THE NORFOLK RIVERS TRUST

RESTORING NORFOLK'S RIVERS

THE RIVER STIFFKEY

A WATER FRAMEWORK DIRECTIVE LOCAL CATCHMENT PLAN

DEVELOPED IN PARTNERSHIP WITH

Environment Agency

WITH SUPPORT FROM

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defra

Photograph: © Jack Perks

CONTENTS

Produced by Dr. Jonah Tosney for Norfolk Rivers Trust

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INTRODUCTION

This plan has been produced by Norfolk Rivers Trust in consultation with a wide variety of agencies, farmers and residents in the Stiffkey Valley. The aim of the plan is to provide a framework for improvement of the ecological status of the Stiffkey River, guided by the Water Framework Directive. Delivery of the actions outlined in the plan will lead to improvements in water quality and flow throughout the catchment, providing benefits for a variety of species and habitats as well as for agricultural and drinking water abstraction.

The plan begins by providing an audit of the current state of the catchment, put together by a combination of river walks, reviews of existing data, consultation with Stiffkey farmers and residents and requests for specialist reviews from relevant individuals and organisations. These data are then used to identify ecological pressures in the catchment. In the final stages of the plan solutions to these pressures are identified, costed and prioritised.

THE WATER FRAMEWORK DIRECTIVE

The Water Framework Directive (WFD) was introduced in 2000 and commits European Union member states to improving the physical and ecological quality of their streams, rivers and lakes. The quality of these waters is measured using a range of indicators outlined below which combine to give a picture of a river's health. Using this combination of indicators a river (or lake) is then graded on its overall "ecological status", and designated as either bad, poor, moderate, good or high. Each member state is required to bring its water bodies to good status by 2015. Where this is not possible, good status must be achieved by 2021 or 2027, depending on the severity of the barrier to good status. In England, the Environment Agency are responsible for WFD delivery.

A number of criteria have been assessed on the Stiffkey, and its major tributary the Binham Stream. These are divided into biological indicators (fish, insects, plants, phytobenthos (single-cell algae living on stones on the river bed), each of which give an indication of river health, and supporting elements (water quality, flow, river channel form) which heavily influence the life in the river. A summary of the current designations appears below. Scores range from poor to moderate (considered WFD failures) to good to high. Overall scores default to the lowest score in an individual category. Some categories have not yet been assessed on the Binham Stream.

Indicator	Stiffkey		Binham Stream	
	Current	Predicted by 2015	Current	Predicted by 2015
Overall Ecological Potential	Poor		Moderate	
Fish	Good	Good	Good	Good
Invertebrates	High	High		
Aquatic plants	Good	Good		
Phytobenthos	Poor	Poor		
Ammonia	High	High	High	High
Disolved oxygen	High	High	Moderate	Good
pH	High	High	High	High
Phosphate	Good	Good	Good	Good
Temperature	Good	Good	Good	Good
Copper	High	High		
Zinc	High	High		
Quality and dynamics of flow	Supports Good	Supports Good	Supports Good	Supports Good
Mitigation measures assessment	Good	Good	Moderate	Moderate

Both water-bodies are classed as heavily modified, a consequence of centuries of modification, and the target for each is to achieve good ecological potential by 2027. Ratings for the failing measures (dissolved oxygen on the Binham Stream and phytobenthos on the Stiffkey are uncertain and currently under review. The frequency and breadth of sampling is necessarily limited, and the number of small sewage works, houses on septic tanks and intensive agriculture suggest phosphate may be a problem, particularly in Summer months when more houses are occupied and flows are lower. Dissolved oxygen and temperature are also likely to be problems in the long reaches where there are no trees to provide shade, and the fish, invertebrate and plant life are threatened by heavy siltation in some areas.

The Environment Agency highlight a number of mitigation measures required to improve the ecological status of the Stiffkey catchment. These are:

1. Increase in-channel morphological diversity
2. Appropriate channel maintenance strategies and techniques
3. Retain marginal aquatic and riparian habitats
4. Set back embankments
5. Improve floodplain connectivity
6. Structures or other mechanisms in place and managed to enable fish to access waters upstream and downstream of the impounding works
7. Operational and structural changes to locks, weirs, beach control etc.

The need and feasibility of each of these measures are discussed in the following plan, along with:

8. Management of riparian vegetation to provide appropriate levels of shade and light, and input of woody debris
9. Management of silt and nutrient input
10. Management of non-native invasive species
11. Spring and wetland restoration

The consideration of each of these points will help the Stiffkey Catchment reach and maintain its Water Framework Directive requirements.

