were relatively consistent, Russell was able to make a reasonably confident estimate of annual mortality of the order of 70% from these data. This confirms that north-east coast sea trout are relatively short lived compared to other stocks in the British Isles, and have a low tendency for multiple spawning, as noted by Nall (1930). The reasons for this lower level of survival are not known, but may be connected with a tendency towards an extended marine phase (mainly 1 SW returners, comparable with salmon grilse).

3.3 Origin and distribution patterns of sea trout found off the Anglian coast

Information on marine migrations of sea trout originating in rivers bordering the North Sea is rather sparse and sometimes contradictory, often reflecting the distribution of fishing effort capable of catching sea trout at that time (e.g. drift net fisheries, near-surface trawls) rather than the actual distribution of the fish themselves. Sea trout catches have previously been associated with the herring fisheries off the Scottish east coast, and Nall (1930) reported concentrations of sea trout off the Norfolk and Suffolk coasts and large catches by Dutch and German vessels on the Danish and Dutch coasts. Potter (1990) observed that nearly all marine recoveries of sea trout tagged as smolts in the Rivers Coquet and Tweed were to the south of their natal river, and suggested that fish from these rivers spend their first year at sea feeding in the southern North Sea. It is well to note, however, that gaps in the distribution of tag recoveries do not necessarily indicate that the sea trout do not go to those areas.

The recapture positions within Russell *et al.*'s (unpublished) study of the English north-east coastal fishery, of sea trout originating from the Coquet, Wear and Esk, were highest around the river of origin and the proportion caught locally was lower further to the north (~80% for Esk, ~60% for Wear & ~30% for Coquet). Most 'non-local' recoveries occurred to the south, including as post-smolts off the East Anglian coast, and post-smolts tagged there have been captured as adult sea trout along the north-east coast of England (Potter, 1990). This all points to a predominantly southerly dispersion of sea trout smolts from rivers on the coast of north-east England and south-east Scotland, to feeding areas off East Anglia and along the eastern side of the North Sea. There is good evidence that these fish return to their natal rivers to spawn. Only two of the 38 smolts tagged in the Coquet in 1951-1957 and recaptured in rivers as adult fish were not in the Coquet (both in the Tweed, whose smolts showed similar home-river fidelity, Potter, 1990), whilst only two out of a total of 422 sea trout tagged as smolts in Russell's study and recaptured in rivers by anglers were reported in non-origin rivers: one each from the Coquet and the Wear. Previously spawned adult sea trout seem to rove less widely, and relatively fewer fish appear to reach the Anglian coast, even taking into account the high mortality rate of first-time spawners and the much higher numbers of post-smolts in the sea.

3.4 Potential implications for the management of Anglian sea trout stocks

The interpretation of the marine distribution and migrations of north-east coast sea trout given above is based on information gained only from catches in the open sea and in coastal nets, and there is a paucity of data that would allow us to weight sea trout catch data to describe the actual local abundance of trout in the sea. This is required to show the probability of exploitation of particular river stocks by the various commercial fisheries, both licensed and unlicensed, as a basis for investigating the relationship between these fish and those running into and originating from Anglian rivers. Only when tagging studies have been implemented in which recaptured fish are easily recognised (even fish carrying internal data storage or archival tags need obvious external tags, fin clips and/or a well publicised and widespread recovery scheme; see Thorsteinsson, 2002), can useful information be obtained on marine distribution and movement patterns of particular river stocks.

Fahy (1985) suggested that, because post-smolts that return early to freshwater (as whitling) may not enter their river of origin, sea trout stocks should be managed on a regional rather than single catchment basis as with salmon. Whilst this argument does not apply for the rivers on the north-east coast of England (where whitling are scarce and homing is quite accurate), the Anglian coastal net fisheries exploits sea trout from a number of rivers (“mixed stocks”), which is why a reducing Net Limitation Order has been introduced to phase out this fishery in line with international policy to protect the most vulnerable stocks (Anon., 2004). These would most certainly include those originating in Anglian rivers, and the relative conservation status of sea trout stocks exploited by the Anglian coastal fishery merits further investigation. Comparative quantitative information on stock status is not yet available for any sea trout population in England (see section 9), and is outside the scope of the present project. Nevertheless, evaluation of the relative exploitation rates in the Anglian Fishery (or indeed in the north-east England coastal fishery), of sea trout originating in Anglian rivers and those on the north-east coast of England and south-east Scotland, should be one objective of the proposed North Sea sea trout project.

4 Characteristics of the Rivers Glaven, Stiffkey, Burn, Nar and Great Eau

The following descriptions of the five Anglian rivers are taken from a combination of information in reports and publications and visits to the rivers, and are presented from a “trout-centric” point-of-view. Because the information available is quite disparate, it is not of equivalent detail for each river, but they are sufficiently similar in character that the features and issues arising from anthropogenic impacts (in terms of trout production and sea trout access) for the Glaven can be considered to apply to all five rivers (and extrapolated to others).

4.1 River Glaven

The headwaters of the Glaven are at Lower Bodham and Baconsthorpe in north Norfolk, from whence the river flows for some 17 km through wooded hills of glacial debris over chalk to enter the sea at Blakeney Point. There are two major tributaries: Stody Beck, which joins the Glaven above Hunworth Mill, and Thornage Beck, which joins near Thornage. The river drains a catchment of approximately 115 km^2, and land-use adjoining the river consists of a mix of arable land and coniferous plantations in the upper reaches above Edgefield, grazing meadows in the middle reaches, and low-lying former washlands below Glandford Mill.

Like all Anglian rivers, the Glaven has been modified over the centuries through a combination of channelisation, drainage and clearance of the floodplain, and regulation of flows by mills and weirs. The gradient is steep for a lowland river and, historically, there were 11 water mills on the Glaven as far up-stream as Bodham. Today, 5 mill structures remain (Hempstead, Hunworth, Thornage, Letheringsett and Glandford, moving downstream), of which Letheringsett is currently the only working mill in Norfolk. There are three ‘on-stream’ lakes associated with the main river channel: Hawksmere (Hempstead mill pond), Edgefield Hall Lake and Bayfield Hall Lake. The latter was dug in the late eighteenth century for ornamental purposes, and the Glaven was partly diverted around the lake through a tunnel built into the valley side in the late nineteenth century and which remains operational today. Together, the mills and on-stream lakes give the river a ‘stepped’ profile, with slower flowing ‘ponded’ sections upstream of these structures. Between the thirteenth and eighteenth centuries, a wide expanse of tidal water between Wiveton, Cley and Blakeney (known as Blakeney Haven) functioned as one of the greatest ports in England, but fell into decline when the river and estuary began to fill with sediment. The river remained tidal below Wiveton until 1824, when the present bank and coast road were constructed, and the tidal limit is now at Cley sluice.

The diversity of habitats and hence plants and animals that are present in the river has been greatly modified in recent decades through changes in farming and land management practices, and in response to policies for flood- risk management. This was a principal reason for the formation of the River Glaven Protection Group (RGPG) in 1999, composed of local naturalists, scientists, anglers and landowners, with the aims to protect the Glaven from pollution and degradation, improve water quality, and conserve and restore important habitats for wildlife within the river corridor. For this purpose, Sayer and Lewin (2002) compiled a report summarising the environmental problems and future threats to the ecological integrity of the river, and outlined the potential for its future protection, enhancement and restoration. The RGPG evolved into the River Glaven Conservation Group (RGCG), which undertook a river restoration project upstream of Letheringsett ford in Autumn 2006, financed through the Cinderella Chalk Rivers Project, a national scheme run by the WTT in partnership with the Agency and English Nature (now Natural England) (Anon, 2006).

Although the river has been severely modified by straightening, over-deepening and impoundment, there are several sections above Glandford Mill that retain a semi-natural form. Some parts of the upper Glaven around Hempstead - Thornage are on a steep gradient and fast flowing with natural bank formations, bends and deep pools and riffle areas over a gravel bed, characteristics which make it good for brown trout and their aquatic invertebrate food. In parts the river is heavily shaded, being thickly wooded on both sides, and with woody debris in the river that adds to the quality of the habitat (Fig. 4.1). The aquatic plant community generally has high species richness, particularly above Letheringsett' where there is a well developed chalk-stream flora of water crowfoot (*Ranunculus penicilliatus* var. *calcareous*), spiked water mill-foil (*Myriophyllum spicatum*), water starwort (*Callitriche* spp.) and horned pondweed (*Zannichellia palustris*). Besides trout, other notable inhabitants of the Glaven include the otter (*Lutra lutra*) and the native white-clawed crayfish *Austropotamobius pallipes*.

Perrow & Jowitt (1996) identified several sections in the middle and lower reaches of the Glaven that have been significantly overwidened and deepened to improve land drainage, leading to loss of riffle/pool and bankside wetland habitat and increased siltation. Many Anglian rivers were widened and dredged in the 1970s and 1980s, with a subsequent lowering of the river bed to leave a high (and dry) bank of spoil, disrupting the natural connection between the river and meadow and resulting in a reduction of the characteristic species of plants and insects that depend on this. Where a river's profile is flatter, the flow is slower, and the substrate is dominated by a sand/silt deposit over the gravel, exacerbated by the river being too wide in places and with a lack of gravel riffles. From a management perspective, re-connection of river and its natural flood plain by removal of the spoil bank and the formation of a more natural profile would help to hold-up water in severe rain events, flooding areas where there are no houses which could be affected. The Glaven below Glandford Mill has been dredged as part of flood defence schemes since the 1970s, lacks gravel and is heavily silted as a result, with consequential poor submerged plant growth and impoverished invertebrate communities.

Sayer and Lewin (2002) considered that siltation is the major environmental problem of the Glaven, and suggested that the silt burden of the river has increased substantially since the mid-1980s. In many areas, the gravel river bed lies beneath 50 cm or more of fine sediment, which encourages the dominance of a 'silty' aquatic plant flora (particularly starwort and *Cladophora* spp.) as opposed to dominance by water crowfoot, reducing reproductive success and food availability for brown trout. They identified several badly affected sections, including the tributaries above Selbrigg Pond, a long reach in the Holt Lowes area, the majority of the lower river below Bayfield, and ponded sections above mills and on-stream lakes. The major source of fine sediments to the river is from arable fields following heavy rainfall, and known silt entry points include the road below Selbrigg Pond, a fording point over the Thornage Beck and Letheringsett and Glandford fords.

The availability of good quality trout spawning habitat varies along the river. Spawning opportunities below Glandford Mill may be limited to riffle areas created along a few 100 m at the top end of the River Glaven Fishing Association section, where some wild trout may be seen. However, the river between Glandford Mill and Bayfield Lake is fast flowing, with a mixture of silt/gravel and good stands of *Ranunculus penecillatus* on gravelly areas, particularly below the lake. Wild brown trout are said to be abundant here (it is not stocked above Glandford Mill), and there is a possible spawning area between Bayfield Lake and Letheringsett Mill, where there is a mix of silty patches in ponded areas and gravels. Above Letheringsett Mill, the Little Thornage restoration reach holds lots of wild brown trout and has good spawning potential, whilst quite a few wild brown trout are seen between Astley Farms and Thornage Mill, where it is now very silty and probably poor spawning habitat, though the upper part of this stretch was gravelly and full of brown trout some 10 years ago. The river is very gravelly between Thornage and Hunworth mills and probably provides the main spawning and nursery area for the river. Trout are seldom see in ponded areas above Edgefield Hall Lake and Hawksmere (Hempstead Mill Pond).

The river has occasionally suffered water quality failures at the Hill House, Bodham site above Hawksmere, which may relate to upstream pollution events or failures at Baconsthorpe Sewage Treatment Works. This may have been the primary cause of reductions in the brown trout population in the Hunworth - Thornage area, which otherwise has good habitat for trout.

The main barriers to sea trout migrating upstream in the Glaven are at the sea sluices at Cley (which are said not to open automatically, though a good run of sea trout into the lower river was reported in 2007), and the mills at Glandford (which appears to be the furthest upstream they can travel, despite it having a fish ladder), at Letheringsett ("fish pass" needs improving) and Thornage (no fish pass), and possibly in that part of the river (>50%) flowing through the tunnel round Bayfield Lake.

Figure 4.1 The River Glaven in May 2008, showing (clockwise, from top left) good "natural" and restored trout habitat above Letheringsett, the "fish pass" at Letheringsett Mill, and the over-deepened channel below Bayfield Lake.

The Glaven was visited on 2 June 2008 to looking specifically at the river between Glandford Mill and the upper extent of the RGCG restoration team's work area. Most of this stretch appears to have good trout habitat, is not over-widened and had plenty of cover in the form of *Ranuculus penicullatus* and riparian vegetation, including overhanging trees and bushes. Spawning gravels are well distributed, though there are signs of sedimentation, and the restoration work has introduced riffles above Leatheringset Mill. It was suggested that the river's water flow is less affected by rain than by operations of these two mills, and though sediment derived mainly from arable field run-off has probably reduced considerably in recent years, much sediment remains in the river. There are some concerns about water quality, but this appeared to be good during the visit.

4.2 River Stiffkey

There is no readily available written report on the Stiffkey, and the information presented below was obtained during a visit on 29th May 2008 and by correspondence with stakeholders. The river appears to have good juvenile trout and spawning habitat above Wighton and, since there has been no recent stocking of trout in the Stiffkey, the fishery clearly relies on natural production. Below Wighton, however, there is a lack of suitable spawning gravel and the river is over-widened throughout, and it is particularly heavily silted with sand (Fig. 4.2). Natural trout reproduction is probably limited as a consequence, though restoration work has been (and is being) carried out to narrow the channel and introduce gravel below Wighton and around Warham All Saints.

Figure 4.2 The River Stiffkey in May 2008, showing (clockwise, from top left) good trout habitat near Wighton, newly introduced riffles bellow Wighton, siltation at Warham, and river narrowing works.

Despite perceived problems with access at the sea sluices (the only solid obstacle to migration on the Stiffkey), sea trout are regularly seen (and sometimes caught) along the lower river, entering from May –September, and are most numerous after heavy rain from July onwards. Sea trout have been seen upstream between Warham and Wighton, where spawning activity (as evidenced by redds) on the introduced gravel riffles suggests that this was carried out by trout larger than resident fish found in the system. However, we require reliable data on the abundance and distribution of first-year fish to know if trout spawn successfully below Wighton. There appears to be a correlation between water flow (due to rainfall, mainly) and brown trout numbers, and it was suggested that, due to a lack of juvenile habitat and adult cover, predation from herons *Ardea cinerea* may be a significant problem in low water years. Otters are also present and may have an impact, particularly as the flounders(*Platichthys flesus*) and eels (*Anguilla anguilla*) that used to be more common are now virtually non-existent.

4.3 Burn

There is no readily available written report on the Burn, and the information presented below was obtained during a visit on 29th May 2008 and by correspondence with stakeholders. The River Burn has retained much more of a chalk stream character than has the Stiffkey, with winterbournes in the upper reaches above North Creake and a constant spring at Manor House Farm, see Figure 4.3. Downstream, the water is mainly slow and heavily treed to below the sewerage farm above Burnham Overy Mill, below which there is a stretch of good gravel and weed until it becomes backed up, wide and silty above Burnham Mill.

Figure 4.3 The River Burn in May 2008, showing (clockwise, from top left) the confluence of the Creake winterbourne and main spring near Manor House Farm, good trout habitat below Burnham Overy Mill, the mill pool at Burnham Mill, and the sea gates.

Sea trout have relatively easy access up to Burnham Mill (the seagates on the Burn are said to work far less efficiently than those on the Stiffkey), and are known to occupy the mill pool in considerable numbers at times in summer (and were reported seen there in June 2008), and have been seen spawning in the spring-fed stream to the west. However, the hatches at Burnham Mill are controlled by the owner and closed permanently to retain water level upstream, and this appears to present the main obstacle for sea trout to reach good spawning habitat further upstream.

4.4 River Nar

The physical characteristics of the River Nar are described in a report of work carried out to evaluate the river's geomorphology and understand its hydro mechanics with a view to better managing sediment transport (Sear *et al.*, 2006). The report does not overtly consider the river's ecosystem, other than as achieving “favourable status” in conservation terms, and only mentions fish (salmonids) in the context of siltation of spawning gravel. Nevertheless, it is a valuable source if we are to understand the characteristics of the river in relation to its ability to support brown trout, and whether the Nar has or could in the future have a run of sea trout.

Like the Great Eau, the Nar can be considered as comprising two river types, an upper river chalk stream and a lower fenland river, with a transition between the two at Narborough, though the river shows characteristics of good trout habitat for some 3-4 miles below Narborough. The upper river is characterised by a higher gradient across a catchment of 153 km^2 with mainly loam and some sandy soils and peat, and with a flow regime dominated by groundwater arising as springs from the chalk/greensand aquifer between Mileham and Castle Acre. The lower river runs off mainly peat, with proportionately less loam and some sand overlaying an alluvial basin, and has a catchment of 208 km^2. Here the Nar's flow is influenced by a network of drains and artificial embankments, which raise the water above ground level from 1 km below Marham, and is subject to ponding and saline intrusion at high spring tides up to 13.6 km above its confluence with the Great Ouse through the tidal flap at King's Lynn.

The flow in the upper Nar peaks in March /April, though luxuriant weed growth in summer sustains water levels. As a consequence, water temperatures are moderated and the habitat is suitable for trout spawning and juvenile feeding. There are records of water control structures (generally associated with water mills or lakes) on the upper Nar since the 11th Century, many of which operated into the 20th century and remain *in situ* today. Fisher *et al*. (2008) provide a comprehensive description of the mills and other structures on the river managed by the Water Management Alliance above Narborough Mill, and consider that fish passage at more than half of these structures is impaired and could be improved. A similar forthcoming study will cover structures on the river under Agency control below Narborough Mill, which will include the tidal flaps at King's Lynn given their significance in relation to sea trout migration into the Nar.

Sear *et al*. (2006) note that attempts to improve navigation on the lower Nar reached as far upstream as Narborough by 1759, and may have been in use until 1932. By the late 19th century, however, installation of the sluice at King's Lynn effectively blocked direct access of vessels from the Great Ouse. It is pertinent that navigation on the lower Nar is once again under consideration, including raising water levels to accommodate a (proposed) marina at Boals Quay. This could have implications for sea trout access to the Nar.

The river has a long history of agricultural impacts, and around 90% of the habitat has been modified from its essentially small chalk stream character (shallow gravel-bottomed with good flood-plain connectivity), though this does not necessarily detract from its ability to produce trout. Sear *et al*. (2006) concluded that sedimentation (potentially blocking spawning gravels and reducing invertebrate production), a lack of gravel flushing (steady flows and no gravel replenishment), and a lack of woody debris and riparian vegetation (which together create scour, shelter fish, and improve habitat diversity) are the main factors that might limit salmonid production, though they provide no evidence for this.

Assuming sea trout can penetrate the tidal flaps near King's Lynn (there is anecdotal evidence of sea trout being seen just downstream of Narborough), they still have to negotiate a Denil fish pass on a sluice gate near the A47 at Kings Lynn (the effectiveness of which is unknown), two structures at Pentney Abbey, the Marham Flume and the Bone Mill, before reaching

Narborough Mill. All these are thought to present a significant barrier to movement, particularly at low flows (Andy Sadler, pers comm.).   At Narborough, there is a sluice gate and a vertical weir of around 1 m, sited on the remains of a pound-lock and now designed to maintain water levels for either Narborough Trout Fishery or the Mill (Fig.4.4). It is believed that no fish are able to pass above Narborough Mill (Agency, and River Nar Fishery angling club, pers comm).