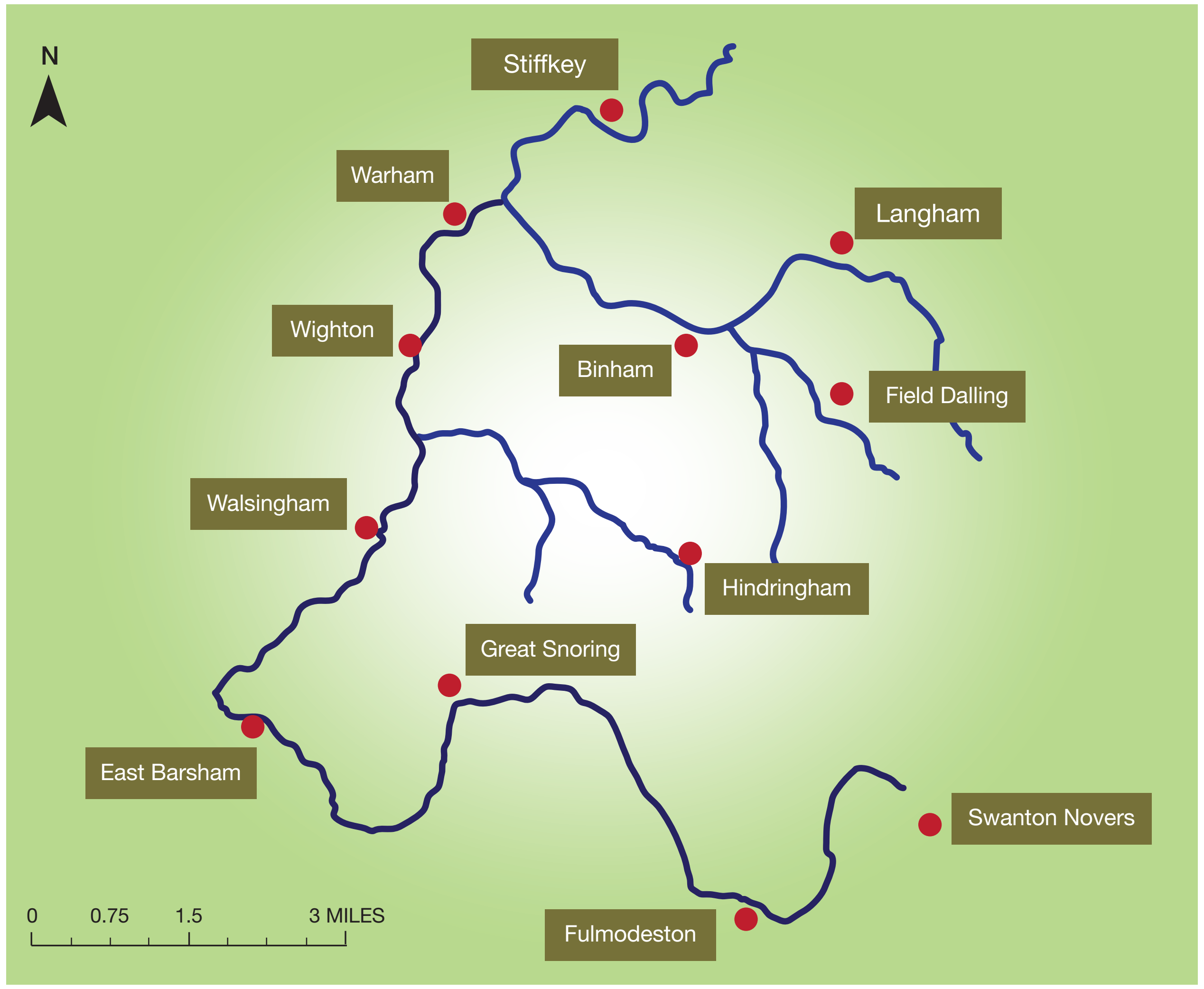

Photograph: © Jack Perks


Photograph: © Jack Perks

SECTION 1 THE CATCHMENT

The River Stiffkey, in North Norfolk, rises from springs throughout the catchment and meets the sea at Blakeney Harbour, close to the village of Stiffkey. The main river originates in Guybon's Wood, close to Swanton Novers and is joined by a number of tributaries, notably the Binham and Hindringham streams and is about 18 miles long from source to sea. The river flows through and over sand, gravel, clay and, crucially, chalk. It is this chalk bedrock which gives the river its clear waters and unique wildlife. The valley is home to a number of small villages, including Walsingham (Great and Little), Wighton, Langham and Fulmodeston.

The vast majority of the land in the catchment is farmed, primarily for wheat, barley, potatoes, sugar-beet and beef, but also for dairy and a variety of other crops. Agricultural productivity in the area is nationally important, but the demands of irrigation, drainage and crop production do not always match the demands of the Water Framework Directive and the ecological well-being of the river. The river has been modified over many centuries to meet our needs and little "natural" river now remains.



GEODIVERSITY

The Stiffkey River has the largest river catchment in north Norfolk (141 sq km), gathering its clear waters from springs and seeps in parishes as far afield as Fulmodeston and Hindringham. Some 22.5 km of the river are classified as a chalk river, being fed directly by groundwater from the chalk bedrock. The chalk forms a vital local aquifer, holding massive quantities of water in its cracks, joints and pores and releasing it steadily into the valleys. By contrast, the remainder of the river including its upper reaches are fed by water flowing over and through the glacial sands, gravels and chalk-rich tills which underlie tracts of open, rolling upland. These deposits make the river more responsive to rainfall than a pure chalk stream, and subtly influence the character of the whole river.

The river and its floodplain have been changed by human activity over many centuries. The channel has been diverted, straightened and deepened: dams and weirs and mills have been installed. The chemistry of the water has been altered by pesticides and fertilisers used in farming, and by excess nutrients such as phosphorus from sewage. The chalk aquifer and river flows have been depleted by pumped abstraction for homes, businesses and farms.