Figure 4.4   The sluice gate and vertical weir on the River Nar at Narborough, June 2008.

The lower river could be seen as a conduit for smolts and adult sea trout to move between the upper river and the sea and, provided water quality and temperature are not limiting, the habitat is less important. Access past barriers and the flow pattern to carry smolts out (April/May) and allow adult sea trout to run are probably more crucial.

4.5 River Great Eau

The Great Eau catchment is situated in north-east Lincolnshire, flowing eastwards from the Wolds to the south of Louth and entering the North Sea at Saltfleet, some 15 km south of the mouth of the Humber Estuary. A number of small streams that originate as springs and are consistent in water quantity and quality throughout the year, except in severe droughts - Brinkhill, Cloven Hill, Driby, South Ormsby, Ketsby, Burwell and Calceby becks – converge to form the Great Eau, all running off moderately sloped mainly shallow calcareous, medium textured soil, with some sand.   The land cover is a mixture of managed grassland, forest scrub and extensive pasture, and arable land that is ploughed nearly to stream's edge along many sections, and all these streams have silted stretches, with some eroded banks and cattle poaching along the stream edge.

The geography of the Great Eau is similar from Ketsby Beck down to its confluence with Burwell Beck, and from there to Withern Bridge it runs over medium textured, sand and clay soils, mostly on level ground, with land cover that includes arable, intensive and extensive pasture, with frequent cattle access to the river. There are 5 abstractions in the vicinity or on this stretch, and 3 discharges, including three trout farms (at Belleau Bridge, Claythorpe Mill, and Withern Mill).

A particular feature of the river downstream of its confluence with Belleau Spring to the sea gate at Saltfleet, is that its channel has been artificially raised above the original valley bottom, probably over a century ago, and it is thus operating as a high level carrier almost entirely disconnected from its floodplain. For this reason the Great Eau is regularly dredged both upstream and downstream of Withern Bridge, where the river flows across a heavily drained area of historic marsh that is managed by the Lindsey Marsh Drainage Board.

The upper reaches appear to have good trout habitat, with spawning gravels, riffles, pools and good aquatic and riparian vegetation cover, Figure 4.5. Below Claythorpe Mill, however, the river becomes deeper, with riffles apparent only where they have been introduced (the results of a programme instituted in the early 1990s) and little obvious spawning habitat for trout. Although the Great Eau maintains a reasonable flow right to the sea (it appears to be well sustained by springs), it becomes much more of a coarse fish habitat (dace *Leuciscus leuciscus*, roach *Rutilus rutilus*, chub *Leuciscus cephalus* and bream *Abramis brama*) as one progresses downstream and riparian tree cover becomes sparse (though no less than on the lower reaches of the Stiffkey, for example).

Figure 4.5 The River Great Eau in June 2008, showing (clockwise, from top left), good trout habitat below Belleau Spring, the fish farm effluent at Claythorpe Mill, a raised and dredged channel above Withern Bridge, and the sea gates.

Neither the gauging weirs nor the lift at the Anglian Water intake at Saltfleet seem to present any great difficulty for sea trout, and the sea gates are easily passable (see photo above). Mr Robert Gibson-Bevan, Chairman of the Great Eau Fly Fishing Syndicate (Belleau to Withern reach), reports that sea trout have always been able to run up to Withern Mill, where the old mill building receives the main flow from the river and a channel some 300 m upstream of the mill feeds numerous raceways and a hatchery, discharging into a return channel placed at the mill pool. Any potential migrating fish would be unable to pass through the mill structure or indeed through the numerous screens that are placed within the bypass channels. Similarly, Claythorpe Mill has a weir discharge of around one m high, some 150 m upstream of which is a bypass channel that feeds the trout farm and receives effluent from the numerous stew ponds, and which is heavily screened at the point where it discharges from the farm. Both the weir within the mill building and the trout farm appear to be effective obstacles to fish passage.

4.6 Overview and conclusions

Information on the natural and artificial physical features of these five rivers is presented in a standard form from surveys by the NRA to describe and quantify their physical characteristics in 1994 to 1997. These were conducted at a number of sites and, though the results summarised below represent only a snapshot of the nature of each river, they do provide a comparison between rivers.

Feature	Glaven (4 sites)	Stiffkey (5)	Burn (6)	Nar (7)	Great Eau (6)
pools	4	5	3	0	0
riffles	1	15	21	15	15
point bars	0	0	7	0	0

The predominant valley form in all five five rivers was either a symmetrical flood plain (18 sites) or shallow vee (8 sites), and the above table suggests that the Glaven lacked one of the features most strongly associated with good trout habitat, riffles, the Nar and Great Eau lacked pools but had many riffles, whilst the Stiffkey and Burn had an abundance of these features. The incidence of man-made features such as weirs and sluices, culverts, outfalls and intakes, and bridges varied considerably, reflecting the use to which the respective rivers had been put.

Although the information presented in this section provides a necessarily patchy description of the nature of these five Anglian rivers, it is sufficient to illustrate the types of habitat that they contain and the modifications to the stream channel that might interfere with trout production and sea trout entry. This should be read alongside the next section (5) on fisheries data, which provides a better insight to each river's capacity to support self-sustaining populations of brown trout (and sea trout). Whether runs of adult sea trout into the rivers could be enhanced depends a great deal on how practicable (and costly) it would be to ease upstream passage past the known obstacles, though only the Great Eau appears to have a potential problem of ensuring downstream migrating smolt do not succumb to water intake structures.

5 Fish communities and evidence for wild trout populations

In their review of the available data and information on trout populations and fisheries in England and Wales, Gray and Mee (2002) suggest that brown trout and sea trout are relatively scarce in Anglian Region. They reported the presence of brown trout in each of the five Anglian rivers under consideration, but were unable to find any records of trout fry or parr in samples (1964-1999) from these rivers, though surveys there have primarily been aimed at coarse fish. Overall, Gray and Mee estimated that only 5% of total river length in Anglian Region is accessible to sea trout, which had been confirmed to be present in the Glaven and Stiffkey. Though they considered that the Nar was accessible to sea trout throughout its length, their presence there had not been confirmed, whilst both the Burn and Great Eau were considered to have barriers some little way above the tidal limit that were impassable to sea trout.

For the present project, the Agency has provided fisheries survey data for Anglian rivers collected between 1987 and 2007, as overviews for the Rivers Glaven, Stiffkey and Burn and raw data for the Nar and Great Eau. In these surveys, fish populations are monitored by electric-fishing between stop nets set across the river channel to prevent movement of fish into or out of the survey area. Where sampling involves two or three passes of the survey area, a reliable estimate of population abundance can be obtained using, for example, the method of Carle and Strub (1978, see Riley *et al*., 2009 for details). All fish caught are measured while sub-samples have scales removed for subsequent age determination.

Because electro-fishing is inefficient at sampling fish below approximately 10 cm fork length, the data are not representative of whole populations (especially not of first -year trout), though the results presented in the graphs below (taken from Agency overviews) denoting fish of all sizes can be used for comparisons between years within one river. The results of using multiple-pass data for fish greater than 99 mm fork length to estimate density and biomass are more quantitatively robust, and do provide comparisons between rivers.

Recent surveys show that, of the five Anglian rivers, the Burn had the lowest number of fish species recorded (4), the Stiffkey 10, and the upper Nar, Great Eau and Glaven have 12, 13 and 15 species respectively (including the introduced alien rainbow trout *Oncorhynchus mykiss*). In all Norfolk rivers, the European eel, and brown trout have been the principal fish species in terms of population density and biomass, whereas coarse fish species (chiefly cyprinids) predominate in the Great Eau catchment as a whole, and probably in the Nar below Narborough. Other important species found in the Glaven and Stiffkey, but not in the Burn, Nar nor Great Eau surveys, are river lamprey *Lampetra fluviatilis*, and brook lamprey *Lampetra planeri*, whilst bullhead *Cottus gobio* was not found in the Burn.

The following resumés for the five Anglian rivers are based on Agency fishery survey records and information from other sources, both published and anecdotal. Summary details of trout stocking events from the Agency's Section 30 consent data base have also been provided.

5.1 River Glaven

5.1.1 Fish populations

Information presented in Sayer and Lewin (2002) includes interviews with fisherman who knew the river in the 1950s and 1960s, when the Glaven above Wiveton Bridge was remembered by John Bailey as a “beautiful, clear river with good weed growth and stunning fish stocks”, with a relatively prolific run of sea trout, some of which he caught. He, like Peter Suckling (former chairman of the River Glaven Fishing Association), described two relatively distinct fish zones, with roach and pike, *Esox lucius,* in addition to perch, *Perca fluviatilis,* and trout in the lower river (there was a particularly good roach fishery below Glandford) and abundant trout and dace in the upper river.

All fishermen consistently report a substantial decline in fish stocks since the mid-1970s, with reductions in numbers of trout, roach and perch in particular. There was a much reduced run of sea trout in the late 1970s and a decline in the eel population has also been noted since the 1980s (although this may reflect a European-wide phenomenon, Dekker, 2003).

Seven sites on the River Glaven between Hunworth and Wiveton Bridge were sampled by electric-fishing in 1988, 1991, 1994, 1999 and 2002, although only 6 sites were surveyed in 1999 and two in 2002. Fifteen fish species were recorded: brown trout, bullhead, common bream, eel, gudgeon *Gobio gobio*, river lamprey, perch, pike, stone loach *Barbatula barbatula,* flounder, 3-spined stickleback *Gasterosteus aculeatus,* roach, rainbow trout, tench *Tinca tinca,* and common carp *Cyprinus carpio*, the last three as escapees from on-stream lakes and Bayfield Hall fish farm at Glandford. During the headwaters survey at 10 sites on the upper Glaven in 2003, 6 species were recorded: 3-spined stickleback, bullhead, eel, roach, pike and perch (NB, no dace recorded). The fish community is dominated by eel and brown trout in biomass terms, and by bullhead numerically. A summary of survey data for the most abundant species is presented below.

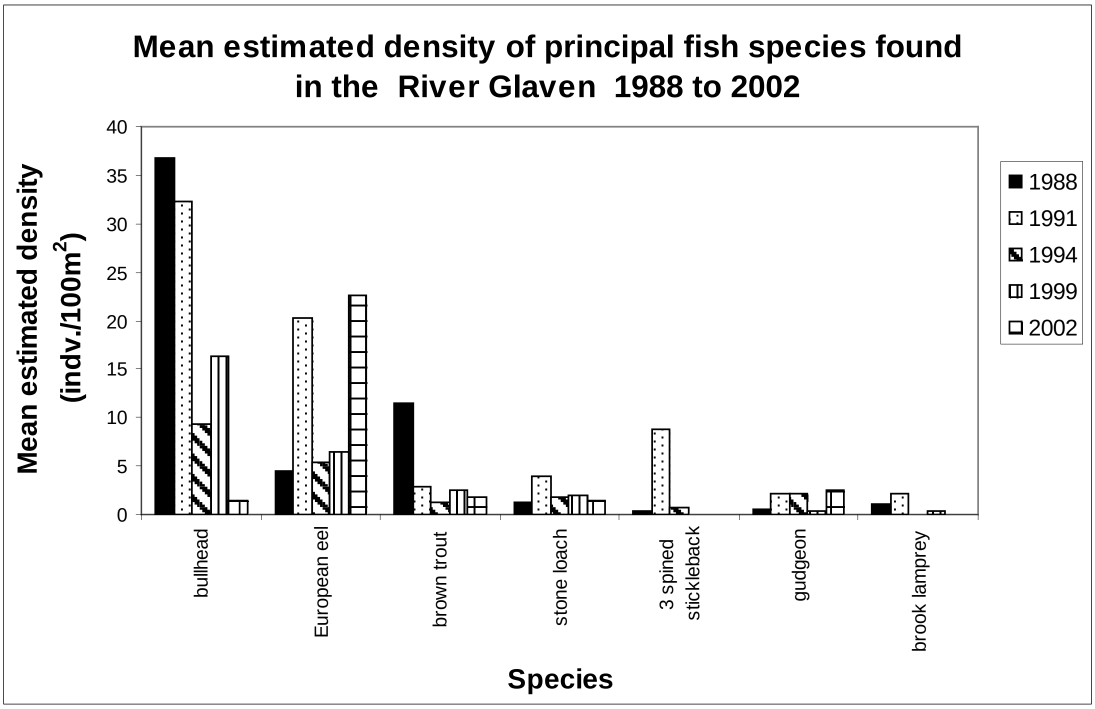


Figure 5.1(a) **Mean estimated density of principle fish species found in the River Glaven 1988 - 2002**

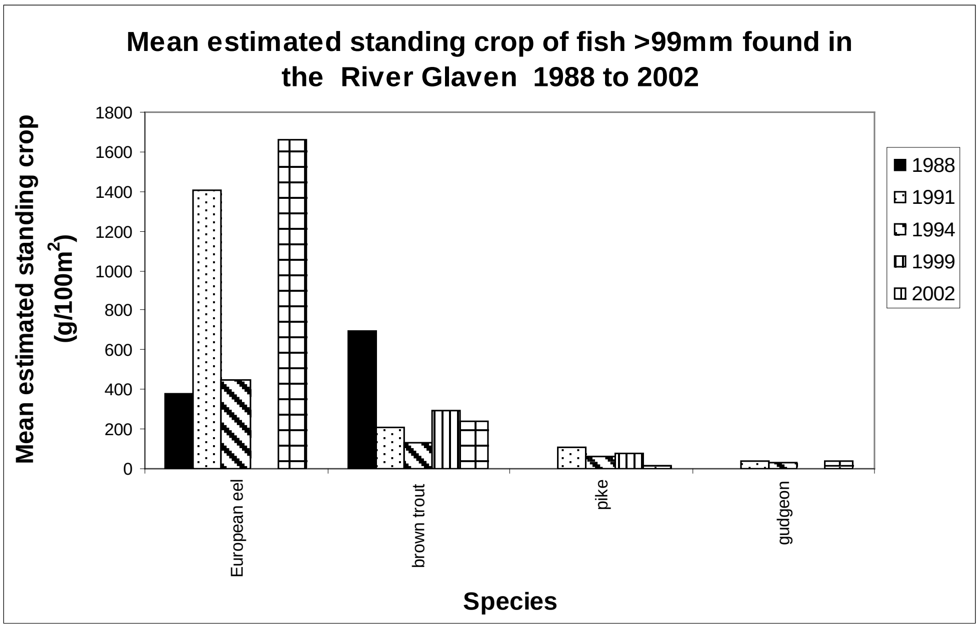


Figure 5.1(b) **Mean estimated standing crop of fish >99mm found in the River Glaven 1988 - 2002**

5.1.2 Brown trout

Sayer and Lewin (2002) concluded that much of the river is unsuitable for wild brown trout production as a result of poor water/ habitat quality, and that the River Glaven Fishery Association's water below Glandford Mill has been heavily dependent on stocked fish for many years in view of the limited natural trout production there (though note that anglers often desire more and larger trout than even a high quality small chalk stream can provide naturally). Their analysis of data from electro-fishing surveys undertaken by the Agency in 1984, 1988, 1991, 1994 and 1999 revealed a 50-90% decline in the brown trout population of the upper reaches, particularly in the Thornage - Hunworth stretch. This part of the river held the bulk of wild brown trout in the Glaven and probably acted as a ‘nursery area’ for first year fish that may disperse to downstream sections. The current River Glaven Fishing Association chairman, David Mostyn, notes that 10-25 cm trout are caught regularly below Glandford Mill, and are assumed to be of wild origin.

Peter Suckling recalls that 10,000 "sea trout" fry were released in the 1970s, but no returns were reported, whilst many of the 800 brown trout stocked each year in the 1980s appeared to drop down to the estuary where they lived as “slob” trout. During this period, there were many escapee rainbows in the lower river. Wilfred Hargreaves Turner (a former River Glaven Fishing Association chairman) caught a few sea trout in the 1990s from the Wiveton area. Though no sea trout have been reported caught recently in the river, they are seen every year in the Association's section in September-October, including c. 10 during 2007. Over the last 8 years, the only known captures were by Carl Sayer from the tidal Glaven close to the Cley beach road, three trout which weighed 5.5 lb (2.5 kg, caught April 2003), 1.5 lb (0.7 kg, May 2004) and 6.5 lb (3 kg, May 2007). The 2003 fish is pictured below. Is it a sea trout, or a slob trout (i.e. it has never ventured beyond the estuary)?

5.1.3 Stocking.

Trout have been stocked regularly for many years on the Glaven, but only below Glandford Mill. Section 30 consent records for 2003-2008 show introductions of between 500 and 900 brown trout in the range 500 – 750 g (approx. 1.1-1.65 lb) in April or May each year, with the exception of 500 x 28 cm rainbow trout in April 2003 and 400 x 28 cm brown trout in May 2005. Between 100 and 500 brown trout of 30-35 cm were stocked each year in 2000, 2001 and 2002 at Wiveton Bridge. Records for 1990 – 1996 show similar annual stockings between Glandford and Wiveton, from both West Acre (Nar, Norfolk: 1994-96) and Belleau Bridge (Great Eau, Lincolnshire: 1990 – 94) trout farms, of between 600 and 1,300 brown trout of 25-35 cm.

5.2 River Stiffkey

5.2.1 Fish populations.

Electric-fishing surveys were conducted in 1988, 1992, 1995, 2000 and 2007 at eight sites on the River Stiffkey, between Great Snoring and Cockthorpe Common, and one on the Binham tributary to the east. There was also a survey at 18 sites within the headwaters of the catchment in 2003.

Ten fish species have been recorded in the Stiffkey: eel, brown trout, 3-spined stickleback, 10-spined stickleback, *Pungitius pungitius*, stone loach, gudgeon, bullhead, brook lamprey, river lamprey and flounder, of which bullhead, eel, brown trout, stone loach and 3-spined stickleback were also found in the headwaters in 2003. The fish community has been dominated by eels, with brown trout the second most abundant in terms of biomass. A summary of survey data for the most abundant species is presented below:

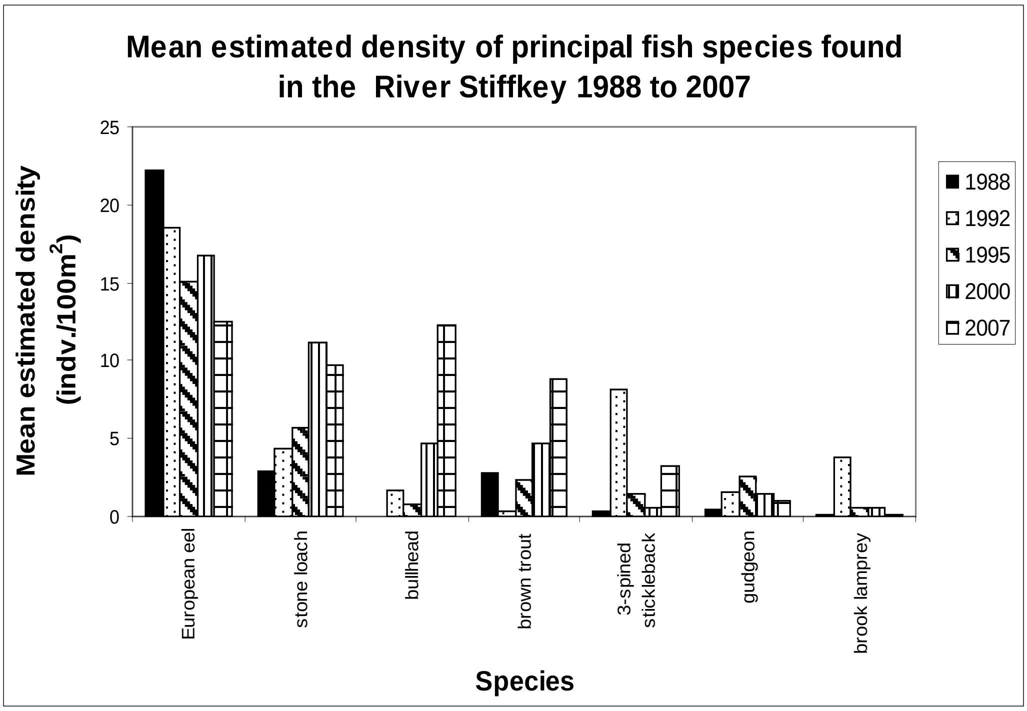


Figure 5.2(a) Mean estimated density of principle fish species found in the River Stiffkey 1988 - 2007

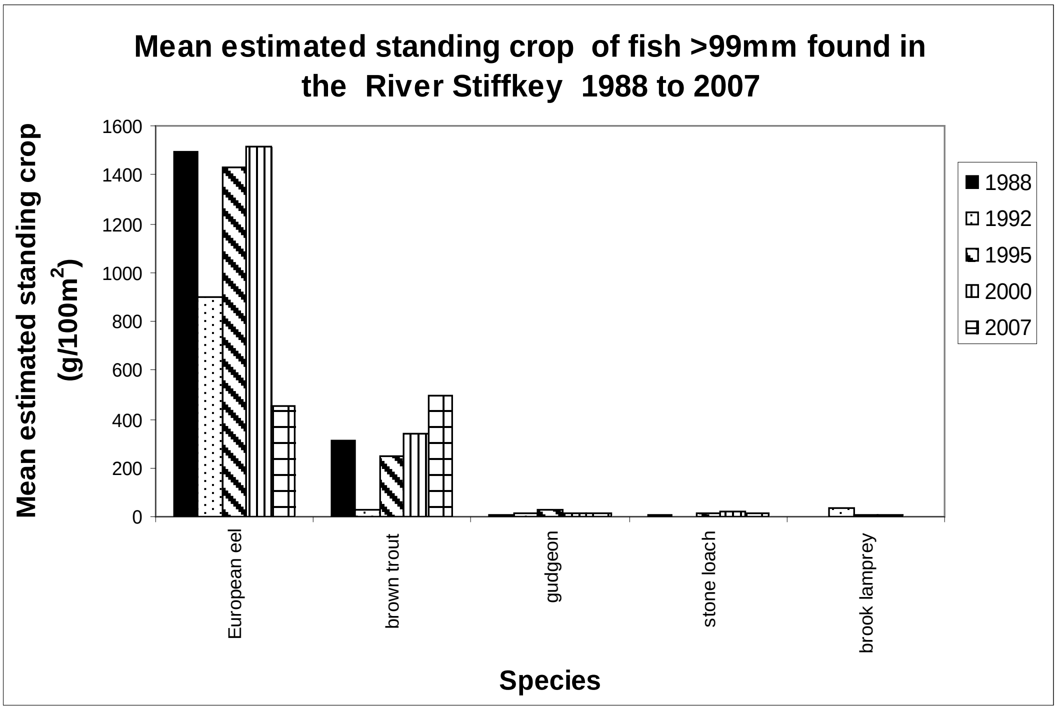


Figure 5.2(b) Mean estimated standing crop of fish >99mm found in the River Stiffkey 1988 - 2007

5.2.2 Brown trout

The above graphs clearly show that brown trout currently comprise a high proportion of the fish community in the Stiffkey and have shown an overall increase in both density and biomass over the last 15 years. Recent surveys, however, have indicated declining trout populations on the

Binham stream tributary (pers comm. Vaughan Lewis, Anglian Water). Survey length frequency data only include a few first-year trout (<10 each year), but given the absence of stocking (see below), the data suggest that the trout population is supported by natural spawning, though the contribution of sea trout to this is unknown. Between 4th May and 10th June 2006, however, the Agency caught 9 smolts in a Rotary Screw Trap positioned downstream of the weir at Church Farm, Warham, ranging in size from 152 to 204 mm (mean 182 mm) fork length and presumably 2-year old fish (S2s, but note the wide length-at-age ranges of sea trout smolts on the Wear, section 3.2).

What angling records that do exist for the Stiffkey are largely anecdotal. Nick Zoll reports that sea-trout are caught in most years, from mid-May through to September depending on the amount of rain, though catches are generally in single figures as very few of the Holkham Club members specifically target them. There appeared to be more than usual in 2007 due to the heavy summer rainfall and, though they were difficult to catch for the same reason, a sea-liced fish of around 2.5 kg was caught and released near Warham in early September.

5.2.3 Stocking.

Section 30 consent records for 2003-2007 show no introductions of trout in that period, and though there are no anecdotal accounts of stocking, 25 x 11" brown trout from West Acre Trout Farm were recorded as being stocked at Walsingham in June 1995. It can be concluded that the River Stiffkey's trout population is reproductively self-supporting.

5.3 River Burn

5.3.1 Fish populations.

The three sites at which electric-fishing surveys have been conducted on the River Burn, at Nelson's Birthplace, Roy's Mill and Burnham Mill, were sampled in 1987, 1992, 1998 and 2004, though Nelson's Birthplace often dries out in summer and has been less often surveyed. In 2005, an additional survey was conducted for Water Framework Directive (WFD) purposes at South Creake, upstream of the routine sites.

Only 4 fish species were recorded on the Burn: eel, brown trout, 10-spined stickleback and 3-spined stickleback. Because only single-pass data exist for 1998, these have been omitted from the following graphs, which show eel as the most abundant species, followed by brown trout, though trout appear to be the most abundant species when the 2005 data for South Creake are included.

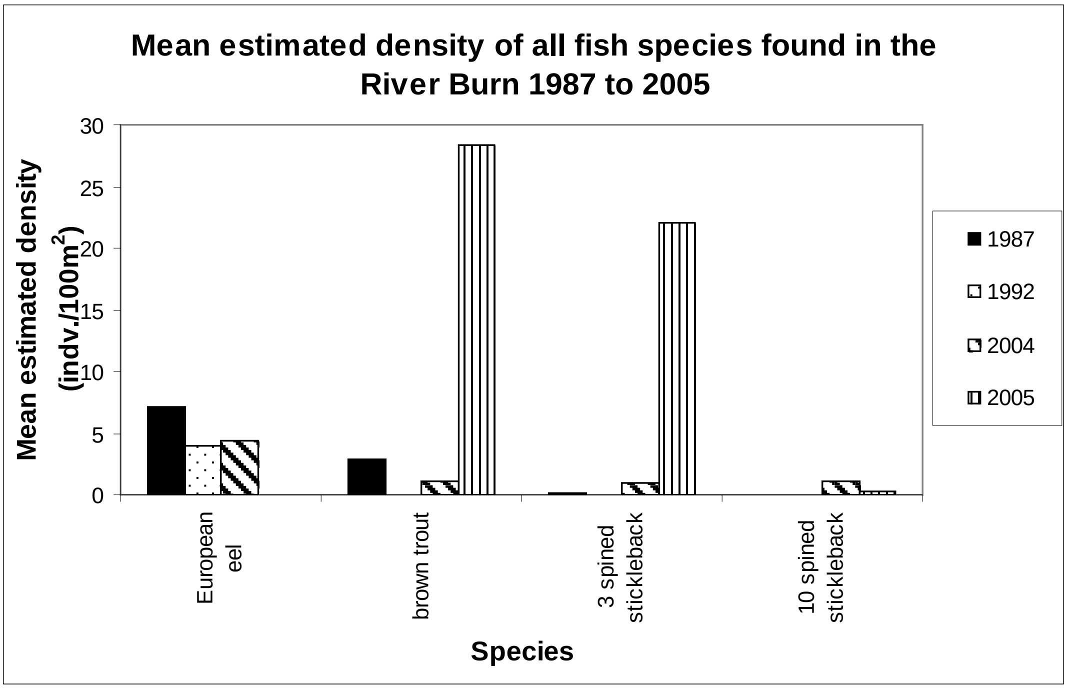


Figure 5.3(a) **Mean estimated density of principle fish species found in the River Burn 1988 - 2005**

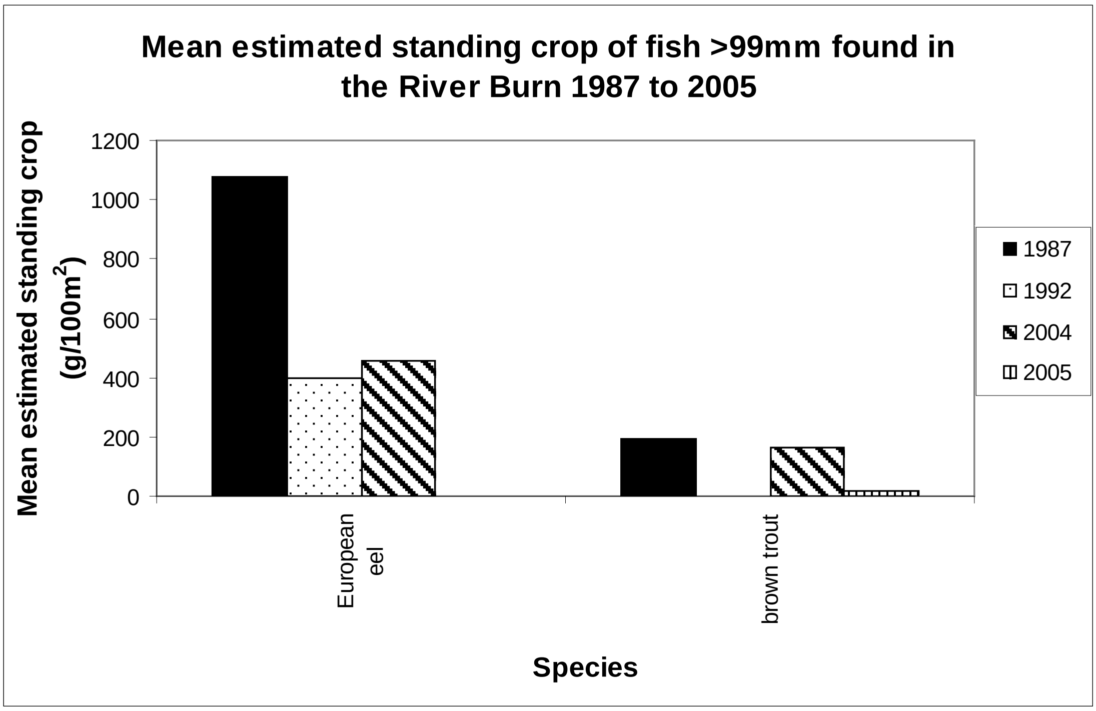


Figure 5.3(b) **Mean estimated standing crop of fish >99mm found in the River Burn 1988 - 2005**

5.3.2 Brown trout

The above graphs suggest that, though brown trout comprise a high proportion of the Burn's fish community, their abundance in survey catches is very variable and especially dependent on the presence of juveniles. The WFD survey at South Creake revealed a much higher density of brown trout in 2005 than at the routine sites in other years and, although these seem to have been mainly smaller fish, this provides evidence that adult brown trout do run up and spawn in this winterbourne.

5.3.3 Stocking.

Though there are anecdotal reports that the Burn is stocked in its lowest reaches, Section 30 consent records for 2003-2007 show only one introduction, of 100 brown trout in the range 679 – 806 g (approx. 1.5-1.75 lb) in March 2004, whilst 225 brown trout of 20-25 cm (near Burnham Mill) and 400 fish of 35 cm were stocked in 2000. Older records, for 1990-1995 show that 57 brown trout from Scarrow Beck (River Bure tributary, Norfolk) were stocked into the Burn in May 1994.

5.4 Nar

5.4.1 Fish populations.

Standard electric fishing population survey were carried at 6 sites on the River Nar between East Lexham and Narford Hall in 1989, 1993, 2003 and 2007. Between 5 and 11 species were recorded each year, the most persistent being brown trout, dace, eels, bullhead and stone loach, whilst rainbow trout and rudd *Scardinius erythrophthalmus* were recorded in two years, and pike, perch, tench, gudgeon and spined loach *Cobitis taenia* were each caught in one year only. Eels were found at all six sites until 2007, and showed a decrease in density (by two orders of magnitude) and biomass (by one order of magnitude) between 1989 and 2007, again reflecting the European-wide decline in eel populations

5.4.2 Brown trout

Brown trout form the dominant component of the upper Nar's fish community, contributing 49% and 65% to the overall weight recorded, with a mean density of 1.42 and 3.3 fish.100m^{-2}, in 2003 and 2007 respectively. Both mean density and biomass were higher in 2007 than in the 1989 and 1993 surveys. The data set suggests that there is no particular pattern in the spatial abundance of trout between West Lexham and Narford Hall, and that juveniles are produced throughout the upper Nar.

The best evidence for natural production of trout in any of the five rivers comes from surveys at Castle Acre on the Nar, which was sampled in 1996 and again in March each year since 2003. Following a decline in the trout population between 1996 and 2004, the estimated biomass has shown a steady increase from 3.3 g.100 m^{-2} in 2003 to 13.2 g.m^{-2} in 2008 (Anon, 2008). The length frequency distributions of trout in these samples illustrate the variability of spawning success in this reach (Table 5.4.1). This ranges from 22 one-year old fish (up to a length of approximately 18 cm) caught in 2004 (2003 year class) to 113 and 84 trout of that size caught in 2006 and 2008 respectively. The last three years (2005-2007 hatching seasons) produced higher numbers of 1-year-old fish than the previous three years, and this was reflected in the numbers of 2- and 3-year old trout caught in subsequent surveys (scale readings indicate that trout usually reach a maximum age of 3 years in the Nar). The 2003 year class was associated with the lowest numbers of trout > 25 cm caught in March 2006 (just 9 fish), whilst the large 2005 year class was manifest when 80 trout of 25-35 cm were caught in 2008. The trout populations at Castle Acre, therefore, appear to be strongly influenced by and may rely entirely on natural reproduction in the Nar, which appears to contain a healthy and expanding wild brown trout population.

Table 5.4 Numbers of brown trout caught in Castle Acre surveys 2003-2007.

Length (cm)	2003	2004	2005	2006	2007	2008
<10	3	0	0	8	2	0
10-11.9	23	9	12	33	6	6
12-13.9	19	5	12	51	29	30
14.15.9	9	5	5	21	19	33
16-17.9	4	3	3	1	2	14
18-19.9	0	0	1	0	3	1
20-24.9	8	20	10	10	37	19
25-29.9	6	7	23	7	23	51
30-34.5	4	1	8	1	2	29
35-39.9	4	1	1	1	1	2
>40	1	2	0	0	1	0

Andy Sadler (Environment Agency) reports that two 60 cm fish, confirmed as sea trout from scales by Agency's National Fisheries Laboratory at Brampton, were caught during a survey between Narborough Mill and the Bone Mill in 2003.

5.4.3 Stocking

The river between the Bone Mill and Narborough Mill has been stocked annually with farmed brown trout for many years by the River Nar Fishery angling club, who control fishing from Narborough Mill down to just above Marham Flume. Section 30 control records for 2003-2007 show annual introductions of 600 – 750 brown trout in the size range (400 – 907 g) in the Nar, generally in April, with a more consistent size of 30 cm since 2005. Between 1999 and 2002, some 325 – 600 brown trout of 0.4 – 1.0 kg (approx. 1-2 lb) were stocked each year. There has been no stocking above Narborough to the Agency's knowledge, and the Castle Acre fishing Club confirm that they are not aware of any stocking over the last 50 years. This section of river is purely supported by the natural recruitment of wild fish.

5.5 River Great Eau

5.5.1 Fish populations

There are 6 sites between Woods farm and Cloves Bridge at which electric-fishing surveys have been conducted on the Great Eau, most recently in 2003 when 13 species were recorded: brown trout, bullhead, common bream, eel, pike, stone loach, flounder, 3-spined stickleback, dace, roach, rudd, tench and rainbow trout. A survey in 1995 also caught perch, brook lamprey, silver bream, *Blicca bjoerkna* and grayling, *Thymallus thymallus*, and eels were then the most abundant species above Claythorpe Mill and roach below.

5.5.2 Trout

Brown trout were recorded at an overall density of 1.9 and 1.4 ind.100m^{-2} in 1995 and 2003 respectively, but occurred only at the three upstream sites above Claythorpe gauging station, where the estimated standing crop of rainbow trout (fish-farm escapees and stocked fish) was around 30% of that of brown trout in 1995 and 40% in 2003. The stretch of the river below

Claythorpe Mill is fished by the Great Eau Flyfishing Syndicate, and brown trout are said to be much less common in catches there than are rainbows. Sea trout are known to have been able to run up the river as far as the pool below Withern Mill, where 5 were caught in one year some time ago.

Evidence for natural spawning in the Great Eau is presented in Table 5.5.1 below, which illustrates the variability of year class abundance between sites and years, with relatively low numbers of 1-year-old fish in 2007 at Woods Farm and Belleau Springs, and none at Claythorpe gauging station in 1995. Records for 1989 show a total of 24, 22 and one trout <20 cm at Woods Farm, Belleau Springs and Claythorpe gauging station, with 4, zero and 14 respectively in 1992.

Table 5.5 Numbers of brown trout caught in Great Eau surveys at Woods Farm (WF), Belleau Springs (BS)and Claythorpe gauging station CGS), 1995, 2003 and 2007 (no survey at CGS in 2007).

Length (cm)	WF 1995	WF 2003	WF 2007	BS 1995	BS 2003	BS 2007	CGS 1995	CGS 2003
<10	1	0	0	2	4	0		
10-11.9	6	3	1	0	10	1		1
12-13.9	2	0	3	6	6	1		
14.15.9	2	4	1	14	7	2		1
16-17.9	5	2	0	1	1	0		1
18-19.9	4	4	2	4	1	0		2
20-24.9	10	7	4	10	0	0	2	1
25-29.9	8	0	0	4	0	0	3	
30-34.5	1	1	0	1	0	0	8	
35-39.9	0	0	0	0	0	0	1	
>40	0	0	0	0	0	0		

5.5.3 Stocking.

The Great Eau is regularly stocked below Claythorpe Mill with rainbow trout, in addition to escapees from the trout farms, whilst brown trout are stocked in the upper beats of the Syndicate's water. Section 30 consent records for 2003-2006 show annual introductions of 100-275 brown and 125 – 750 rainbow trout in the range 450 – 500g (approx. 1.0-1.1 lb) stocked in March and April. In 2007, 300 brown trout at 20-28 cm and 200 rainbows at 453 g (1lb) were stocked between April and June. Anecdotal information suggests that the Eau is being run mainly as a put-and-take fishery for both brown and rainbow trout, at least below Claythorpe Mill, though undersized brown trout were stocked in 2007 upstream of Claythorpe Mill, where attempts to manage this as a brown trout fishery have apparently been thwarted by escapee rainbows from the trout farm

5.6 Conclusion

Despite the lack of evidence for natural reproduction reported by Gray and Mee (2002), all five rivers, Glaven, Stiffkey, Burn, Nar and Great Eau, clearly have self-supporting populations of brown trout, and there is anecdotal evidence that sea trout enter at least the lower stretches where they are sometimes caught. There is, however, no evidence that sea trout are spawning successfully in any of these rivers, nor that juvenile trout produced in these rivers migrate as smolts and return as sea trout (though outward-migrating trout smolts were recorded on the Stiffkey in 2007).