These changes to the river's natural dynamics and water composition have led inevitably to impoverished biodiversity. In terms of geodiversity, the Stiffkey River can be divided into three thematic sections:

a) Upstream from Thorpeland Hall

The headwaters of the Stiffkey River drain sandy uplands around Swanton Novers, Thursford and Fulmodeston. The springs and wet flushes which feed its upper reaches can best be seen in their natural state at the Norfolk Wildlife Trust reserve at Thursford Wood, where the river is flanked by an extensive tract of boggy ground and alder-carr woodland. Downstream of Great Snoring, the river picks up further baseflow from the valley floor.

The River Stiffkey flows through alder carr at Thursford Wood. Calcareous springs rise in tracts of boggy ground overlying glacial till.

b) From Thorpeland Hall to Warham

Downstream from Thorpeland Hall the river becomes a chalk river, fed directly from the aquifer via springs in the valley floor and sides.. Some of the springs are cultural landmarks: pilgrims to the famous shrine at Little Walsingham may fill their bottles from a natural spring on site, and there are two historic 'wishing wells' in the grounds of Walsingham Abbey.

In many places the course of the river has been artificially straightened, though a few natural meanders can be seen near Houghton St Giles.

Evidence for water-meadow systems of early 19th century origin can be seen at Houghton St Giles and in the valley of the Hindringham Beck at Wighton. These water-meadows were an early form of agricultural intensification for raising sheep. Networks of channels directed a continual flow of water over the floodplain in winter to stimulate an early growth of grass in spring. Once the sheep had moved to summer pastures, the meadows could be irrigated again to promote the hay crop.

Downstream of Wighton, the floodplain becomes wider and the river is, in most places, an over-deepened, straight-sided drainage dyke. The Iron Age fort of Warham Camp demonstrates the impact of this drainage work; the ramparts in the south-west corner of the fort were demolished in the 18th century and the river was routed to cut off a corner of the site.

The valley floor west of Barsham comprises layers of peat, alluvium, sand and gravel, suggesting that the floodplain here once supported areas of wet fen. Peat may once have been more extensive, but has oxidised and shrunk as a result of land-drainage.

The sand and gravel may be associated with a possible glacial Lake Stiffkey ponded up in the valley during the Devensian glaciation, c.20,000 year ago. An ice sheet is thought to have advanced from Wells-Next-The-Sea as far as Warham where it stopped, blocking the northern end of the valley. Meltwaters streaming from the glacier in summer may have built up in a proglacial lake which backed up as far as Barsham and also extended up the Hindringham Beck valley. The evidence may be seen today in beds of sand and gravel beneath the floodplain, and noticeable breaks of slope along the valley sides which suggest the likely margins of the former lake.

The Stiffkey River at Warham flows some 2m below its floodplain level, due to artificial channelling. It has now lost an active, formative relationship with its floodplain, and now functions as a through-drain with graded sides and a flattened bottom. Flow scouring effects limit marginal plant life and iron out natural pool and riffle formation in the river bed, and are thus detrimental to fish spawning. The steep banks of the river constrain habitat diversity.

Remaining meanders north of Houghton St Giles.

c) From Warham to the coast

Downstream of Warham, the Stiffkey River enters a meandering valley with steeper sides, most likely an overspill channel created by meltwaters from glacial Lake Stiffkey. Once the glacier retreated from the Warham area, it unblocked the mouth of the valley, and the lake waters escaped energetically eastwards along the ice front, carving through the chalk bedrock. Stiffkey village is attractively set in this glacial ‘gorge’.

Upstream of Stiffkey, the valley has a dry, open aspect. Faden’s map of 1793 shows the river once flowed through a series of broad, looping meanders here, but these were removed in the early 19th century and it now runs in a sequence of straight ditches.

Downstream of Stiffkey village, the lower reach of the valley is designated a SSSI (Site of Special Scientific Interest) for its wetland biodiversity interest. The floodplain comprises layers of freshwater alluvium and peat overlying layers of marine alluvium, showing that tidal flows formerly penetrated up the valley. Today, tidal influences are controlled by a flap in a sluice installed at the mouth of the river. This acts to prevent natural interaction between freshwater and seawater and hampers the migration of anadromous fish.

However, rising sea levels due to human-induced global warming may well see tidal influence extending up the valley once more, perhaps as far as the village. Norfolk County Council estimates that sea levels are likely to rise by 0.88 m or more this century. If so, the river will be grading to a rising base level, which is likely to have knock-on effects on freshwater levels upstream in the catchment. Also, unstable weather patterns are likely to lead to episodes of more intense rainfall alternating with drought, all of which have implications for river, floodplain and water management in the catchment.

The Stiffkey River valley is clearly still evolving.

The deeply-dredged lower reaches of the Stiffkey River, about 1 km from the coast. The dredgings are piled along the river bank forming a levée, which further acts to disconnect the river from its floodplain.

Text © TD Holt-Wilson, 2013
Images © TD Holt-Wilson

A HISTORY OF HUMAN MANAGEMENT

The first Neolithic settlers arrived on the North Norfolk coast about 6,500 years ago. Not only were they the first cereal farmers but they also cultivated other crops such as hazel nuts and the ancestor of what the Victorians called the ‘Christmas pear’.

The same farmers imported and raised cattle and to fence in their livestock they planted “settlement elm” as stock-proof hedging. *Ulmus minor var. vulgaris* is a clonal hybrid and does not seed: it survives by putting out suckers from the main stem and remains in the landscape only where man has planted it. Its presence today identifies where those early Neolithic farmers lived and worked and the pattern of their habitation corresponds closely with soil type and the passage of the Stiffkey River.