Brown trout were recorded at a mean density of around 2 fish.100m^{-2} between 1988 and 2002 in the Glaven; they increased from < 2 to around 8 fish.100m^{-2} in the Stiffkey between 1988 and 2007, whilst densities in the Burn were generally below 3 fish.100m^{-2}, but with a much higher abundance of first year trout in the South Creake winterbourne. The upper Nar had a mean density of 1.42 and 3.3 trout.100m^{-2} in 2003 and 2007 respectively, and the three upstream sites of the Great Eau had around 4 and 3 trout.100m^{-2} in 1995 and 2003 respectively. In all five rivers, standing crop estimates of brown trout varied between 50 and 350 g.100m^{-2} over the period 1988 to 2007, depending on sampling site and year, with a long term average of around 200 g.100m^{-2}.

In general, habitat modifications to improve drainage and prevent flooding have resulted in limiting good spawning habitat for trout to the upper reaches of these rivers, often above barriers (mills) impassable to sea trout. The trout populations in these upper reaches tend not to be supplemented by stocking (though this is clearly considered necessary to support viable angling fisheries in the lower reaches of the Glaven, Nar and Great Eau), and brown trout are sufficiently abundant in all five rivers to suggest that natural spawning and feeding opportunities there are adequate.

This combination, of restricted reproduction (the available spawning habitat being limited to the upper reaches of each river) and relatively high population growth potential suggests that there is little pressure for these trout populations to adopt an anadromous habit (often associated with high juvenile densities and low production potential in fresh water, Solomon, 2006), which could explain the current relatively low incidence of sea trout in these Anglian rivers. If habitat restoration could extend spawning opportunities downstream (which appears to be being achieved on the Stiffkey), and the upstream penetration of potential anadromous spawners enhanced by easement of passage at barriers, at mills in particular, the production of juveniles should improve and a greater proportion may adopt a sea-going habit. This would benefit both in-river availability of adult sea trout and production of sea trout smolts.

6 Environmental quality of Anglian rivers

This section of the report is intended to identify and explain to stakeholders the most important physical and chemical qualities of a river's water that determine whether it can support a trout population. If the water is too acid, lacks oxygen or is otherwise so polluted that it cannot sustain invertebrate or fish life, then no amount of habitat restoration or removal of barriers will result in more sea trout. The chemical composition of water will vary naturally each day and with the season, as will the inputs from anthropogenic activities such as farming, industry and housing. Much of the latter could be regarded as chronic pollution, which is relatively straightforward to measure but more difficult to track down as a cause of failing fish production, whereas episodal (or one-off) pollution often has very obvious impacts (dead fish in the water). The Agency has developed water quality indices in order to assess the health of rivers, the impact of any discharges into them, and to enable the source of any pollution to be tracked down.

6.1 Water quality

Possibly the most important quality is the amount of oxygen that is dissolved in the water. Generally, the higher the dissolved oxygen value the greater the number of plants and animals that can be supported, and trout are particularly sensitive to low levels of dissolved oxygen. Warmer water or water with a high level of dissolved salts can hold less oxygen. Pollution often causes dissolved oxygen levels in a river to fall due to the increased uptake of oxygen by bacteria and other micro-organisms breaking down organic matter (see Biochemical Oxygen Demand, below), but natural processes can also have a significant effect. For example, photosynthesis by aquatic plants and algae during the daytime produces oxygen that is released into the water, causing the dissolved oxygen levels to increase. At night (or when the sunlight is weak), the plants stop photosynthesising but continue to respire and so use up oxygen. This diurnal cycle can cause wide fluctuations in oxygen levels, particularly during the spring and summer growing season when daylight hours are longer and strong enough to promote a high level of photosynthesis among the increased numbers of plants present in the water, and when there is a strong growth of algae.

The most commonly used measure of the depletion of oxygen in water caused by bacteria and other micro-organisms breaking down organic matter, such as that found in sewage and other effluent discharges, is Biochemical Oxygen Demand (BOD). When more organic matter is present, especially if it is of a type that can be degraded faster than others, there is a corresponding increase for oxygen needed by the bacteria to respire, leading to depletion of oxygen levels. If the water does not have, or is unable to produce, enough oxygen to satisfy the BOD from any discharge, oxygen levels will fall, adversely affecting fish and invertebrate life. Typical levels of BOD (mgl^{-1}) are 1-5 in a clean river and 2-20 for treated sewage, whilst crude sewage might have a BOD of 200-300, farmyard runoff 1500-2000, and silage liquor 60000. A higher BOD, therefore, indicates a more polluted river and a greater threat to trout.

Ammonia occurs naturally in rivers, but it is also a waste product of animals and is often found in high levels in untreated sewage effluent and farm waste. It is directly toxic to fish, increasingly so in more alkaline conditions (higher pH), and the pH in unpolluted chalk streams in the UK is around 9, on the alkaline side of neutral (pH = 7). Sampling in 2004 – 2006 showed a mean pH of 8.02 in the Calceby to Withern stretch of the Great Eau.

Nitrate is an important plant nutrient, and elevated levels can change the balance of aquatic plant and animal species. High nitrate levels in watercourses are associated with nutrient enrichment, or eutrophication, particularly in the winter months when heavy rainfall flushes nitrates from land where agricultural fertiliser has been used. Another source of nitrate is sewage effluent, often entering as a relatively harmless break-down product of ammonia in human waste. Nitrate can also be produced naturally by nitrifying bacteria and blue-green algae present in rivers. A measure of the amount of nitr<u>ate</u> in the water is given as Total Oxidised Nitrogen (TON), which also includes nitr<u>ite</u>.

The main symptoms of eutrophication are algal blooms, both in suspension and on river bed gravels, which can cause unbalanced oxygen levels, and the rapid growth of plant species such as duckweed and 'blanket weed' (filamentous macro-algae), which 'shade-out' aquatic plants such as water starwort, water crowfoot and horned pondweed and so reduce the quality and diversity of habitat for invertebrates and fish. This is particularly evident in the slower flowing, low gradient sections of the Glaven below Bayfield, and in lakes that have received direct river and STW inputs, such as Bayfield Lake, Edgefield Hall Lake and Letheringsett Lake on the Glaven (Sayer and Lewin, 2002).

Because phosphate (measured as Ortho-Phosphorus, Ortho-P) is naturally present at lower levels than nitrate in freshwater and is therefore the more limiting nutrient for plants and algae, it is considered to be the most important factor affecting eutrophication when present at elevated levels. The main source of phosphate in rivers is from sewage effluent containing detergents, although some may enter the river through runoff from agricultural land treated with fertilisers. Because of their catchments' agricultural characteristics, Anglian rivers are at risk of becoming eutrophic, and phosphate is removed from the effluent of larger sewage treatment works prior to discharge to ameliorate this problem. Ortho-P values tend to be lowest at the most upstream sampling points in rivers, and are generally lower in summer and highest in winter.

A less obvious (though immediately apparent) factor in aquatic environment quality is the amount of material suspended in the water column. A clean, healthy river will have low suspended solids and/or turbidity readings. There are two types of suspended solids, both of which may occur naturally or be introduced via discharges. Inert suspended solids most commonly occur when rivers have an increased flow after heavy rainfall, which re-suspends material from the river bed in the water column and receives fresh supplies from nearby arable fields, bank erosion, roads and water treatment works. Organic suspended solids can be re-suspended sediment and decaying vegetation from the river bed or, more significantly, can be introduced via discharges from sewage treatment works or agricultural and industrial operations. This component can create a huge BOD.

Both types of suspended matter eventually settle out of the water column onto the river bed, where they may reduce the populations of macro-invertebrates that are food to fish, infiltrate gravel and prevent fish from spawning successfully, and kill aquatic plants by settling on their surface and preventing photosynthesis. Suspended solids can also reduce the amount of sunlight available to aquatic plants and cause physical damage to the gills of fish.

It should be noted that the detrimental impacts noted above are exacerbated by low flows, which reduce a river's capacity to dilute nutrients and other contaminants, lower dissolved oxygen concentrations (since they are often associated with high temperatures), and impair its ability to flush out accumulating silt. The overall perception is that river flows in the Anglian Region have declined since the 1970s, and this was particularly evident during the late 1980s and early 1990s when flows in parts of the upper reaches were reduced considerably and many tributaries ran dry. The catchments variously suffer from the impacts of water abstractions both for public water supply and agricultural (spray irrigation) and industrial (sand and gravel washing) purposes.

6.2 Assessing water quality

The Agency's General Quality Assessment (GQA) scheme provides a measure of water quality and how this changes over time. For the purpose of this report, I have focused on Chemical GQAs, which are based on levels of organic pollution and are determined using measures of dissolved oxygen, BOD and ammonia, and classify river sites and sections as very good (A-B), fair (C-D), poor (E) or bad (F). Nitrate and phosphate values are presented where readily available. All these analyses inevitably underestimate nutrient concentrations in certain areas and at certain times, for example where there is an influence of organic effluents immediately below sewage treatment works (STWs) or when there are failures at a STW. Further information is available from the Water Quality Public Register of the Environment Agency, Anglian Region.

Biological GQAs use data from standard aquatic macro-invertebrate kick-net sampling and laboratory sorting protocols (Environment Agency, 1999) to indicate the overall "health" of rivers and, as their potential food supply, these are obviously crucial to the welfare of trout. There are a number of such indices, but the most immediately relevant indication of environmental quality is provided by the presence or absence of invertebrate taxa (species groups) that are susceptible to the effects of physical disturbance or pollution. A biological index of water quality has been developed by the Biological Monitoring Working Party (BMWP, National Rivers Authority, 1994), under which the more pollution-sensitive invertebrates, such as stoneflies (Plecoptera), receive a high rating, whereas relatively robust invertebrates, such as oligochaete worms, score low. The BMWP score is the sum of all taxa scores, irrespective of the abundance of each taxon, such that a high BMWP score reflects a low impact of biodegradable organic compounds.

The following resumés of water quality indices for each of the five Anglian rivers are largely based on information provided by the Agency, and are intended to provide an insight to the chemical factors that might be limiting trout production. A more quantitative analysis would require a knowledge of how trout and their food respond to different levels of the various constituents of water (including a vast array of man-made contaminants, see section 7), which is beyond the scope of this report.

6.3 Glaven

Using GQAs based on data from the Agency's seven chemical and biological (invertebrate) sampling sites, Sayer and Lewin (2002) noted that the overall environmental quality of the Glaven is 'good', the best sections being Holt Lowes - Thornage Beck (B) and Thornage Beck - Letheringsett mill (A) in the middle reaches. The two worst sections are Hill House farm Bodham to Selbrigg in the upper reaches, which declined from C (1990-1995) to D (1996-1999), and Glandford ford to Cley Sluice, which declined from B (1990-1994) to C (1995-1999). The former reach has consistently failed to meet water quality targets, and there have been sporadic storm overflows of raw sewage into Blakeney Harbour, where a new pumping station was installed in 2000.

As with many other rivers in the English lowlands, concentrations of P and N are relatively high in the Glaven. The Agency's overview of water chemistry data for the Glaven in 1995-2007 shows a downward trend in TON since 1999 at all sampling points, with modal values at Glandford fluctuating between 4 and 10 mgl^{-1} since 1981, though higher concentrations have been recorded at Hill House Bodham, where TON has generally exceeded 10 mgl^{-1}. Recent TON levels in the Glaven have been around 7-8mgl^{-1}. Ortho-P levels on the Glaven have been relatively stable over the last decade at around 0.03 mgl^{-1} at all sampling points except the furthest downstream, Letheringsett Mill, where they have declined from 0.4-0.8 mgl^{-1} in the mid-late 1980s to around 0.2 mgl^{-1} in 1997-2001 and 0.1-0.15 mgl^{-1} in 2007. Mean BMWP scores for the Glaven over the period 1995-2006 were 87 at Hempstead Mill, 130 at Edgefield Bridge and Letheringsett Mill, and 115 at Glandford Mill.

6.4 Stiffkey

The Agency's overview of water chemistry data for the Stiffkey shows TON values to have been relatively stable in 1995-2007, ranging from around 4-6 mg/l at the most upstream sampling point, Great Snoring Bridge, to around 8 mg/l further downstream. There has been no overall trend in Ortho-P levels at Great Snoring Bridge on the River Stiffkey, at around 0.05mg/l, but a downward trend from peak levels of 0.3 mg/l in winter 1996/97 to around 0.1 mg/l was observed further downstream. Mean BMWP scores for the Stiffkey over the period 1996-2006 were 111 at Great Snoring, 116 at East Barsham, 126 at Wighton and 97 at Stiffkey village.

6.5 Burn

The Agency's overview of water chemistry data for the Burn in 1995-2007 shows an upward trend in TON values at all three sampling points from 1998 until 2004, from around 12 to13 mgl^{-1}, since when there has been greater variability between the South Creake site (generally higher, to > $15mgl^{-1}$) and the two downstream sites (declining slightly). Ortho-P tends to be lower at South Creake, at around 0.05-0.1 mgl^{-1}, than at downstream points, where it has recently been between 0.2 and 0.3 mgl^{-1}, having fallen from a high of up to 0.6 mgl^{-1} in winter 1996/97. Mean BMWP scores for the Burn, 1995-2006, were 61 at South Creake, 87 at Roy's Mill, and 84 at Burnham Overy Mill, which are the lowest values of the five rivers, though there has been an increasing trend in the taxa sensitive to organic pollution (BMWP >6) and a reducing trend in the tolerant taxa (BMWP <4) on the Burn since 2000.

6.6 Nar

Chemical GQA values on the upper Nar have improved over the period 1985 to 2006, but remain relatively poor at C or B downstream to at least Lexham Hall. Below there, emergent springs result in a marked improvement, raising chemical GQA to A at Castle Acre (sustained in 2007), though this falls to B below Bradmoor STW. Phosphate GQA grades show the same temporal and spatially improving trends, at 4 above Lexham Hall to a consistent 2 downstream to the Nar's confluence with the Great Ouse, whilst Nitrate GQA grades are 4 or 5 above Castle Acre, where it is 6, and then a consistent 5 down to its confluence with the Great Ouse.

Sampling on the Nar at Castle Acre has shown an increasing trend in the mean BMWP score, from around 90 in 1992 to 160 in 2004, though mean values in most intermediate years ranged between 110 and 140. Sampling between West Lexham and Narford Hall in March and April 2007 noted excellent biological quality (GQA Grade A), based on the diversity of organisms living in the river and on the riverbed.

6.7 Great Eau

Chemical GQA values have improved on the Great Eau over the period 1985 to 2006, and are presently consistently at B for the river above its confluence with the Long Eau below Theddelthorpe All Saints, and B/C from there to the sea gates at Clover Bridge. Phosphate GQA grades have also improved, and have been at 2 since 2002, whilst Nitrate GQA grades are 6 above the Long Eau confluence and 5 below there. Sampling in 2004 – 2006 in the Calceby to Withern stretch showed a mean ammonia value of at 0.12 $mgNl^{-1}$ and a BOD of 1.5 mgl^{-1}.

The Agency has used macro-invertebrate data from 11 sites in the chalk-stream section of the Great Eau catchment, from Brinkhill to Withern, in 2000 and 2001 to derive a Lincoln Quality Index (LQI, Extence *et al*, 1987). Most sites had a moderate to high species diversity, and the LQI usually indicated excellent water quality, though Burwell Beck, the second largest tributary of the Great Eau, had a relatively low diversity and LQI indicated moderate water quality, most likely due to a combination of pollution from livestock farms and discharges from septic tanks in Swaby village.

6.8 Conclusion

The information given above suggests that water quality in the five Anglian rivers is generally good to excellent, and the upper reaches in particular are certainly capable of supporting trout, as evinced by the fish population data presented in section 5 and by the high macro-invertebrate quality indices. Impacts from STWs, fish farms and "industry" are generally negligible, whilst agricultural inputs appear to be the greatest threat, albeit a lessening one (see Catchment Sensitive Farming Programme at 7.7 Solutions).

7 Factors potentially affecting the production of sea trout, and opportunities for management

7.1 Introduction

The previous sections of this report have presented an account of what is known (and available) about the Rivers Glaven, Stiffkey, Burn, Nar and Great Eau in terms of their physical and environmental characteristics and the fish (especially trout) populations inhabiting them. This provides a basis upon which the Anglian Rivers Sea Trout project can identify and then act to ameliorate the factors that limit production of brown trout and its anadromous form. There are many conditions that limit sea trout production, such as degraded habitat for spawning and juvenile production in freshwater, increased mortality due to pollution, fishing or predation, barriers to accessing productive areas, both at sea and in freshwater, including our knowledge and ability to conserve sea trout and their environment and manage their fisheries.

A point made repeatedly at the International Sea trout Conference in Cardiff in 2004 (e.g. Walker et al. 2006), is that brown trout and sea trout are two life-strategies of the same species, *Salmo trutta*. Therefore, we cannot consider threats to sea trout without being mindful of the factors that limit wild brown trout production in freshwater. These factors can be grouped into three broad categories:

- Degradation and loss of habitats
- Sources of mortality, and
- Climate change

7.2 Degradation and loss of habitat

When considering threats associated with habitats, there are those that prevent the fish from gaining access to and utilizing suitable habitats, and those that limit the productive potential of these habitats.

Weirs and other barriers stop fish from accessing habitats for feeding and breeding. In each of the five rivers under consideration, there are a number of obstructions that prevent or reduce migration, both between the sea and freshwater, and within the freshwater system, and constrain the colonisation of suitable habitats. Apart from on the Stiffkey, water mills appear to be the main barrier to the fishes' upstream passage, and are also likely to result in an increase in mortality. Though recent drives for renewable energies may result in greater use of hydro schemes like barrages and run-of-the-river turbines, which may impact the migrations of juvenile and adult trout, this is unlikely to be a factor on Anglian rivers.

Two factors that can impact the quality of habitat in relation to trout production are increased sediment loading and the presence of contaminants. Changes in land use and agricultural practice over the last 50 years mean that more silt has entered rivers than in the past, and there is concern that in some parts of England and Wales increased sediment loads in water courses may be having a significant impact on trout stocks. This is particularly apparent in Anglian rivers, where the traditional *status quo* of operating mills and river-side fields put down largely to pasture has been replaced by intensive agriculture and non-operative sluices, as well as over-deepening and widening in attempts to improve drainage and for flood prevention during the 1970s (and still continuing in the Glaven and Great Eau). Silted-up stream gravel means there are fewer areas for trout to spawn, and infiltration of silt and fine sediments into trout redds on existing gravels fills gaps within the gravel matrix and reduces its permeability to water and the supply of oxygen to the eggs. As a consequence, fewer eggs and young fish survive. Fine silts also act as a pathway and store for toxic metals and organic compounds, which bind to their surfaces.

Competition for good spawning habitat between salmon and sea/brown trout is not a problem in Anglian rivers, where salmon seldom if ever breed, though this in itself may indicate that good juvenile salmonid habitat is limited on these rivers.