The landscape was virtually treeless – what we could describe today as heathland on the valley stops and sides – and rich in ground water, making the floodplain a wet marsh. There is evidence that water levels were, at some points in history, about 1.8 meters higher than today, with tell-tale tidal shoulders of mud and gravel, suggesting historic periods of inundation from the sea.

But these shoulders were planted with settlement-elm hedging, which also suggests that early farmers deliberately excluded their livestock from the stream and its marshy margins and that undamaged wetland was a vital resource: reed-cutting, gathering watercress and fishing are, to all intents and purposes non-destructive and may be regarded as renewable resources.

Varied examples and evidence of human interaction with the river include:-

- Tapering V-shaped inlets usually cut at right angles to the stream, which may have been decoys to trap wild foul or fish.
- Wet rectangular beds surrounded by a bund, used for the cultivation of basket willow or hazel.
- Dams with central sluices.
- Mill leats.
- Fishponds.
- Spring-fed moats.

The Enclosure movement brought significant changes to the way the valley was farmed: common grazing-land was turned to plough and marshland to grazing. From the late Nineteenth century to this day, the mechanisation of farming, large-scale land-drainage and afforestation of wet ground has brought about an inexorable destruction of that natural wetland and marsh, a wholesale drying-out of the floodplain.

Text by Andy Rampley, Langham, 2013

FARMING

The Stiffkey valley is at the heart of one of Britain's most productive agricultural areas. A variety of foods are produced in the catchment, most notable barley, wheat, potatoes and sugarbeet, as well as beef and dairy. A number of other crops are also produced. Typically the fields away from the river are cropped while those in the valley bottom are grazed. Both the crops and livestock rely on a constant supply of water, some of which is taken directly from the river and some of which comes from boreholes and winter storage reservoirs. Along with the provision of drinking water, agricultural production is arguably the most important use of water in the catchment. In times of drought when the need for irrigation is at its greatest the Environment Agency may order abstraction to cease if river levels fall too far. This has not happened in recent years, despite prolonged dry periods, but may be increasingly likely in the future should long dry spells become more frequent.

It is now recognised that many of the ecological threats to the river have agricultural origins, notably the input of fine sediment and phosphates and nitrates from fertilisers. Through initiatives such as Catchment Sensitive Farming and farm stewardship schemes, as well as through personal endeavour, farmers having been working to address these problems for several years. Rough field margins and riverside fencing are now commonplace throughout the catchment and are working to protect the river. Problems still remain, however, (see Ecology section), and the key aim of this plan is to work to address these issues.

Farm profiles

Where and what do you farm?

Copys Green, Wighton. Cropping is winter and spring barley, spring beans, fodder beet, energy beet, maize, grass. The barley is grown for seed and cattle feed, beans for cattle feed, beet and maize for cattle feed and for the digester. Some is sold off farm. "Exports" are primarily seed barley, cheese, milk and electricity.

Why is water management important to your farm?

We need a reliable water supply for irrigation. From a business perspective, the river Stiffkey isn't of major concern however we personally feel it is important to look after.

Has the river changed in recent years?

Stephen feels that the river level seems to fluctuate more now to the greater extremes of weather. Whilst he spent quite a long time away from the farm, he does not remember the meadows we have adjacent to the river ever flooding until recently.

Would you like to see any changes to the river?

From a personal perspective it would be nice to see more wildlife. From a business perspective so long as our fields aren't flooded and there's water in the aquifers we're OK. We're having a chuckle because the boundary of land we own and land we rent is the river, so anything that moved the course of the river back towards its original route would work in our favour.

Farm profiles

Where and what do you farm?

Vale Farm , Stiffkey. Mixed arable (potatoes, sugar-beet, rape, wheat, barley) and beef.

Why is water management important to your farm?

The cattle need water, and the crops need irrigation. Our irrigation supply comes directly from the river.

Has the river changed in recent years?

We have worked to improve the river for 70 to 80 years. We now have extensive grass margins and fencing to protect the river , and we also cross-drill the arable fields to minimise soil loss. There seemed to be more fish 30 to 40 years ago. Weeds in the river should be cut annually for flood prevention, and this also helps the fish. This can be done sensitively. There is a lot of silt coming into the river now, particularly from the public highways which would benefit from better and more regular management.

Would you like to see any changes to the river?

It's good to see the river cleared regularly.

Farm profiles

Where and what do you farm?

Stiffkey Farms. From a farming perspective we wish to maintain grassland throughout the year to support livestock (sheep and cattle). We do not apply sprays or fertiliser to the grassland, in accordance with the SSSI Management Plan.

Why is water management important to your farm?

From a conservation viewpoint we wish to maintain sufficient water in the river and the back channel to irrigate the grassland from October to July. We also wish to encourage brown trout in the river, and of course a wide range of wetland plant life on the river bank and within the grassland.

Has the river changed in recent years?

Would you like to see any changes to the river?

We are considering changes to the river to improve the ecology of the SSSI nature reserve.

ABSTRACTION

The Stiffkey is relatively heavily abstracted, supplying irrigation water for agriculture and drinking water for the villages of the catchment and also for Wells and Fakenham. Although some agricultural abstraction is taken directly from the river, the majority of abstraction (and all the drinking water abstraction) is taken from boreholes into the chalk aquifer. The effects of draining water from the aquifer are harder to gauge than that of taking water directly from the river, although, the immediate effects would be to reduce the amount of water entering the river from springs in the headwaters and a reduction in overall flow . Environment Agency data classes the aquifer as being of "good quantitative status". Aquifer levels fluctuate seasonally and annually and in dry periods can drop some way below long term averages.