There is a growing awareness that a range of chronic, sub-lethal pollutants may be having an impact on fish reproduction and recruitment and may be limiting the restoration of healthy, self-sustaining trout populations. These contaminants comprise a wide range of man-made chemicals, including pharmaceuticals, veterinary medicines and pesticides, and natural or synthetic endocrine-disrupting chemicals. There is evidence that certain trace contaminants have significant effects on salmonids and other migratory fish at "sensitive" stages in the life cycle (e.g. reproduction, embryo development, migration and seawater entry: Lower & Moore, 2007; Jaensson et al., 2007), and this gives rise to concern over others with similar properties, especially where they might have additive impacts.

By their very nature, pesticides are lethal to living organisms. Indeed, where pesticides are used inappropriately and exceed acceptable levels, they can cause significant fish kills or destroy the aquatic invertebrates upon which fish rely for food. Examples are spills and leakage of sheep dip into upper reaches of rivers and the increased use of herbicides and insecticides, all of which impact on the survival of young trout in fresh water. Gross pollutants such as ammonia (e.g. from slurry) and substances that suffocate fish by creating a high BOD are still a problem in some areas.

Reduced flow regimes, through changes to precipitation patterns, abstraction, and/or competing uses of the water resource, may concentrate contaminants. The extent to which these may be having an impact on wild trout production in Anglian rivers is not known.

Water quality in estuaries can be a significant threat to migrating fish and, though there have been huge improvements to many estuaries in England and Wales over the past 30 years or so (e.g. Tyne), pressures on this environment are increasing. For example, construction of port facilities and estuarine barrages may modify the flow characteristics, temperature and water quality of an estuary. This may be less of a problem in the five Anglian rivers (though note proposals for navigation on the lower Nar) than in other sea trout-producing areas with industrial and urban development around estuaries (e.g. north-east England and south Wales)

It has been suggested that, since sea trout are less dependent than salmon on spates to trigger migration from the sea into freshwater, they are potentially less exposed to the effects of poor water quality in estuaries. However, many populations of sea trout move in an out of estuaries for feeding and prior to their spawning migration (as on the Burn). Under these conditions, the fish may be exposed to poor water quality and be further at risk from contaminants through prey items they consume.

7.3 Sources of mortality

7.3.1 Aquaculture

Studies conducted over 20 years strongly suggest that the marine salmon farming poses a threat to sea trout stocks migrating through coastal waters (Gargan *et al*., 2003), and strategies are now in place to limit the placement of aquaculture facilities in sea lochs with significant runs of migratory salmonids. Whilst this is not an issue affecting Anglian sea trout, in-line trout farms on the Nar and Great Eau may contribute increased sediment and organic matter loading to these rivers, raise water temperatures and enable pharmaceuticals, disease organisms, parasites and non-native fish species to enter water courses. Water intakes from a river to trout farms (or any other intakes, for that matter) constitute a potential hazard for downstream migrating smolts, and all such intakes should be screened to prevent smolt entry.

7.3.2 Exploitation

Sea trout runs are monitored in several rivers around the UK, and we can compare the numbers caught and killed in fisheries (both commercial nets and rod-and-line) with the numbers of fish entering the rivers. Agency counter and catch data for the Kent, Lune, Fowey and Tamar in England, and the Dee in Wales, indicated that between 3 and 20% of the sea trout entering these rivers during 1993 to 2004 were caught by anglers (Shields *et al.*, 2006). However, many sea trout anglers practice catch and release, and the proportion of the run actually killed by anglers was lower, at <3 to 10%. Exploitation of these stocks by nets has been <1% in recent years, due to some extent to restrictions on the salmon fishery and resulting reductions in netting effort. Whilst Russell *et al*. (unpublished) estimated an overall annual mortality of the order of 70% for sea trout populations in rivers in north-east England, they were not able to apportion this between exploitation (neither in the north-east coast nor Anglian fisheries) and natural causes, and suggested that these sea trout are naturally relatively short lived compared to other stocks in the British Isles, returning as 1 SW spawners (comparable with salmon grilse). There is very little comparable data on the exploitation of brown trout – which may form part of the same population.

7.3.3 Predation

Predation is a normal part of the biology of any species and trout form part of the diet of a wide variety of predators. The main known fish predators in freshwater are pike, trout, zander *Stizostedion lucioperca* and eel, otter and mink *Mustela vison*, and goosander *Mergus merganser*, red-breasted merganser *Mergus serrator* and cormorant *Phalacrocorax carbo*. Cod *Gadus morhua*, pollack *Pollachius pollachius* and saithe *Pollachius virens*, and dolphin *Lagenorhynus* spp and seal *Phoca vitulina* and *Halichoerus grypus* are the main known threats in coastal areas. Assessing and quantifying any predator's impact on stocks is difficult, and determining whether the level of predation is unnaturally or unacceptably high is even more difficult, since we have no benchmark of what constitutes a "normal" level, and estimates can vary widely from site to site and over time.

Fish, especially young fish, are vulnerable to predation by birds, and cormorants in particular. Following a significant increase since the 1970s, there are currently around 1,600 nesting pairs at inland sites and 10,000 over-wintering cormorants in UK inland waters. Reasons for this may include the increased availability of prey in stocked reservoirs and gravel pit fisheries, legal protection from persecution, and immigration of a separate sub-species from the nearby continent. Whilst cormorant numbers are more likely to respond to fish abundance than to limit it, they can have an impact on stocks and catches in stocked fisheries (e.g. in Loch Leven, Stewart *et al.*, 2005), but there is little evidence that this applies to wild trout in rivers.

Historically, the culling of predators has been considered a legitimate management option in salmonid fisheries. However, many predator species are now protected under UK and European legislation and, while killing some avian predators under licence is still possible, this can only be carried out where there is evidence of 'serious damage' to the fishery. Thus, alternative management measures (e.g. habitat management) need to be sought in order to minimise the impact from predators (see "Protecting your fishery from cormorants", produced for anglers and fishery managers by the Moran Committee Joint Bird Group: www.cormorants.info).

7.4 Non-native species and diseases

There is a potential significant risk to any native fish from the spread of parasites and diseases from Europe or the rest of the world, and transferring non-native fish can also damage native fish communities through competition, habitat loss, predation and cross-breeding. This is a potential threat, but may not be relevant to Anglian trout at present, except where rainbow trout are competing for space and food (e.g. in the Great Eau).

7.5 Stocking

Managers are always under pressure to allow stocking of trout and salmon to supplement natural production. However, there is growing evidence that the only beneficial effect of stocking is to temporarily increase anglers' catches, and it may well have detrimental effects on the native stock (Ferguson, 2008). An often quoted exception is on the River Tyne, where stocking from the Kielder hatchery may have assisted the recovery of the salmon stock as river quality improved (Milner *et al*., 2004), but sea trout in the Tyne also recovered at a similar rate despite very little stocking.

There are many examples of sea trout runs arising from introductions of brown trout, and some examples where resident trout populations may retain a residual potential to produce sea trout. A prime example is trout in the Kielder Burn where, despite being isolated from the sea by Kielder Reservoir, trout smolts are still trapped migrating downstream every spring (Environment Agency, pers. comm.). In contrast, others report the establishment of resident brown trout populations from stocking with progeny of sea trout (e.g. Walker, 2006). We have very limited understanding of what drives a juvenile trout to become a sea trout or to remain in freshwater throughout its life, and programmes stocking juvenile “sea trout” may have no discernible benefit to the migratory component of the population.

7.6 Climate change

Climate models suggest a marked increase (for example, 2-3°C, Hulme *et al*., 2002) in average annual temperatures by 2080, compared to the 1961-1990 baseline, and even higher increases for some regions, possibly as much as 5°C in summer in East Anglia. Such a change will undoubtedly affect trout and their environment. Extreme temperatures (above approx. 23 °C) may be lethal, but the effects of sub-lethal temperatures on growth and maturation are more difficult to predict. Trout have a cool and narrow temperature range for positive growth (4-19 °C: Elliott *et al*., 1991, 1994), and studies based on historic data and future projections of growth of trout in English and Welsh rivers suggest that a warmer climate may have a negative effect on juvenile trout growth in freshwater (Davidson *et al*., 2006).

Recent studies suggest that there may be genetic control over the extent to which migratory and non-migratory forms of trout are expressed in different situations, and the adoption of a sea-going strategy is controlled by both genetic and environmental influences (Ferguson, 2006). It is suggested that juveniles are more likely to migrate to the sea when this combination of factors exceeds a threshold, which may vary between individuals and between populations. If juvenile growth rate influences the ‘choice’ of life history strategy, climate change effects could have major implications for the relative proportions of resident and migratory trout produced by different populations. However, we lack sufficient understanding of this process to do more than speculate at this time.

Another potential threat to sea trout stocks may be modifications to the freshwater environment (for example due to general climatic change - which may be more complex than just warming - and/or changes in flow regimes due to agricultural and other land-management practices, such as groundwater abstraction), that result in changes to the thermal regime, thereby reducing the habitat available to adult sea trout and affecting their survival and reproductive success. Higher temperatures raise metabolism and cause energy stores to be used up more quickly, which reduces their ability to reach spawning areas and to produce viable eggs. Furthermore, egg and alevin survival is reduced in Atlantic salmon at higher temperatures (King and Pankhurst, 2004 a,b; King *et al*., 2003). The presence of water exceeding a particular temperature threshold may also act as a thermal barrier, preventing fish migrating to the spawning grounds until the occurrence of suitable freshwater conditions. Under these conditions, the fish may be vulnerable to increased exploitation, predation or poor water quality.

In addition to these temperature changes, the climate models suggest drier summers in future and more frequent storm and high rain events in the autumn and winter. While increased river flow events in autumn and winter may provide trout with easier access to spawning areas, more frequent and more powerful winter spates may damage spawning habitats and destroy redds, and bring increased sediment run-off and siltation. Summer droughts may delay their migration into freshwater, increasing their susceptibility to exploitation and predation in coastal waters and estuaries.

7.7 Solutions

These potential threats to populations of sea trout appear to present a daunting challenge to those who would seek to address them, whether as managers, conservationists or anglers. There are, however, many opportunities to restore or enhance habitats and reduce anthropogenic impacts on the sea trout stocks and their environment. The Glaven and Stiffkey provide apposite and recent examples of local works to restore or enhance physical habitats to benefit trout and sea trout.

In some catchments, fishery owners and the Agency have invested in 'Landcare' projects to minimise the amount of silt entering rivers from agricultural land, and in regular gravel cleaning to flush out silted spawning beds. Where gravel cleaning has been undertaken, there is convincing evidence that more trout or salmon eggs survive (Scott and Beaumont, 1994; Riley *et al.*, 1999).

The Catchment Sensitive Farming Initiative, a joint venture between the Agency and Natural England funded by Defra, aims to tackle diffuse water pollution by encouraging best practice in use of fertilisers, manures and pesticides; promoting good soil structure to minimise run-off and erosion; protecting watercourses from faecal contamination (e.g. with fencing and livestock crossings), and from sedimentation and pesticides (e.g. with buffer strips); reducing stocking density or grazing intensity; reverting to grassland etc. The Nar, North Norfolk Rivers and Lincolnshire Coast Rivers are all priority catchments for this programme (2006 – 2008 report at: http://archive.defra.gov.uk/foodfarm/landmanage/water/csf/documents/ecsfdi-phase1-report.pdf).

The Agency has developed a national strategy to reduce eutrophication or to mitigate for its impacts on vulnerable waters. They collaborate with water companies and the agricultural community to make best use of the regulatory framework, as well as providing incentives, educational and voluntary measures to reduce diffuse and point sources of pollution. The implementation of the EU Water Framework Directive will give this issue added prominence, since it aims to improve habitats and water quality and quantity and will use fish (among other flora and fauna) as ecological indicators to assess the status of water bodies. Further information can be found at "www.environment-agency.gov.uk/wfd".

By 'fingerprinting' sediments, it is possible to establish their origin, thus allowing remedial measures to be targeted (Collins *et al*., 2008). If the majority of the sediment is from the catchment surface, control measures have to be targeted at farming practices. If, on the other hand, the sediment is from the channel bank, bank stabilisation and fencing may be more appropriate (see section 8).

In recent years, we have become increasingly aware of the potential problems for salmonids due to water-borne contaminants. Whilst this presents us with a huge task to establish which of the numerous contaminants are the most damaging to stocks, our improved understanding of the more subtle effects of contaminants provides opportunities to promote changes in their use and thus reduce their impacts. For example, recent work by Cefas in conjunction with the Agency and other stakeholders resulted in a ban on the sale of cypermethrin-based sheep dips, which have been shown to have serious impact on reproduction and embryo survival in the Atlantic salmon (Moore and Waring, 1994; Lower and Moore, 2003; Jaensson *et al.*, 2007).

Barriers to migration (not just for sea trout, but for resident brown trout to spawning areas) were noted as significantly limiting the use of some potential productive habitats in Anglian rivers. Removing these barriers may not be practical or desirable for other reasons (such as the spread of the North American signal crayfish, *Pacifastacus leniusculus* on the Glaven), but the Water Framework Directive is relevant to issues of connectivity and barriers to fish migrations, and may offer opportunities to implement measures to provide fish passes in obstructions.

7.8 Research

All these opportunities for conservation and management are limited to some extent by our scientific knowledge. To this end, research has been directed to further our understanding of trout population dynamics, the factors that influence them, and the mechanisms we can use to best conserve stocks and manage fisheries. These initiatives can be grouped under three broad headings:

- Resource monitoring and stock assessment;
- Processes and responses to pressures; and
- Supporting management

7.8.1 Resource monitoring and stock assessment

Fisheries management requires a quantitative, risk-based framework for measuring and evaluating stocks, fisheries (including socio-economic features) and habitat resources. This may include monitoring programmes of juveniles, smolts and adult sea trout; tracking studies to investigate their habitat use in relation to environmental cues (e.g. Riley *et al.*, 2006; Bendall *et al.,* 2005); GIS studies of habitat utilisation based on juvenile surveys (Coley, 2003); and providing information to ensure the sustainable management of fisheries.

For this to be successful, it is necessary to be able to assess the status of sea trout stocks and establish management targets (see section 9), and the Agency are developing a sea trout stock assessment report along the lines of the annual salmon stock status report for England and Wales (Anon, 2008). One area of research that is supporting this assessment is the partitioning of angling effort between salmon and sea trout. There is a requirement for anglers to report sea trout catches to the Agency, but until recently, anglers only reported their total fishing effort for both species combined. However, all migratory salmonid angling effort reported for the Anglian region rivers will be for sea trout, but only one sea trout caught by rod-and-line has been reported in recent years, and we need to know whether the returns made are actually representative of both fishing effort and catches of sea trout in these rivers.

7.8.2 Processes and responses to pressures

The interpretation of stock and fishery assessments and practical management of fish and their environment require a good understanding of the natural processes regulating fish populations and their responses to management intervention. Research to develop the River Fish Habitat Index is aimed at understanding the relationship between fish stocks and production, the productive potential of waters, and life history strategies, and focuses on habitat utilisation of juvenile and adult salmonids (Wyatt *et al.*, 2007).

To better understand the linkages between fish populations and habitats and to determine the effects of human activities on the physical habitats in freshwater and estuaries, work is being conducted on tracking of adult and juvenile salmon and sea trout (e.g. Riley *et al*., 2006; Bendall *et al*., 2005); optimising fish habitat descriptors (Wyatt *et al*., 2007); evaluating the effects of land use practices on habitats (e.g. sedimentation, see Smith *et al*., 2003); modelling sediment levels in salmonid spawning gravels (Defra project SF0225), tracing sediments back to source, and developing flow protection criteria.

Research to determine the effects of human activities on water quality and the implications for fish stocks is looking at factors that affect distributions of adult and juvenile salmonids; the effects of diffuse pollutants such as pesticides and endocrine disrupters, and acidification; effects of barriers on water quality; and synergistic effects of sediments and associated contaminants on egg and juvenile survival and development.

In order to understand and forecast the effects of environmental change, including long-term climatic change, on future conservation of fish stocks and management of fisheries, research is being carried out on the effects of varying flow on juvenile salmonids (Riley *et al.*, submitted), migration of smolts and adult sea trout (Bendall *et al.*, 2005), changes in age structure, growth rates and maturation rates.

Last, but not least, there is a need to understand the effects of predation and predator control, diseases and parasites.

7.8.3 Management practices

Practical fisheries management requires methods to monitor fish stocks (using, for example, electro-fishing, netting, automatic counters); to manipulate or restore habitat; to ensure fish passage and to manipulate stocks and protect them from parasites and diseases through control of rearing, transfers and stocking. These apply across rivers, still waters and estuaries.

Research to this end includes remote fish observation methodologies (most recently with the Didson acoustic camera), tag developments (data storage tags such as the Cefas G5s), and splitting fishing effort between salmon and sea trout. Guidance is being developed on methods to protect and improve habitats and environments for fish, including GIS analyses, gravel cleaning and reversing sedimentation, managing abstraction (flow protection criteria); fish pass designs; and effective water quality standards (e.g. impacts of diffuse pollutants).

This also includes methods to evaluate the use of stocking as a management tool, identify optimum methods of stocking, and determine the effects of released fish on wild stocks. To this end, the Agency has developed a trout stocking policy (Anon, 2003), trialled the use of triploid trout (Chatterji *et al*., 2008), and collated the results of studies of potential genetic impacts (Ferguson, 2007), impacts of non-natives and effects of climate change, and the impacts of fish farms (contaminants, introductions).

7.9 Conclusion

It is apparent that there are many factors that potentially constrain trout and sea trout production, and that we have a limited (but improving) understanding of their effects and how to manage them for the better conservation of trout stocks and management of their fisheries.

Though there have been significant improvements in water quality in most of the rivers of England and Wales in recent years, including Anglian rivers, habitat damage continues to limit wild trout production. Work continues on habitat improvement and controls on impacts, backed up by national and international legislative efforts and research to better understand these limiting factors, which should help to increase and support sustainable trout and sea trout stocks. However, the effects of sub-lethal mixtures of chemicals, including some known to disrupt the endocrine systems of fish, are largely unknown, but are suspected to be significant. Research in this area is now being given high priority.

Climate change is emerging as a major consideration in fisheries management. Whilst temperature changes alone may have direct effects on trout stocks, warmer, drier summers and increased severity and frequency of flooding would also impact on sea trout production. Rising temperatures may also increase the variety of fish species and fish diseases that can survive in our climate. Strict disease and parasite screening of fish destined for transfer into the wild, together with controls on the movement of non-native and non-indigenous fish into and around the country, are essential. Understanding the effects of climate change on freshwater fisheries will be a major challenge over the next decades.

In considering the threats, and potential opportunities, for sea trout and trout in general, we should not lose sight of the fact that *Salmo trutta* is a very adaptable and opportunistic species, with a flexible life strategy that enabled it to re-colonise British rivers after the last ice age. In short, trout can adapt to a changing environment, but this adaptation might not proceed in the direction we expect or want. For example, increased nutrients in freshwaters may enhance juvenile growth and productive capacity, leading to a reduction in the drive to migrate to the sea, i.e. fewer sea trout. For the moment, we simply do not know enough about the mechanisms that influence this ‘choice’, in order to go further than speculating on such scenarios.

8 The habitat needs of trout.

8.1 Habitats for feeding and hiding

In order to better understand the ecology of trout in the Anglian rivers covered by this project, it is useful to view them as small chalk streams that have been modified to provide irrigation, “improved” drainage, and energy, and as sources of drinking water either direct from their aquifers or by extraction. They still retain some typical chalk-stream characteristics, having a tightly contained channel system, with a relatively rapid and sustained flow of high quality water at moderate (to trout) year-round temperatures, except where abstraction or pollution have made their mark. This contrasts with the considerable variation in water flow and temperature that trout experience in their more usual spate river habitats.

The spring-fed chalk streams of central southern England have historically been held to represent all that is good as brown trout habitats and fisheries, but they are generally far from natural in their topography and character (Solomon, 2005) and have been heavily managed as fisheries for well over a century (Riley *et al.* in press.). Despite this, there has been relatively little research on the ecology of trout in chalk streams, apart from that of most direct interest to anglers (i.e. entomology). However, an intensive study on habitat use by juvenile brown trout and how trout populations respond to management of their physical environment has recently been conducted on carriers of a mid-river reach of the River Itchen in southern England. These are, effectively, small chalk streams similar in character to the five Anglian rivers (where they have not been over-deepened or widened), and contain wild populations of salmon, trout, grayling, pike, minnows, *Phoxinus phoxinus*, bullhead, stone loach and eels (Riley *et al.* 2006). They can thus be considered as having essentially “wild” natural ecosystems, which have been monitored both under the prevailing “natural” conditions and when subject to events such as the opening of previously closed riparian canopy and its subsequent re-growth, and modifications to discharge (by manipulating hatches, to simulate droughts down to 10% of “normal” August flow). The results of this research provide an insight to the way in which trout use the available habitat, their preferences, and implications for management.

In order to enable the movements and habitat preferences of individual fish to be monitored undisturbed under “natural” conditions, trout (and most other fish species) at one study site were caught each summer, using electric fishing, and scanned for the presence of a Passive Integrated Transponder (PIT) tag. Those without a tag (usually 0+ groups = first year fish) were PIT tagged and had their adipose fin clipped (Riley *et al*. 2002). Their movements were then monitored using PIT antennae systems fixed across the stream (Wyre Micro Design Ltd, Lancashire, UK), while arrays of PIT antennae within the stream determined their microhabitat use (see Riley *et al.* 2003 for details). Under these conditions, it was found that trout utilised a wide range of habitats that varied by season and by day and night, and by age, with older trout tending to occupy water of increasing depth and velocity.

In their first year, trout were found along the shallow (5 - 10 cm) and slow flowing (-0.1 – 0.4 ms^{-1}) margins of the stream, among tree roots by day in early autumn and on silty substrates by day in winter and at night in both seasons. Trout in their second year were more likely to be associated with mud, gravel and chalk substrates, although a strong preference for sand was noted at night in autumn. Older trout tended to avoid marginal habitats such as tree roots and reeds, and to increasingly use coarse substrates, showing a preference for gravel and weed at night in winter, at a depth of 50 – 55 cm and a velocity of 0.5 – 0.7 ms^{-1}. This preference for gravel (and weed) and faster-flowing locations was possibly due to a shortage of deeper areas in these shallow streams

Although it is unlikely that restoration work in Phase 2 of the Anglian Rivers Sea Trout project will be concerned with microhabitat *per se*, it may be useful to understand what this means and how it is measured. In Riley *et al.'s* studies, water depth was measured to the 5 cm below, whilst water velocity was determined (over 60 seconds) in mid-water using a Valeport ‘Braystoke’ BFM002 current flow meter (accuracy: +/- 0.01 m s^{-1} reading below 0.5 m s^{-1}; +/- 2.5% above 0.5 m s^{-1}). Substrate types were visually grouped according to Wentworth’s size classification (see Folk, 1980): 0.063 – 2 mm in diameter recorded as sand, and 2 - 63 mm as gravel. Other substrate categories were visually allocated as silt (fine, soft and easily dispersed), mud (fine, relatively hard and permanent), chalk (bedrock), peat (hard) and aquatic macrophytes (plants), emergent reeds and tree roots. Details of adjacent bank and over-head canopy were also recorded. Other technical details of this work can be found in the respective publications, but it is worth noting that estimates of the abundance of trout (and all other species) were obtained by electric fishing surveys conducted according to the Agency protocol given in section 5. The maximum likelihood model of Carle & Strub (1978) was used to determine the population size (with 95% confidence limits) of each age group of trout obtained from electric fishing surveys. This figure was then divided by the site area to give the fish density per m^2.

To determine whether the removal of closed tree canopy affected the production of macro-invertebrate prey and/or juvenile salmonids, a long-term study was instigated by cutting back the closed tree canopy along two wooded stretches in two different streams and then allowing it to re-grow, whilst maintaining another two adjacent open stretches of the same streams that contained few large trees and therefore had little or no riparian canopy cover (and little shading). Surveys of marco-invertebrates were undertaken at the four sites in May and October prior to, and for two years after, the canopy at the two wooded sites was removed (Riley *et al.,* in press). In each survey, the invertebrates in sub-samples were sorted, identified and counted to family level, and raised to whole sample numbers for which dry-weight biomass was calculated. Prior to canopy removal, the mean biomass of invertebrates was significantly greater at the open sites, and remained so for up to 10 months after canopy removal. By the following spring, however, there was no significant difference between open and previously wooded sites, though on one stream the trend of decreasing difference was reversed by October (22 months after canopy removal), and the mean biomass of invertebrates was once again significantly greater at the open site.

The effect of tree canopy shading on aquatic macrophytes (primarily *Ranunculus* spp.) was assessed by visually estimating the percentage weed cover across the entire stream-bed, each month. After the canopy was removed, aquatic weed cover increased over the next 2-3 years, but as canopy re-growth gradually resumed, shading increased and there was a decrease in seasonal weed coverage at the previously wooded sites. Before canopy removal, 0+ trout had occurred in the open sites at more than twice the density than in the wooded sites, but after canopy removal, trout densities increased at the previously wooded site in association with increased weed cover (in summer). Overall, however, densities of 0+ trout tended to be higher at the open sites than at the wooded sites, whereas older trout were more abundant in at least one of the wooded sites.

During low flow, 0+ group trout showed an increased preference for gravel in mid-stream and a reduced use of mud and tree roots in the margins (which were both probably out of the water under low flow conditions), whilst older trout tended to occupy relatively faster flowing locations in deeper water by day and shallower water by night, showing an almost exclusive preference for gravel during the day, and for gravel and aquatic weed at night.

During the low flow periods (over two summers), mortality rates of 0+ trout were estimated to be at or above the high end of the range observed in “normal” flow years (0 – 4% per week). Mortality within the study site was higher than in the stream as a whole, and there was little or no net movement of 0+ trout into or out of the study site. Though some older trout moved frequently in and out of the study site during the control periods of normal flow, fewer moved during the low flow periods. From a management perspective, it is important to note that the increase in the mortality rate in 0+ group trout may be related to their relatively small size and increased vulnerability to predation under low flow conditions, and to the loss of stream margins that are their preferred habitat under normal flow.

These observations on habitat use and preferences by trout in chalk streams can be compared with those in the literature that are mainly based on rain-fed pool and riffle rivers, which contain a greater diversity of substrate types and depths and may, perhaps, be considered more typical salmonid habitats than chalk streams. Armstrong *et al.* (2003) reported that newly emerged trout prefer shallow (<20 – 30 cm) slow flowing (0 - 0.20 ms^{-1}) riffle margins that offering suitable refuges, and Maki-Petays *et al.* (1997) reported that juvenile trout favoured habitats with a high percentage of aquatic vegetation, whilst Milner (1982) suggested that the availability of cover was possibly the most important single attribute determining young trout abundance. Older trout are often reported as occupying deeper areas (40 – 75 cm), with increased velocity (0.20 – 0.70 ms^{-1}) and medium-sized substrate (Armstrong *et al.* 2003). Heggenes *et al.* (1993) noted that over-wintering trout become nocturnal as temperatures fall below 10 ^{o}C; small fish sheltering in the interstices of the substrate or among macrophytes during the day, and larger fish aggregating in deep, slow flowing areas.

Despite these commonalities, there is considerable disparity between the results of published studies, most likely related to the availability of particular microhabitats, which in turn depends on the geology of the study site. To these confounding factors one might also add the differing methods used to classify habitat variables and to assess habitat use and preference, hence the need to be quite clear about what we are measuring. Comparisons between studies or simple extrapolation of results from one river system to another are, therefore, not always straightforward or advisable, though the five Anglian rivers in this project could probably be considered to be sufficiently similar in this respect.

In relation to habitat management, Riley *et al.'s* studies showed that closed tree canopy and reduced in-stream weed growth due to shading diminish macro-invertebrate production. Canopy removal appeared to have positive effects on the availability of potential prey for juvenile trout, since 0+ group trout had lower densities under closed canopy with little in-stream weed, relative to adjacent open sites with substantial weed cover. The preference of 0+ group trout for the cover afforded by the stream margins suggests that wild trout production might benefit from more sympathetic management of cover provided by riparian vegetation (which is enhanced by canopy removal). It is important to note, however, that larger trout and sea trout appear to prefer areas that have shading and, with the additional impact of a predicted reduction of summer flows and higher temperatures due to climate change, this presents contradictory pressures on management to achieve a balance between canopy shading (cooling) and encouragement of bank-side and in-stream vegetation, noting especially that stream margins may be a critical habitat in low flow conditions.

Sayer and Lewin (2002) made a number of recommendations on behalf of the River Glaven Protection Group (RGPG) in relation to depleted brown trout populations, highlighting in particular a huge increase in the accumulation of fine sediments. They proposed that the approach to restoration should be holistic, with efforts initially directed to upstream areas and then progressing downstream, and emphasised that the detrimental changes that have been taking place in the Glaven cannot be separated from changes occurring in the estuary (particularly in terms of water quality and siltation). This, of course, applies especially to sea trout.

Specific actions would be to improve water quality, where necessary, by working with Anglian Water and the Agency to improve sewage disposal and remove other localised sources of nutrients and organic pollution relating to septic tank and farm inputs, and to promote research into hydrological aspects of the river and the analysis of existing data, and the increased development and use of winter water storage systems.

Establishment of buffer strips alongside the river was identified as another priority to reduce the impact of agriculture on the aquatic environment, especially to reduce inputs of nitrate and silt to a river whilst providing important habitats for terrestrial food items for trout, in addition to providing the all-essential cover for juveniles. Riverine and floodplain habitat restoration schemes include reinstatement of gravel riffles, re-profiling of the channel (including narrowing) and re-connection with the flood-plain.

8.2 Sea trout spawning habitat

One factor that is almost certainly limiting sea trout production in Anglian rivers is the availability of suitable spawning habitat within that part of the catchment that is accessible to adult sea trout. It is worth reminding ourselves that anadromy is a strategy to increase production in a trout population, in terms of both biomass (numbers and size of fish) by taking advantage of better feeding opportunities in the sea, and the resulting increase in population fecundity (number and quality of eggs spawned), which is wasted from a biological perspective if returning adults cannot spawn successfully (Solomon, 2006).

An understanding of the spawning habitat requirements of trout allows us to evaluate the potential impacts of habitat change/destruction (or even to explain why trout have always been scarce in a particular reach or river) and establish priorities for the effective and sustainable conservation of populations and the management of their habitat. In order to assess spawning habitat availability, however, it is necessary to know what we are looking for, and this section briefly reviews what is known about the spawning habitat requirements of sea trout.

The physical habitat characteristics associated with spawning sites (redds) chosen by various salmonid species can be grouped into three broad classes as: 1) hydraulic (water depth and velocity); 2) spatial (redd dimensions, stream width, distance from the bank); and 3) substrate (particle size distribution, % of fine materials and various related indices) (Bardonnet & Bagliniere, 2000). There have, however, been relatively few studies of the specific habitats used by spawning sea trout: by Crisp and Carling (1989) in spate rivers and chalk-streams in England and Wales; Heggberget *et al.* (1988), in Norway; Ingendahl *et al.* (1995) in France and, most recently, by Walker and Bayliss (2006) who measured the physical microhabitat characteristics in the immediate vicinity of sea trout redds in a number of English and Welsh rivers.

This latter approach facilitates the identification of suitable habitats, but it is difficult to apply microhabitat-based knowledge across a whole catchment, except where the catchment has been comprehensively mapped and analytical methods developed that allow the availability of spawning habitat to be quantified using survey techniques applied at a much greater geographic scale. Such models have been developed to study the distributions of fish species and the abundances of salmonid juvenile populations at catchment (e.g. Beechie *et al.*, 1994; Porter *et al.*, 2000), and even regional scales (e.g. Kruse & Hubert, 1997; Argent *et al.*, 2003) in the U.S.A., but few studies have focussed on the habitats used by spawning salmonids (Montgomery *et al.*, 1999; Dauble & Geist, 2000). To this end, Walker and Bayliss (2006) also investigated whether it was possible to assess the distribution of spawning sea trout throughout a catchment using Geographic Information System (GIS) and other map-derived habitat features. Whilst this may enable an assessment to be made of catchment-wide spawning habitat availability, and provides a method by which to prioritise areas for protection or restoration, it is unlikely to be effective with the small size of the Anglian rivers (and see 8.3 below in relation to siltation issues). This review is, therefore, restricted to what we know about the characteristics of habitats used by sea trout for spawning, with a view to enabling suitable habitat to be identified, or targeted for remedial action.

Walker and Bayliss (2006) surveyed five spate river catchments in England and Wales: the Blackwater and Beaulieu in the New Forest; the Fowey in Cornwall; the Melindwr, an upper tributary of the Rheidol in Wales; and the Kent in Cumbria; during the sea trout spawning season (typically October to January). Redds were examined within 24 hours of the fish identified as sea trout having completed spawning and, where possible, the lengths of spawning females were visually estimated with reference to objects in or near the redd.

The length and width of both the ‘pot’ (from which the female fish has disturbed gravel) and the ‘tail’ (the resulting downstream scatter of excavated gravel) of redds were measured and total area calculated as if pot and tail were two ellipses (Ottaway *et al.*, 1981). Water depth and velocity were measured immediately upstream of the pot. In some rivers, channel width and distance from mid-pot to the nearer bank were measured, and cover was assessed in terms of the depth of undercut bank, height above water surface of the bank nearer the redd, and the proportion of sky directly above the redd that was occluded by vegetation (visual estimate).

A measure of substrate size can be obtained by collecting a sample at the side of the tail, sorting through a stack of sieves, and calculating the cumulative percentage weight against particle size to characterise substrate composition (Kondolf and Wolman, 1993). If the river conditions impose time constraints (by spates), redd substrate can be more rapidly sampled using a graduated quadrat placed on the surface of the redd tail and recording through a digital video image (Geist *et al.*, 2000). Substrate particle size can then be measured from still frames from the video footage using image analysis software (Optimus).

Walker and Bayliss's (2006) analysis of microhabitat data for 49 sea trout redds indicated significant differences between rivers for redd area, water velocity and substrate. It was not possible to determine whether differences in redd parameters between rivers were due to differential habitat selection by spawning fish or reflected differences in the habitats available to the fish. Whilst redds were located across the entire width of the channel, they tended to be constructed towards the channel margins. In particular, overhead cover was present above eight of 15 redds surveyed on the River Kent, with a mean estimated sky occlusion of 53% (range 10 to 75%).

All studies of salmonid spawning in the UK report considerable variation amongst the hydraulic and substrate conditions utilised (Ottaway *et al.*, 1981; Crisp & Carling, 1989; Moir et al., 1998; Walker and Bayliss, 2006). It is generally considered that larger fish tend to spawn in areas of greater depth and higher water velocity, and with larger mean substrate size, because they can maintain station in higher velocity currents and, by way of the greater power of tail thrusts, facilitate the downstream movement of large substrate particles from the cutting site (Kondolf & Wolman, 1993). This presupposes, of course, that the fish have a choice in this respect.

Crisp and Carling (1989) suggest that redd dimensions in salmonids reflect female size and might, therefore, explain some of the reported variability in spawning microhabitats. However, Walker and Bayliss (2006) reported up to a two-fold error between the predicted lengths of sea trout (from redd dimensions) and visually-estimated lengths of spawning fish. The relationship between fish size and redd dimensions may be complicated by more than one spawning female using a particular redd site, the construction of several redds by a single female, and by physical site characteristics such as substrate size distribution and flow. Therefore, caution should be taken in inferring fish size (i.e. was the spawner a sea trout or a brown trout, or did more than one female use that site?) from redd dimensions, unless fish size can be visually estimated.

It is important to recognise that reach-scale habitat characteristics are associated with (and thereby indicate) the type of microhabitat that is important to the fish in the choice of spawning site. For example, water velocity will be influenced by gradient, catchment area and land-use, and is recognised as a key microhabitat feature of salmonid spawning sites, but it will also influence riverbed substrate size distribution (Richards, 1982). Argent *et al*. (2003) assigned gradients into three categories, and stated that low gradient streams (=<2%) are typically characterised by sand, silt and clay substrates, while high gradient streams(>4%) typically have cobble, boulder and rock (and bedrock) substrates. The former is more typical of Anglian rivers; for example, the upper Nar has a gradient of 0.2%. Gradient and catchment area will also affect the form of the channel, i.e. its sinuosity and the ratio of riffles to pools, both of which will influence the amount of suitable spawning habitat within a reach, as will the degree to which the river channel has been altered for milling, drainage, etc purposes. Salmonids tend to spawn at the tails of pools, where intra-bed flow is maximal and siltation low, thereby providing oxygenated water to the developing embryos and transporting waste materials away from the redd (McNeil, 1969).

At a catchment scale, over 3,000 sea trout redds recorded by Agency staff on the Kent during five spawning seasons suggested that, whilst sea trout utilised nearly all of the catchment for spawning, this tended to be associated with middle to upper areas of rivers and streams. This seems to be a common feature in most rivers with sea trout and, despite the small size of the five Anglian rivers covered by this project, it may be a limiting factor due to the restriction of adult sea trout to the lower reaches on all but the Stiffkey. Equally relevant, possibly, is the observation that the year-on-year variation in the distribution of sea trout redds throughout a catchment reflects patterns in river levels, with higher flows immediately prior to spawning providing greater access throughout the catchment (Moir *et al.* , 1998). The flow regimes encountered by fish will vary depending upon their time of entry into freshwater and the pattern of precipitation throughout the year, and will almost certainly influence a fish's ability to reach some spawning grounds and thereby the distribution of spawning fish.

We can conclude, therefore, that the wide range of microhabitats used by spawning sea trout is such that it is unlikely to be able to analytically quantify the availability of sea trout spawning habitat within the five Anglian rivers, nor to estimate how much "good" spawning habitat is necessary to sustain the population. It is, however, possible to identify those areas of a catchment where spawning would not be expected (e.g. where the river flows over silt or sand), and those areas where spawning is limited or non-existent but could be improved through restorative actions to improve habitat or enable sea trout to reach it.

8.3 Siltation

Excessive input of fine sediment from arable fields into rivers and estuaries is a major problem in lowland England. Important negative effects include; (i) 'clogging' of gravels and consequent destruction of spawning habitat for trout; (ii) increased in-channel trapping of nutrients and toxic micro-pollutants (e.g. pesticides); (iii) increased turbidity, and; (iv) significant, often detrimental reductions in habitat diversity and availability affecting plant, invertebrate and fish communities.