In terms of water usage, 28.7% (684647 cubic metres *per annum*) of the water licensed to be taken from the catchment is for agriculture, 71% (1693727 cubic metres *per annum*) for public water supply and the remaining 0.3% (7157 cubic metres *per annum*) for private water supply. Abstraction pressure is at its most intense in the Summer months when crops need the most water and a higher proportion of homes in the catchment are occupied. In recognition of this, an increasing number of farms in the catchment now use winter storage reservoirs, which can be filled in periods of high rainfall and drained at times of peak demand with a lesser impact on the river. Anglian Water are actively participating in initiatives around the region to increase the resilience of all sectors and the environment to the effects of drought, climate change and growth. One example is a collaboration in the Wissey catchment, with farmers and other stakeholders looking at options to alleviate predicted water scarcity for agriculture and public supply.

ECOLOGY

An iconic chalk stream

The Stiffkey is one of a very few chalk streams worldwide. These streams are found flowing from the chalk bedrock that stretches from Yorkshire to Dorset and across the English Channel into France and Belgium. There are somewhere around 200 chalk streams worldwide, the vast majority of which are in England. It is the chalk itself which gives these streams and rivers their unique character and ecology. The porous chalk acts as a sponge, soaking up rainwater, filtering it and releasing it slowly. This means the water is clean and clear, and river levels remain fairly constant. The water is also mineral rich, particularly in calcium. The constant, clear flows allow rich plant growth, and the clean, mineral rich water is ideal for invertebrates, particularly molluscs and crustacea.

Consequently these streams have an abundance and diversity of life unseen in other rivers. This rich productivity allows the river to support a variety of iconic species such as trout, water-voles, crayfish and kingfishers.

The geology not only influences life in the river, but also throughout the catchment, with widespread springs and low gradients producing wet woodlands and meadows, some of the UK's most threatened habitats. Remnants of these habitats can be seen in the Stiffkey valley although centuries of drainage for grazing and woodland management mean they are greatly diminished.

Invertebrates

The invertebrate community is typical of an English chalk stream, dominated by insect larvae (such as mayfly, caddisfly and damselfly), crustaceans such as the freshwater shrimp, and a variety of freshwater snails and bi-valves. The habitat and water quality requirements of each species are slightly different, and the diversity of invertebrate life in the river is an indication of the variety of habitats found in the river.

Species profile: the green drake mayfly, *Ephemera danica*

The green drake is one of the Stiffkey's more common mayflies. It needs clean flowing water and a gravelly or sandy river bed.

It spends up to two years as an aquatic larva (or nymph) before emerging from the water. After mating with the male, the female flies upstream where she deposits her eggs (8000 or more) into the water and then dies, spent.

Text, Mark Rylands, Photo Jack Perks

Photograph: © Jack Perks

Species profile: The white clawed crayfish, *Austropotamobius pallipes*

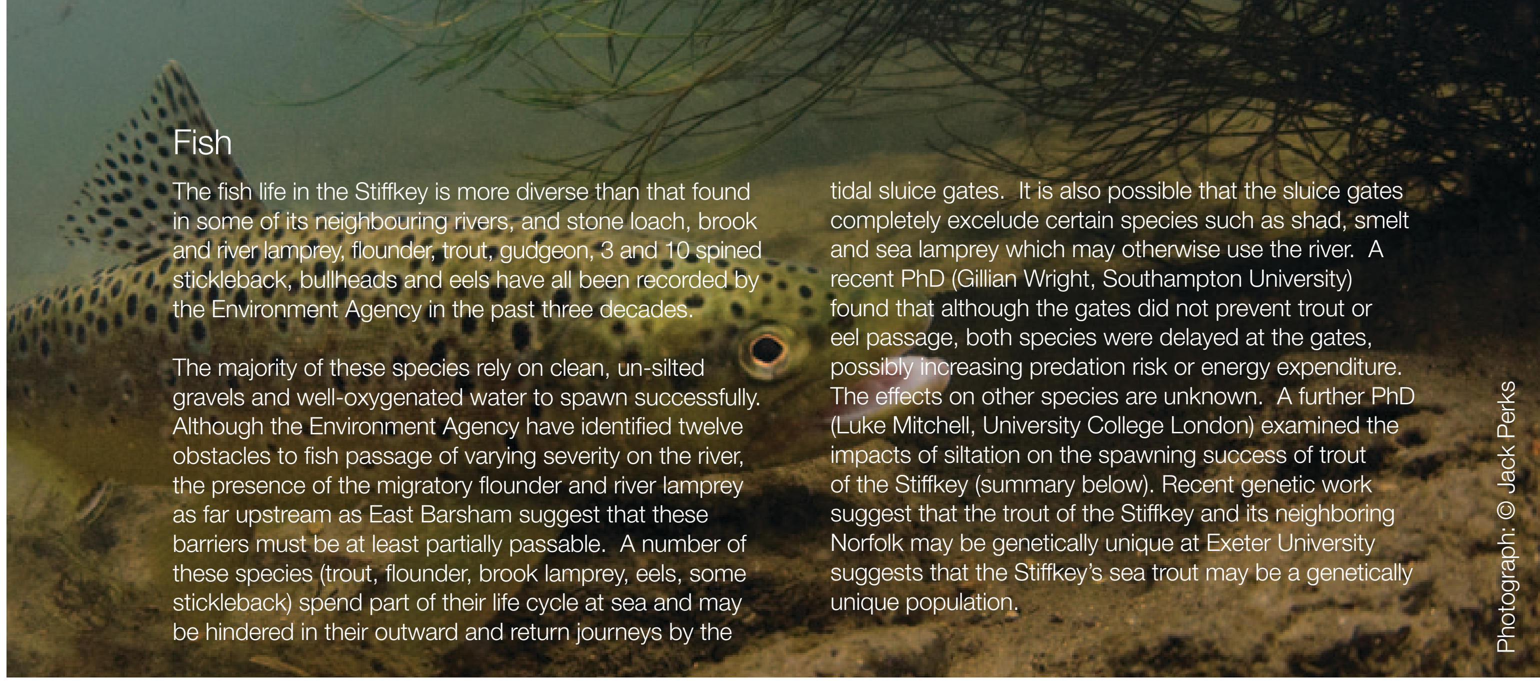
Britain's only native crayfish requires clean, well oxygenated, mineral-rich water and was once common throughout southern and eastern England, but is now on the verge of extinction following the introduction of the American signal crayfish. A population of white-clawed crayfish was recently transferred to the Stiffkey from the neighbouring Glaven where they are threatened by the introduction of signal crayfish.