Siltation is a major cause of loss of ecological diversity and good habitat for spawning and juvenile rearing in brown trout (and sea trout), and is particularly important in many Anglian rivers where changes in farming practices have clearly influenced siltation rates. Sayer and Lewin (2002) and Sear *et al*. (2006) included sedimentation among the main factors that might be limiting trout production in the Glaven and Nar respectively, and decreases in the amount of land used for permanent pasture and increases in arable farming in the Great Eau catchment have left more soils vulnerable to erosion and have resulted in increased siltation within the river and its tributaries (Dr. Lynsey Craig, pers. comm.). Where point sources contribute to siltation, they may be more amenable to remedial measures. This section describes how areas with the potential to be sources of silt within a catchment can be identified, illustrated by work carried out through the Environment Agency Anglian Region, Great Eau Siltation Project (from Campbell and Rose-Vogel, 2008).

The first stage of the project was a desk study, in which all existing environmental data for the Great Eau catchment upstream of Withern Bridge were collated onto a geo-referenced Ordnance Survey GIS map for the region. These included data collected at all Agency environmental monitoring points, JNCC macrophyte monitoring points and River Habitat Survey (RHS) sites, together with GIS layers indicating slope, rainfall, soil type, land use, conservation areas, and areas where Environmental Stewardship and Countryside Stewardship Scheme agreements were in place. The locations of all licensed abstractions and discharges within the Great Eau catchment were indicated, along with the locations of major impoundments.

Some of the most valuable data in terms of identifying point sources of silt are photographs of the catchment. However, the available aerial photographs covering the whole Great Eau catchment were taken in 1999 and had a relatively low resolution (25 cm), making them potentially out of date and difficult to use to identify areas of poaching and other point sources of silt. Whilst RHS data gave clear indications of point silt sources, they were available for only two sites upstream of Withern Bridge and were collected in 1995-1996.

Once collated, the data and images contained on the map were examined to identify all structures and features that could potentially introduce silt into the watercourses (both point and diffuse), and which would be verified (or otherwise) in the next stage, a walkover survey, conducted in March 2008.

Given the relatively small size of the Great Eau catchment, and the above limitations of the data available for the desk-based determination of silt sources, the entire length of the Great Eau and its major tributaries upstream of Withern Bridge was surveyed, and each of the potential sources identified in the desk study were visited to confirm whether they were actual sources of silt.

Though a total of 62 potential silt sources were identified on the Great Eau catchment during the desk-based study, 31 actual silt sources were identified during the walkover survey, many of which were not identified during the desk study. Thus, more than half of the locations identified as potential silt sources in the desk study were not confirmed during the walkover survey, when sources of sedimentation were observed to be largely due to cattle encroachment (14 out of 31 point sources), followed by bank erosion (8) and field drains, fords and runoff from arable fields (6) (Table 8.3.1). Most of the 32 bridges did not appear to contribute to siltation.

Table 8.3 Silt sources and their frequency of encounter during the desk study and the walkover survey of the Great Eau catchment (from Cambell *et al.*, 2008).

Silt source	Desk study	Walkover survey
Cattle drink/encroachment	4	14
Bank erosion	0	8
Farm drains	0	3
Runoff from field	5	2
Deforestation	0	1
Farm ford	3	1
Runoff from bridge	32	2
Fish farm effluent	3	0
Effluent from silty pond/silt build up behind obstruction	15	0

One aim of this project was to formulate a simple prioritisation tool for subsequent site visits of suspected silt sources. Based on the above results, cattle drinks should be assigned the highest level of priority for site visits as, although fencing will restrict cattle access to a given length of the watercourse, it will not prevent silt being introduced through poaching.

Areas where banks have been denuded will always increase the potential for silt introduction, and deforestation near watercourses destabilises the banks and surrounding soil. Both can lead to bank erosion and a source of silt and should be considered for remediation measures, though neither were identified in the desk study. Most other potential sources of silt (such as runoff from road bridges) which were initially identified as potential silt sources during the desk study were considered as the lowest priority for a site visit.

It should be noted that this project largely addressed the issue of point source siltation, but if siltation is mainly due to changes in farming practice that have resulted in increased soil runoff (i.e. diffuse siltation), then addressing point sources of siltation may have little or no remedial effect. Large areas of the Great Eau catchment upstream of Withern Bridge are under high pressure from cereals, pig farming and sugar beet, all of which are high risk in terms of siltation (Defra, 2005). This strongly suggests that diffuse siltation contributes considerably to the level of silt within the Great Eau and its tributaries, possibly from wind driven transport of fine sediments from adjacent fields. In fact, Campbell *et al*. (2008) concluded that point sources may not be the major contributor to siltation of the Great Eau system.

The results of this project were used to propose possible remedial measures to deal with point sources of silt in the catchment (see Appendix 1). Appendix 2 in Campbell *et al.* (2008) contains some general suggestions for dealing with diffuse sources of silt derived from EA soil and best practice farming publications.

9 Setting targets for sea trout management.

9.1 Introduction

In order to ensure that sea trout stocks can be managed sustainably, it is necessary to be able to assess the status of sea trout populations and to establish targets against which the effects of management action can be judged. Although the fisheries associated with sea trout in the UK and Ireland have a considerable social, recreational and economic value (e.g. Mawle and O'Reilly, 2006), efforts to conserve sea trout stocks and to manage their exploitation have often been reactive rather than proactive (Harris, 2006), and have been implemented principally as a by-product of salmon fisheries management. This weakness became particularly apparent during the late 1980s and early 1990s, when sea trout catches declined in many rivers throughout the UK and Ireland (Whelan, 1991; Anon, 1992; Walker, 1994). Sea trout catches in rivers in England and Wales recovered quickly and many stocks are now considered to be healthy: the declared rod catch has exceeded 40,000 fish in 7 of the last 10 years (Anon, 2007). In contrast, some sea trout stocks in rivers in the north and west of Scotland and Ireland that crashed during the same period have failed to recover (Gargan, 2000; Butler, 2002). While a number of possible causes have been investigated, it is generally agreed that the crashes were due primarily to reduced survival in the marine environment (Walker, 1994; Poole *et al.*, 1996). These events have emphasised the need to address the specific management requirements of sea trout and, within England and Wales, the Salmon and Freshwater Fisheries Review (Anon, 2000) recommended that sea trout fisheries should be managed “to protect stocks from overexploitation”. The Review Group also suggested that the principles applied to the regulation and management of salmon fisheries might be applied to sea trout, given the broad similarities between the life history and fisheries of the two species. With this in mind, Walker *et al.* (2006) reviewed the tools used for managing Atlantic salmon fisheries with a view to evaluating whether they could be applied to sea trout.

9.2 Salmon

Declines in the abundance of many salmon stocks during the last two or three decades have forced scientists and managers to reconsider and improve their approach to management (e.g. Crozier *et al*., 2003). This has led to the adoption of a precautionary approach to salmon management and the use of biological reference points (BRPs) to provide the scientific basis for measures designed to bring about reductions in fisheries exploitation and improvement of habitat.

The present approach to managing salmon stocks throughout the North Atlantic region is to ensure that an adequate number of spawners enter each river to optimise annual production (NASCO, 1998). The derivation of an ‘adequate’ spawning stock size is based on the assumption that the number of fish produced in the next generation (recruitment, R) is related to the number of adult fish in the previous generation (stock, S). Recruitment in anadromous salmonids is largely determined by density-dependent regulation in the early life stages due to limited resources (chiefly space and food) in freshwater (Gibson, 1993; Elliott, 1994), and is strongly influenced both by genetic and environmental factors.

Use of a density-dependent stock/recruitment (SR) model (reviewed by Elliott, 2001) assumes that the proportional survival of offspring decreases as the stock size increases, with the effect that the number of recruits (or offspring that survive to adulthood) increases to a maximum as the spawning stock increases, and may then decline again at high spawning stock levels; the so-called “SR curve”. Once the prime objective of salmon fisheries management, the conservation of the stock and the diversity within it, is achieved, we can then begin to determine sustainable levels of exploitation (catch), whilst still allowing sufficient recruits to maintain that stock size (replacement). However, the risk to sustainability varies considerably between different levels of spawning stock, and there is a need to ensure reasonable protection against years in which recruitment is unexpectedly poor for other reasons (e.g. drought, or spates washing out redds). There is, therefore, a need to demarcate stock levels (and/or levels of fishing activity) that are undesirable, and the ultimate objective when managing stocks and regulating fisheries is to ensure that there is a high probability that these undesirable levels are avoided (Potter, 2001). This has been achieved by setting Conservation Limits (CLs) for salmon stocks.

In 1996, the National Rivers Authority (NRA) in England and Wales introduced the requirement to develop river-specific management targets in terms of numbers of spawning salmon and egg deposition (Anon., 1996), and adopted the use of SR models and a CL approach (Milner *et al*., 2000). Because there were no SR estimates for salmon stocks in the rivers of England and Wales, the NRA (Anon, 1998) used the salmon SR curve for the River Bush in Northern Ireland (Kennedy & Crozier, 1993), a river similar in character to many in England and Wales and for which a long-term (1973 onwards) dataset of adult (S) and smolt (R) run size has been obtained using trapping facilities.

River-specific CLs for England and Wales are calculated based on the egg (adult escapement)-to-smolt SR curve for the River Bush, but adjusted for freshwater habitat availability in each river, and a replacement line derived from estimates of marine survival and other life history parameters, also specific to each river (Wyatt & Barnard, 1997). River-specific habitat availability (wetted stream area) was quantified in 22 categories of altitude and stream order (Strahler, 1952), assessed by GIS, whilst the carrying capacities for salmon parr of each habitat category were derived from EA electro-fishing surveys of pristine (i.e. not affected by adverse water quality or habitat) sites throughout England and Wales. The estimated number of eggs produced per smolt leaving the river was calculated using river-specific sex and sea-age ratios for spawners, national estimates of marine survival for grilse and multi-sea-winter salmon, based on data from the River North Esk, Scotland (ICES, 2003), and a length-egg production relationship derived for salmon from six Scottish rivers (Pope *et al.*, 1961).

The reason for explaining how the river-specific CLs are estimated for salmon in England and Wales is to highlight both the type of information required and the assumptions and inferences that are implicit in combining the available data from disparate rivers. This becomes relevant when we come to consider sea trout, for which such data are even less readily available.

The CL in itself tells us nothing about the status of a river's salmon stock (it is a management reference point). Stock status in each of the 64 major salmon rivers in England and Wales is assessed annually in relation to compliance with the CL using estimates of egg deposition by salmon that escape to spawn in that river (e.g. Anon, 2008: Table 29). These are derived either from rod-catch data, raised to include an estimate of non-reported catch and an estimate of exploitation rate (that proportion of the salmon run estimated to have been caught by anglers) or, in 13 rivers, from upstream trap or counter data. Clearly, there are areas of uncertainty associated with this method, not least the use of rod catches to estimate run size (Milner *et al*., 2000), and the available data do not show a simple, consistent relationship between catch and stock (as measured by counters, for example). This type of information is likely to be much less robust for sea trout than for salmon, especially in rivers where salmon or sea trout fishing is more or less incidental (as in Anglian Region).

Two other components of the salmon's life history that could be monitored to assess the status of stocks are juveniles (fry and parr) and smolts, both representing freshwater production resulting from egg deposition. Juvenile abundance is surveyed on most salmon-producing catchments throughout England and Wales, whilst the smolt run is monitored on six rivers (Anon, 2004), but only estimated on two. Though these data are not used in the assessment of salmon stock status, but they are used as diagnostics to support interpretation of the CL compliance results.

9.3 Sea trout.

To follow the above model for salmon, it would be necessary to establish a sea trout SR relationship for at least one 'typical' sea trout river that could be extrapolated to other rivers, based on the assumption that the population dynamics (eggs-to-smolts-to-adults-to-eggs) of each stock are similar and that differences in river-specific production are due primarily to differences in habitat quantity and quality (Wyatt & Barnard, 1997). We would also need a knowledge of the numbers and sex composition of spawners, and a spawner size-egg production model. At present, published data for sea trout SR relationships are available for three rivers in north-west Europe: Black Brows Beck in England (Elliot & Elliott, 2006); the Burrishoole system in Ireland (Poole *et al.*, 2006) and the Bresle in France (Fournel *et al.*, 2006).

Black Brows Beck is a small, shallow tributary (length approximately 500 m, mean width 0.8 m) of a spate river, the Cumbrian Leven, in which almost all the trout population migrate to sea at age 2 and then return to spawn either that same year (males only, as whitling) or the following year (both sexes): very few survive to spawn a second year (Elliott, 1994).

The Burrishoole is a spate river catchment in western Ireland, drained by approximately 45 km of shallow streams (16.7 km accessible to sea trout) and with two freshwater lakes (410 and 46 ha) where the majority of freshwater trout production occurs (Matthews *et al.*, 1997). Prior to the stock collapse in the late 1980s, sea trout smolts were typically 2 (70%) or 3 (30%) years old and the majority of sea trout returned as whitling (0 sea age: ~56%), with the remainder being predominantly of sea ages 1 or 2 years .

The Bresle is a chalk stream in Normandy, with a main channel of approximately 72 km in length, 40 km of which is accessible to sea trout. The majority (78%) of sea trout smolts go to sea at age 1, after which adults return annually to spawn, with the oldest fish having a sea age of 4 years (Euzenat *et al.*, 1999).

The physical characteristics of these three systems are very different, as are the life histories of the sea trout they produce. Furthermore, the population dynamics of sea trout stocks are, in many cases, far more complex and diverse than those of salmon, both between and even within river systems (see section 3). To complicate matters even more, we have a poor understanding of the reproductive contribution of freshwater-resident trout to sea trout runs, due in part to the technical difficulties in distinguishing between parr of resident, migrant or 'mixed' origins (but see Charles *et al*., 2004).

It is, therefore, highly unlikely that a SR model based on a single donor stock, especially one with such a limited dynamic as that of the Black Brows Beck population, or three stocks with such disparate population dynamics and habitats as those noted above, could be sufficiently representative of sea trout rivers throughout England and Wales. While some of these differences might be accounted for during the SR transport process, they would require a detailed knowledge of the population dynamics that is not available for most stocks, and certainly not for those using Anglian rivers.

Walker *et al*. (2006) suggest two alternative approaches that are more applicable to sea trout in Anglian rivers. The first is to derive sea trout abundance indices from catch records and compare them against reference catch levels, an approach being developed for salmon stocks in Scotland (Potter *et al*., 2003). For this, however, rod catch records need to have been (and continue to be) collected in a systematic manner for many years, and there are additional problems with catch-based indices (for both sea trout and salmon) including the influence of non-stock related factors (e.g. national Spring Salmon bye-laws since 1999; Foot & Mouth Disease in 2001, individual anglers' perversity) on catch and effort. Furthermore, catches may appear stable in the short-term, but the inferred stock size could be insufficient to provide stable recruitment in the long-term. It is difficult, therefore, to envisage how such a catch-based approach could be applied to sea trout stocks in Anglian rivers, particularly as sea trout catch records could miss a potentially significant part of the spawning stock, the freshwater-resident trout, and these are generally not recorded. Therefore, catch data alone do not provide a sound basis for making decisions on management of sea trout fisheries.

A more promising approach is through measures of juvenile abundance, which have been used to estimate salmon spawner numbers in the previous winter (Kennedy & Crozier, 1993) or predict smolt output the following spring (Bagliniere et al., 1993). The Agency's routine monitoring of juvenile trout could easily be made more comprehensive in Anglian rivers (at a cost). However, the parentage of juvenile trout can only be determined using destructive (and expensive) sampling methods, such as comparison of stable isotope ratios in recently emerged fry (Charles *et al*., 2004) or analysis of carotenoid pigment profiles (Youngson *et al*., 1997), and the future form of juvenile trout cannot, at present, be predicted until a few days or weeks prior to them migrating as smolts (Nielsen *et al*., 2004, Giger *et al*., 2006). Thus, since the majority of sea trout stocks include both freshwater-resident and anadromous components, and we have a limited understanding of the brown/sea trout dynamics and how their environment affects their relative contributions to stock production, juvenile trout abundance data cannot, at present, be used to estimate sea trout spawning stock or to predict smolt output *per se.* Though smolt output clearly represents freshwater production and indicates the potential production of adult sea trout, sea trout smolts are only regularly monitored on six major salmon rivers in England and Wales, none of which is in the Anglian Region.

This suggests that the most promising approach would be to consider the trout stock as a whole, and to focus monitoring and conservation efforts at that part of the stock that incorporates both freshwater-resident and anadromous components – the juveniles. A healthy juvenile trout population is the essential resource for a sea trout population, though the environment and genes will determine what proportion adopts anadromy as a life strategy. This approach would be catchment-specific, assessing the state of the juvenile trout population in relation to potential freshwater production and explicitly focusing management on both the fisheries for sea trout and brown trout and on the environmental quality and availability of spawning and juvenile rearing habitats in freshwater. The information presented in section 5 provides a basis for each of the five Anglian rivers.

There has been extensive study of the freshwater habitat utilisation and requirements of juvenile *S. trutta* (see section 8), and several attempts to model their abundance, density or biomass based on habitat characteristics (e.g. Belaud *et al.*, 1989; Milner *et al.*, 1993; Baran *et al.*, 1996; Lek *et al.*, 1996; Jutila *et al.*, 1999; Maeki Petaeys *et al.*, 1999). One empirical model, HABSCORE (Barnard *et al*.,1995; Milner *et al*., 1995), has shown that the spatial component of trout abundance in English and Welsh streams can be up to 73% of the overall variance, of which the HABSCORE model explained up to 63%. This offers a mechanism by which to predict the potential average maximum abundance, the carrying capacity, of juvenile trout for riverine parts of a catchment, against which to compare measured densities and set BRPs. Recently, the entire freshwater salmon habitat of Ireland has been quantified in terms of wetted surface area, channel gradient and water quality using GIS (McGinnity *et al.*, 2003), and efforts continue to improve the river-reach classification method for England and Wales.

However, it is not possible to predict the effects on adult sea trout numbers of either reducing or increasing juvenile trout abundance. Therefore, the *a priori* assumption of any juvenile-based BRP would have to be that, providing the juvenile abundance exceeded some predetermined level in relation to carrying capacity, the numbers of adult trout (anadromous and/or freshwater-resident) would be sufficient to meet the needs of stock conservation and associated fisheries.

This approach is based on the conservation of the whole trout stock in a catchment, and could be regarded as a first step towards estimating the scope for management to increase production of sea trout in Anglian rivers. Other stock characteristics, such as the size and age structure of the stocks, the relative abundance of repeat spawners, and the contributions of resident and migratory fish, should also be considered, since these may buffer recruitment against the impacts of short-term environmental change to habitats, and obscure the impact of habitat restoration on trout production.

10 Developing a monitoring programme for Anglian sea trout, and setting priorities for Phase 2

The objective of Phase 1 of the Anglian sea trout project is to convince potential funders (of restoration actions to enhance sea trout populations) that the Rivers Glaven, Stiffkey, Burn and Nar, and the Great Eau are capable of supporting sea trout populations, and to identify and quantify impacts that may be limiting sea trout production on each of these rivers. This has been achieved (in part) by collating information and data on the character and trout populations of the respective rivers (sections 3-5) and identifying factors that are potentially limiting trout production (e.g. barriers to access, areas of degraded habitat, siltation; sections 6-8).