Aquatic plants

The clean, mineral rich water and lack of flow variation mean that chalk streams are ideal ideal habitats for a wealth of aquatic plants, and the Stiffkey is no exception, although the plant community may be showing signs of nutrient enrichment and occasional low flows. The chalk stream classics, water crowfoot (*Ranunculus species*), Fool's water cress (*Apium nodiflorum*) and water starwort (*Callitriche species*) are present, along with water dropwort (*Oenanthe fluviatilis*), water parsnip (*Berula erecta*) and horned pondweed (*Zannichellia palustris*). Water milfoil, *Myriophyllum spicatum*, is also present and can be a sign of a overly high nutrient input, and in drier years bur-reed, *Sparganium erectum*, spreads from the channel edge to dominate the main channel. These are more typically still water species and would not thrive mid-channel under normal flow conditions.

The main threats to the aquatic plant community are a change in the nutrient status of the water (typically caused by phosphates and nitrates leaching from agricultural land or coming directly from septic tanks or sewage works), changes to flow (sudden floods or prolonged low flows) or a heavy input of silt smothering the river bed, as appears to have happened on the Binham Stream in 2013. Aquatic plants are also absent from heavily shaded areas, but quickly colonise and thrive when a break in the canopy appears.

For many decades aquatic "weeds" and bankside vegetation have been removed from the river channel to improve drainage and lessen flood risk, as heavy plant growth slows the passage of water downstream. The Environment Agency regularly cut the lower end of the Stiffkey, although this is now being done with greater sensitivity than in recent decades. Aquatic plants can be important morphological agents, with fast channels appearing between clumps of growth scouring clean gravels, and silt being deposited in the areas where the growth slows the water.



Fish

The fish life in the Stiffkey is more diverse than that found in some of its neighbouring rivers, and stone loach, brook and river lamprey, flounder, trout, gudgeon, 3 and 10 spined stickleback, bullheads and eels have all been recorded by the Environment Agency in the past three decades.

The majority of these species rely on clean, un-silted gravels and well-oxygenated water to spawn successfully. Although the Environment Agency have identified twelve obstacles to fish passage of varying severity on the river, the presence of the migratory flounder and river lamprey as far upstream as East Barsham suggest that these barriers must be at least partially passable. A number of these species (trout, flounder, brook lamprey, eels, some stickleback) spend part of their life cycle at sea and may be hindered in their outward and return journeys by the tidal sluice gates. It is also possible that the sluice gates completely excelude certain species such as shad, smelt and sea lamprey which may otherwise use the river. A recent PhD (Gillian Wright, Southampton University) found that although the gates did not prevent trout or eel passage, both species were delayed at the gates, possibly increasing predation risk or energy expenditure. The effects on other species are unknown. A further PhD (Luke Mitchell, University College London) examined the impacts of siltation on the spawning success of trout of the Stiffkey (summary below). Recent genetic work suggest that the trout of the Stiffkey and its neighboring Norfolk may be genetically unique at Exeter University suggests that the Stiffkey's sea trout may be a genetically unique population.

Photograph: © Jack Perks

The Ecological Impacts of Excessive Siltation in the Stiffkey River

Rivers are important landscape architects, eroding and transporting sediment from one area, depositing it in another. But this natural process is often greatly accelerated by the activities of man, by construction, mining, deforestation, and farming: often with adverse ecological impacts.

The Stiffkey River is particularly vulnerable to the impacts of high loads of sediment washing off farmland during heavy rain-showers and storms and during wet winters.

Fine sediment alters both water quality and the physical environment with consequent impacts on fish, insects and plants and the ecosystem as a whole.

Sediments washed off farm-land tend to have a high organic and nutrient content that, once deposited, creates oxygen-poor environments which are detrimental to many aquatic organisms. Few species manage to thrive in these conditions.

Widespread loss of habitat in the River Stiffkey has altered the character of the stream bed, triggering a shift to more silt-tolerant species in places.