It has proved less rewarding to attempt to collect evidence that would convince potential funders that the rivers currently support sea trout populations. Whilst a number of anglers have provided anecdotal information of sea trout caught in the rivers, and especially of numbers of sea trout seen in the lower reaches, evidence that these fish stay in the rivers to spawn and contribute to future generations is lacking. Even catches of sea trout smolts emigrating from a river do not necessarily prove that sea trout are currently spawning there: there is a tendency for all trout populations to retain an anadromous trait (see Kielder Burn example). It is possible that the sea trout that enter these rivers are not fish of local origin, but are part of the population that originates in rivers to the north on the eastern coasts of England and Scotland and feeds off the Anglian coast, displaying the species' propensity to enter freshwater from time to time. Sea trout are regularly reported and caught at New Mills on the Wensum in Norwich, fish than have swum 30-35 km through a Broadland river but have very little chance of reaching suitable spawning habitat. From an angler's perspective, whether sea trout do or do not spawn in a river is immaterial as long as they enter and can be caught there.

10.1 Assessing stock status

More work needs to be done if we are to verify that sea trout complete their full life cycle in Anglian rivers, and to demonstrate that the remedial actions carried out under Phase 2 of this project have been successful. These tasks should be aimed at providing evidence under four headings: Entry; Spawning; Juvenile production, and Smolt output. It would also be informative to know whether these rivers support distinct populations of sea trout, but that is a secondary aim which could be pursued as part of a more wide-ranging study of sea trout in the North Sea.

10.2 Entry

From a management perspective, it is essential to implement a system that enables us to judge whether there are any changes to the in-river sea trout populations that are associated with (it is very difficult to demonstrate cause and affect) the success of any remedial action on access or habitat in the relatively short term (1-5 years, say). The most straightforward approach (that has hitherto been almost entirely relied upon nationally) is to use anglers' catch records. Experience in using logbooks to record catch information from commercial fishermen and anglers has shown that it can be labour-intensive, in the sense that participant's buy-in and motivation have to be earned. This should not be a problem with the relatively few people who fish for (or catch) sea trout in the five Anglian rivers, but they have to be reached.

The most effective approach would be to publicise this project and ask any angler likely to or already catching sea trout in the rivers to keep records, including photos and scale samples from candidate sea trout. A scale collection protocol has already been issued, which asked people lucky (or skilful) enough to catch sea trout in or around Anglian rivers this year (2008) to take a scale sample from each fish and preserve them dry in a paper envelope on which details of capture place, date, fish size and sex should be written. A sample of half a dozen scales should be taken (with tweezers or by scraping) from an area near the posterior of the dorsal fin and above the lateral line (see Elliott and Chambers, 1996). The Agency has alread tried to obtain more data from anglers on sea trout captures in the Anglian region, and has produced a guidance sheet as to what is required (Annex 2). The response so far has been disappointing, though this may not be surprising given the relative scarcity of recent sea trout captures by anglers revealed by the present study. A more targeted publicity aimed at anglers fishing the Rivers Glaven, Stiffkey, Burn, Nar and Great Eau might elicit a greater response.

Scale samples are necessary if we wish to compare smolt age and growth of individual fish with those from sea trout known to originate in rivers in north-east England, for example, and possibly to begin to establish charateristics for sea trout from each of the five Anglian rivers. DNA can also be extracted from dry scales and used in the same way, but only as part of a much larger genetic study on sea trout in the North Sea (as currently proposed).

A more direct, but expensive, means of monitoring sea trout entry to the rivers is to mount fish counters and/or cameras at the sea sluices, lowest mills or other obstacles to migration. This will also have the merit of demonstrating whether fish are able to negotiate such potential obstructions, and whether measures taken to ease their passage there have been successful. The Agency has experience and expertise in this area.

A possibly more rewarding approach is to use visual surveys of areas where sea trout are likely to lie in the rivers. These include below sluices and mills (Burnham and Withern mill pools come to mind), and shaded or deeper areas of the river channel. The anglers who might be expected to catch sea trout will already know where to look for them, and it would be useful to provide some guidance as to how to distinguish sea trout from resident brown trout (there is a negligible risk of finding salmon in these rivers).

10.2.1 Spawning

The lack of good spawning habitat has already been identified as one of the major factors potentially limiting trout production in Anglian rivers, and work in Phase 2 should aim to identify suitable substrates and assess their accessibility to sea trout (see section 8). Once potential spawning areas in each of the rivers are known, surveys of these areas at spawning time (late October to early December, say) should provide evidence that sea trout are spawning, particularly in those rivers where resident brown trout seldom exceed 40-45 cm in length, whilst most sea-run trout will be 50+cm. Walker and Bayliss (2006) provide details of the techniques that can be used.

It is important to note that the longer a sea trout has been in a river, the more it will take on the appearance of a resident trout, and only scale reading will allow them to be distinguished with any certainty. Similarly, there is no means of distinguishing the fry of resident brown trout from those with sea trout parentage (assuming that they do not interbreed, which they certainly do), other than by genetic fingerprinting when both parents are known to be sea trout.

10.2.2 Juvenile production

The previous section (9) suggests that the most promising approach to assessing the status of sea trout stocks in the five Anglian rivers is by utilising the Agency's routine juvenile trout monitoring programme. Since the majority of sea trout stocks include both freshwater-resident and anadromous components, however, juvenile trout abundance data cannot, at present, be used to estimate sea trout spawning stock or to predict smolt output *per se.* Nevertheless, a healthy juvenile trout population is the essential resource for a sea trout population, and it is suggested that the state of the juvenile trout population should be assessed in relation to potential freshwater production, which will enable management actions to be judged against environmental quality and the availability of spawning and juvenile rearing habitats in freshwater.

10.2.3 Smolt output

Anyone trout fishing in April or May in a river that holds sea trout will be familiar with the appearance of sea trout smolts, and they are readily distinguished from stay-at-home trout of the same size, being silvery in appearance and typically with bright yellow pectoral fins (see picture below). Anglers fishing Anglian rivers should be asked to report any such catches, as for sea trout.

Rotary Screw Traps (RST) are being used to catch and tag salmon and sea trout smolts on a number of rivers in England and Wales as part of a Monitored Rivers Programme run jointly by the Agency and Cefas (Anon 2008), and an RST was deployed in the Stiffkey in 2007 with encouraging results. This equipment is expensive, costly on man-power, and requires a minimum flow and depth to operate effectively. Nevertheless, the Agency should be encouraged to trial an RST on each river (if a suitable site can be found), especially where it is suspected that sea trout numbers have increased.

The elements of a putative monitoring programme outlined above are aimed at measuring the success (or otherwise) of the Anglian Rivers Sea Trout Project, which is to improve sea trout production in the respective catchments. To this end, the scheme is designed to be implemented at a catchment level, and is based on experience in monitoring salmonid populations to assess their stock status. It is not intended, at this stage, to include evaluations of the effectiveness of individual in-river restoration or passage-easement work at barriers, that focus on the components of improving fish production, viz: spawning habitat extent, juvenile habitat, parr/smolt distribution and survival, movement/migratory access. This will be part of a pre- and post-remediation monitoring programme that Dr Andrew Gill has been asked to design for both brown trout and sea trout (jointly, if necessary) in relation to work undertaken within Phase 2, and which would also apply to any river restoration work that is not specifically actioned within the Anglian Rivers Sea Trout project. Since the project involves the Rivers Glaven, Stiffkey, Burn, Nar (all in North west Norfolk) and Great Eau (in Lincolnshire), which already have had and will probably require different levels of restoration, comparative monitoring based on existing river management/restoration and trout production status is required, which can be used to inform the cost/benefit of future actions at the appropriate time and spatial scales and in relaton to the resources available. The catchment monitoring programme will complement, and to some extent utilise, these protocols, and will help to establish baseline data that would be compatible with future assessments.

10.3 Stock identity

One action identified as part of Phase 1 was to design a programme that would provide evidence as to whether different sea trout populations use each of the five Anglian rivers, and on the relationship between these fish and those taken in the Anglian coastal fishery. Section 3 provides a summary of tagging data and biological characteristics of sea trout that originated as smolts in the rivers of the north-east English coast, and which are regularly caught in the Anglian coastal fishery. A similar approach could be utilised to obtain comparable data for Anglian rivers but, given the low numbers of smolts leaving these rivers, it is unlikely that useful results could be obtained (quite apart from the increased risk of mortality of smolts subject to capture and tagging processes; Lower *et al*., 2006; Riley *et al*., 2007).

It may be more efficacious to use genetics or scale characteristics (pattern and/or chemical signatures) to identify stocks to which these fish belong, but this is an expensive approach to a question that may not be immediately relevant, and I suggest that any investigations along these lines are left until we know the outcome of plans for a North Sea sea trout project.

10.4 Prioritising remedial action in Phase 2

The most important outcome from Phase 1 of this project, possibly, is the demonstration that each of the five Anglian rivers has a self-supporting trout population and plays host to sea trout, some of which have been caught. For Phase 2, however, we need to identify those factors that potentially limit trout production and sea trout access in these rivers, and prioritise actions to reduce or remove these bottlenecks. The review of data and information presented in this report provides an insight as to why natural trout and/or sea trout production is limited in each of these five Anglian rivers, and habitat surveys to be conducted by the WTT should enable the limiting factors to be identified and quantified, reach by reach. In order to prioritise remedial actions under Phase 2, however, a mechanism is required that will provide a (subjective) analysis of the relative benefits of ameliorating factors that are expected to enhance sea trout production in (or at least sea trout entry to) these rivers, in light of associated costs and resource availability.

Whether we are seeking to increase sea trout production in Anglian rivers as a whole, or just those covered by this project, we need to start with basic knowledge about sea trout populations in Anglian rivers and the factors that limit them. This is what Phase 1 has sought to do, for five named rivers and in general. Because actions that might enhance sea trout populations can only be applied where we know there is a problem, and the scale of that problem (and its solution) is best known for individual rivers, I suggest that each of the five rivers is treated separately in assessing the benefits and costs of remedial work. That is, weight the various factors within each catchment (e.g. siltation vs dredging effects vs barriers to passage), rather than comparing siltation levels and their remedies between rivers. We should also take account of evidence for existing sea trout usage and production in each river, since it is more likely to be able to demonstrate (and possibly to engineer) enhancement in a river already known to harbour sea trout.

Following this rationale, a weighting can be given to the factors limiting brown/sea trout production in each of the five rivers as illustrated in the table below, where 0 signifies no constraint on trout production by that factor, in that river, and 10 implies that the factor is important to and very strongly limiting trout production in (or sea trout entry to) the river. These scores (for illustration at present) are, of necessity, my subjective estimates, and should be updated by the Project Steering Group. I have not attempted to identify costs against remedial measures, since these depend on whether there is a solution (physically and/or politically), who will do the work and what materials are at hand.

Limiting factor	**Glaven**	**Stiffkey**	**Burn**	**Nar**	**Gt Eau**
Sea gates/ sluices	5	5	0	5	0
Mills/weirs	10	0	10	10	10
Spawning habitat	3	5	3	0	6
Siltation	4	8	2	2	5
Water quality	0	0	0	0	0
Juvenile habitat	0	0	4	0	4
Intakes (smolt entrapment)	0	0	0	4?	4?
Exploitation in estuaries	3	3	3	0	5
Exploitation in rivers	0	0	0	0	0

The combination, on most of these rivers, of the available spawning habitat being limited to the upper reaches and relatively good quality habitat for both juveniles and older resident trout throughout the rivers (though many anglers on the Glaven, Nar and Great Eau seem to require more and larger trout than even a high quality small chalk stream can provide naturally; hence supplementary stocking), suggests that there is little pressure for these trout populations to adopt an anadromous habit, and this could explain the current relatively low incidence of sea trout in Anglian rivers. If habitat restoration were to focus on extending spawning opportunities downstream (which appears to be being achieved on the Stiffkey), and easing upstream passage of potential anadromous spawners around barriers at mills in particular (it is not evident that sea gates and sluices are the main problem, other than in particularly low-water years, when sea trout in these small rivers might be expected to be particularly vulnerable to predators), the production of juveniles should improve and a greater proportion may adopt a sea-going habit. This would benefit both in-river availability of adult sea trout and production of sea trout smolts. Siltation is clearly a detrimental factor that requires attention on all five rivers.

A final point is that the last time the Anglian coastal fishery for sea trout was reviewed, in 1992, with a view to developing a management plan in light of legislation introduced under the Salmon Act 1986, Champion (1992) concluded (among other recommendations to restrict netting fisheries) that there would be no gains from providing protected areas around river mouths in which net fisheries likely to take sea trout would be prohibited. However, this is an important conservation measure in areas where salmon and sea trout runs are particularly vulnerable to netting fisheries, whether licensed to take migratory salmonids or not. The ESFJC's enabling Byelaw 13, authorising 'fixed engines' (as defined in the Salmon and Freshwater Fisheries Act 1975) for the fishing of seafish throughout the District (between Donna Nook in Lincolnshire and Dovercourt in Essex), is the only such byelaw in England and Wales that does not contain conditions restricting netting to protect migratory salmonids. This project should, therefore, consider whether the benefits of any actions to increase production of sea trout or their entry into Anglian rivers would be dissipated if netting were to continue unrestricted along the Anglian coast. At the very least, areas around the mouths or in the estuaries of the Glaven, Stiffkey, Burn, Nar and Great Eau in which all netting is prohibited would help to protect sea trout running into these rivers, and promote and publicise the idea that Anglian rivers do harbour sea trout, a key action of Phase 2.

APPENDIX 1 – Remedial Actions for point sources of siltation (after Campbell and Rose-Vogel, 2008, and see Environment Agency, 2003)

Cattle Poaching (riverbank): Fencing to restrict access to river bank; introduce a hard base on which cattle may walk.
(in field): Encourage farmer to space out mobile feeders and drinkers, and to introduce a hard base around them or regularly move them; reduced stocking rates; move stock to other land or housing; or lay down cow tracks using well-drained bark, rock and quarry dust or concrete situated to avoid run-off, with any being diverted to rough ground or blind ditches.

Farm bridge/river crossing: Even if a bridge is present, bank erosion and sediment input can occur if cattle are allowed to congregate directly next to the river whilst waiting to cross. If there is no bridge, encourage farmer to have one constructed, and to restrict stock access to the stream with temporary electric or permanent hanging fencing (ensure fences do not impede stream). Where bridges are not possible, a graduated well-drained access point can be provided, made from suitable material to harden and stabilise both banks.

Fields ploughed to river edge: Create a blind ditch with stream vegetation (reeds and rushes) to intercept water draining down slopes (remove excess silt from ditches periodically).

Pig farming: Outdoor pigs should be kept in areas such that the risk of erosion is minimised, taking into account location, slope, soil type and rainfall. The site should be managed to maintain grass cover and pigs should be moved to an alternate site when necessary to prevent run-off (Ministry of Agriculture Fisheries and Food, 1998).

Steep river bank: Plant trees (such as willow) and shrubs whose root structure will protect banks from erosion (Environment Agency, 2003), but note increased potential for fallen trees blocking river causing erosion and silt-traps. Planting can be used effectively in combination with structural bank protection in the form of riprap (Shields *et al.*, 1995).

Sandy or silty soils: Where there is a risk of soils slaking and forming a surface cap, avoid creating a very fine smooth seedbed, and do not roll.

Steeply sloping arable land: Encourage farmer to protect land from soil erosion by using buffer strips of grass or hedgerows set at various positions along the contour. Land should be drilled across the contour where possible; tree banks may be planted to reduce the length of slopes (DEFRA, 2007).

High soil erosion risk crop (such as sugar beet root, late-sown winter cereals, forage maize and potatoes): Encourage the use of cultivation techniques that allow water to percolate into the soils as opposed to running off and creating gullies. Sow winter cereals and grass reseeds no later than mid/late September to achieve a minimum of 25% ground cover before early winter; drill spring crops rather than winter cereals after late harvested root crops, with rough ploughing after root crops to remove rutted and compacted surfaces and increase surface storage of water. Land left as stubble over winter can provide some soil protection; where grass is to follow a spring cereal crop, consider under sowing (e.g. clover/perennial rye grass under wheat). Consider early establishment of a cover crop such as rye or mustard, or forage crops such as stubble turnips after harvesting crops where high-risk soils would otherwise be left bare through the winter. When planting sugar beet on light land, consider drilling directly into loosened cereal stubble or a sprayed-off cover crop (like rye) to prevent erosion until good crop cover is established. Consider under sowing maize with ryegrass or, alternatively, plant a winter cover crop after maize harvest, integrating grass into the rotation in vulnerable areas. For further information consult Best Farming Practices (EA, 2003).

Fish farm/watercress farm: Monitor discharge to ensure water quality (in particular suspended solids) fall within Agency recommended guidelines.

Discharge: Monitor discharge to ensure water quality (in particular suspended solids) fall within Agency recommended guidelines.

Canalised stretch: Instream structures may be introduced into canalised stretches of streams where necessary to increase habitat diversity.

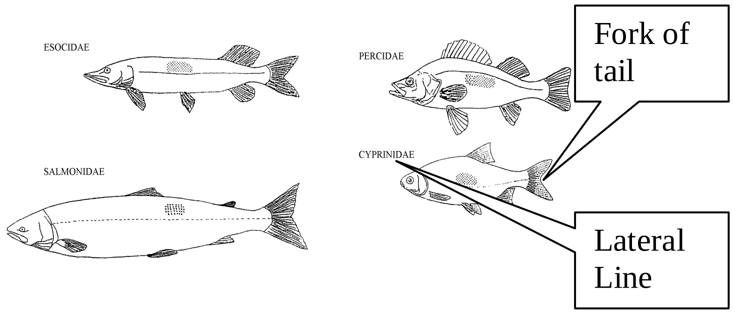
Field drains: Ensure these drain into ditches and not river, encourage regular ditch maintenance (clear part of ditches each year to settle out sediments). Ditches should be vegetated with stream vegetation such as reeds and rushes which will uptake nutrients. Ditches should be fenced off to exclude livestock.

APPENDIX 2

Anglian Sea Trout Angler Catch Recording Programme

Thank you for taking part in our new recording programme to get better data on the distribution and numbers of sea trout in Anglian Region. For us to get the best from your capture submission we need the following pieces of information:

- *Date of capture*
- *Location of capture*
- *Weight of fish* In kgs or lbs
- ✓ *Length of fish* This should be taken from nose to the fork of the tail in cms
- ✓ *Scales* The diagram below shows the best area on the fish to remove scales. Any areas of damage should be avoided and another area selected. Lateral line scales should also be avoided as the line across the scale can inhibit ageing.



Fish can occasionally have replacement scales that cannot be accurately aged. Therefore a minimum of 5 scales from each individual should be removed.

- *How to remove the scales*- Use a fine pair of tweezers or forceps. Hold the tweezers parallel to the surface of the body pointing to the snout of the fish and carefully slide one side of the tip between the scale and the body wall. Grip the scale with the tweezers and gently pull backwards away from the head at a slight angle to remove from the socket. Do not pull the scale off at a sharp angle to the body as this may cause unnecessary damage to the fish.

Scales should be stored in buff manilla envelopes as these dry the scales and make locating them easier. The envelope should be labelled with all the capture information.

Photos These really help in confirming the identification of the fish. Any digital images can be emailed to: **http://www.anglian_seatrout_returns@environment-agency.gov.uk**. Alternatively prints can be sent to Roger Handford at the address below. All prints will be returned back to you (so please remember your to provide your contact details).

Prize Draw!

If we confirm you have caught a sea trout then you will be entered into a draw on the 1st December, the winners will receive vouchers for tackle etc that can be redeemed in time for Christmas!

Further Information: Please contact Roger Handford at Environment Agency, Bromholme Lane, Brampton, Huntingdon, Cambs. PE28 4NE. Tel: 01480 483990

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