The Stiffley River should, in its natural state, run clear even after heavy rain. But loaded with sediment the turbid water blocks out the sunlight aquatic plants require for photosynthesis. Prolonged periods of turbid flows adversely impact the aquatic plant abundance, with consequent knock-on effects throughout the food chain.

High levels of silt deposited throughout the Stiffkey River have degraded habitat used by fish to spawn. Trout (and sea-trout) lay eggs in gravel nests called redds. As the fish cut their redds they create a bed of clean gravel with all the sediment removed, through which water can freely pass delivering oxygen to the developing ova. Silt has the effect of smothering these redds and of suffocating the fish eggs. Even if the eggs develop and hatch, a smothering of silt can trap young fish in the gravel.

Unfortunately peak sediment input occurs during the seasonal winter rainfall and this coincides with trout spawning, placing developing embryos at an even greater risk.

Deposits of silt and sand in the Stiffkey River are so extensive that much of natural river bed, the rough, cobbled habitat of gravel and flint on which so many aquatic invertebrates and young fish depend, has been drowned out in drifting dunes of sand and mud.

Overall the siltation problem in the Stiffkey River has resulted in a loss of aquatic organisms through habitat degradation and poor water quality. Siltation has had, and will continue to have, long lasting effects on the food chain and ecological structure and function of the river.

Text and photograph: Luke Mitchell, UCL, 2013

Birds and mammals

Beyond the sluice gates – salt marsh and estuary

The area beyond the sluice gate, where river meets sea, is arguably the least degraded part of the river system, and is of international importance for it's plant and bird communities as well as for its landscape. Although the sluice gates disrupt the natural gradient from fresh to salt water, the cleanliness of the river and the quantity of sediment it carries are still crucial to life in the estuary, not least for the mussel growers, as explained below.


Photograph: © Jack Perks

The Link Between the River and the Marshes

The Stiffkey River flows into the freshes creek via sluices from Stiffkey fen.

Sediment and nutrient levels in the river water can have a significant impact on the salt-marsh through which it flows on its way to the sea. All the silt that washes downriver fetches up here, accelerating the naturally slow accretion of the tidal flats. As the flats build "pioneer species" grow rapidly upwards out of the level of tidal inundation and the salt marsh, eventually, develops a distinct cliff at the seaward edge.

Salt marshes are naturally nitrogen-poor environments. Increased nutrient loads derived from river-water and ground-water, adversely effects the natural community of plants species which thrive on a salt-marsh. A consequent loss in biodiversity is not only manifested in changes to flora assemblages, but there is a consequent impact on the habitat and food resources of birds and insects. The same is true of the impact brought about by other pollutants, by pesticides, herbicides and heavy metals: all have adverse affects on the dynamic structure of plant communities and the associated species that graze on the plants such as Brent and Pink Footed Geese.

Rising sea levels increase the possibilities of both accretion and erosion, with the whole coastal system becoming more dynamic. Climatic changes are likely to affect both the growth and distribution of salt-marsh plant species. Ultimately the ability of salt-marshes to adjust to climate change will be limited by their ability to expand landward.

Increased sedimentation, partly derived from the River Stiffkey and the impact of rising seas are likely to accelerate the lift in salt-marsh levels in the coming years.
And as salt marshes rise above the level of the landward ground to the south there will be associated issues of drainage and the control of water levels.

Victoria Egan and Matthew Twydell –
The National Trust.


Photograph: © Jack Perks

The effect of river management on the marine environment in Blakeney Harbour

One could think that the life of a river has no It would be easy to under-estimate the impact of a river and the groundwater of its valley on the estuary into which it flows. In truth these things are integral.

Blakeney Harbour estuary is formed at the outflow of the rivers Stiffkey and Glaven and is also fed by many of the chalk-aquifer springs that well up all along the North Norfolk coast.

For Blakeney Harbour there are three main issues: pollution, abstraction and siltation.

Chemical pollution from agriculture, sewerage and road-drain run-off effects the reproduction and growth-rate of marine species, in particular molluscs and bi-valves. High levels of nitrate and phosphate lead to excessive algal blooms and turbidity, which inhibits and smothers aquatic life.

Many shell-fish reproduce in the estuarine environment simply because the less saline quality of the water is conducive to their breeding. This is, of course, effected by the abstraction of fresh-water from the rivers and aquifers.

Silt and sediment run-off from is a major problem too, especially for mussels, as they cannot tolerate sand in their systems at all.

Silt and pollution in rivers can only go one way: seaward..

Text by Geraldine Green, 2013

Nature conservation in the Stiffkey Catchment

The Stiffkey valley is home to a large number of designated wildlife and conservation sites, and hydrology and water quality are integral to the health of each of these. The headwaters of the river flow through the Site of Special Scientific Interest (SSSI) at Swanton Novers Woods, and the river passes through nine county wildlife sites and one local nature reserve before entering the Stiffkey Marshes SSSI and the sluice gates. The lower end of the river flows through the North Norfolk AONB, and the salt marsh and estuary are designated as a Special Area for Conservation, a Special Protection Area, a SSSI, a RAMSAR site and a Biosphere Reserve. The designations range from ancient woodland (Swanton Novers) to wet meadows (most of the county wildlife sites) to the Stiffkey Marshes site designated for it's breeding waders (particlularly Avocet and Lapwing) to the internationally important salt marsh bird and plant communities. It is noticeable, even from the names (Stiffkey Meadows, Bridge Marsh, Pond Meadows) the water plays an essential role in supporting the wildlife at many of these sites. It is also apparent that the hydrology of the river and floodplain have been altered so severely that although these sites remain worthy of protection, their nature value is probably a fraction of what it was before the river was channelized and embanked.

County Wildlife Sites in the Stiffkey Valley

Most of the County Wildlife Sites in the Stiffkey valley are composed of species-rich, marshy grassland, often bounded by large hedges. They are a characteristic and distinctive component of the North Norfolk landscape. Many of the meadows straddle the River Stiffkey and some are grazed by cattle, as they have been for centuries.

Species-rich grassland is now a rare habitat in the wider countryside: approximately 97% of unimproved grasslands were lost between the 1930s and 1980s. Marshy grassland in particular is rare and declining in Europe as a whole, with less than 22,000 ha now left in England.

Generally found in river valleys, or on land with impeded drainage and subject to seasonal flooding, marshy meadows are often also flushed with springs and seepages. The flora associated with this habitat includes grasses, rushes, sedges, broad-leaved herbs, as well as mosses and liverworts, and a wide range of aquatic and emergent plants.

Marshes occur on a variety of substrates, but those on waterlogged peaty soils are usually the most diverse, because their low nutrient levels inhibit the growth of competitive plants, allowing the rarer species to thrive. Plant species typically found on marshy grassland and fen sites include common spotted, early marsh and southern marsh orchid; marsh marigold; ragged robin; marsh and fen bedstraw; greater bird's-foot trefoil; tufted vetch; common knapweed; red and white clover; and a range of sedges and rushes. Most of these species depend on a high water table within the soil and will happily survive periodic inundation. However, they soon die out on heavily drained land, usually to be replaced with a narrow range of coarse and common species.

Marshes also provide a valuable habitat for a range of faunal species. Invertebrates such as dragonflies and damselflies thrive along the ditches while hoverflies, bees, moths and butterflies are able to forage in flower-rich swards. These rich invertebrate communities in turn make marshy grassland a valuable feeding habitat for species which prey on them, including bats and insect-feeding birds. Extensive areas of marshy grassland also provide rich hunting grounds for owls and kestrels, and are particularly important for birds which need seasonally wet grassland for feeding and roosting such as lapwing, redshank and snipe.

One of the richest parts of this habitat are the ditches and drainage channels, especially where they retain water for long periods and where cattle graze only lightly and occasionally and do not destroy the banks and margins.

Aquatic and marginal plants provide refuge for aquatic invertebrates such as diving beetles and water snails and amphibians including newts, frogs and toads. Water voles can also be particularly abundant in the dyke systems in low intensity grassland.

In Norfolk, as elsewhere, marshy grassland is often found in association with other habitats of high conservation value such as wet woodland and scrub, dry grassland and heath. These mosaics of interlinking habitats are able to support an extremely diverse and wide-ranging array of plant and animal species.

The greatest threats to marshes and fens are activities which damage the quantity or quality of water which feeds them, or which actively change the composition of the vegetation.

Under-managed and neglected sites eventually scrub over, leading to drying out and enrichment through leaf drop and build-up of dead vegetation or litter.

Deep or heavy drainage dramatically lowers the water table, resulting in the rapid loss of plant species which depend on damp or wet conditions.

'Improvement' by the application of fertiliser or reseeding, inappropriate planting of trees and overgrazing or grazing with unsuitable livestock can all change the composition of the vegetation permanently, making the site difficult or impossible to restore.

Activities on neighbouring land can also be very damaging, particularly on smaller more vulnerable sites: drift from chemical sprays, pollution and run-off are all potential threats.

All species-rich grasslands require regular management to retain their diversity, keep nutrient levels low and reduce competition from vigorous plant species.

Marshy grassland, in addition, needs to have high water levels maintained within the site to support its specialised flora. This is best done by sympathetically managing ditches and drains, and sluicing them where necessary to prevent loss of water from the site. Ditch clearance is best done on rotation, and should avoid over-deepening and total clearance wherever possible.

Management of the grassland itself should be either by low intensity grazing or by cutting. Grazing is generally best done by native breeds of cattle which are less selective grazers, though some native breeds of sheep or pony may also be used. Depending on the size and wetness of the site, grazing is likely to be limited to the summer / autumn months, but on some sites, particularly those in the early stages of restoration and where there is sufficient high ground, winter grazing can be beneficial, especially if suitable areas for supplementary feeding can be found which will not damage sensitive parts of the site.

Low-density grazing of grasslands produces a variable sward height which varies the habitat and significantly increases its value for invertebrates and small mammals.

Cutting is generally carried out on smaller sites. It is best done in late summer, to allow flowering species a chance to set seed and to avoid the risk of damaging the nests of ground-nesting species.

It is essential that all the cut vegetation is removed (eg. as hay bales, even if these cannot be used as hay), rather than left to rot in situ, as the decomposing vegetation increases nutrients in the soil and over time produces a taller, ranker sward. Lightly grazing the aftermath for a few weeks in autumn is highly beneficial, as it varies the structure of the sward and further reduces the vigour of taller species which recover more quickly after cutting.

Andrina Walmsley, Norfolk Wildlife Trust

> "The greatest threats to marshes and fens are activities which damage the quantity or quality of water which feeds them, or which actively change the composition of the vegetation."

Photograph: © Jack Perks

COMMUNITY

Collaborative working: VISUALISING The Stiffkey catchment

"Visualisations are known to provide a common focus for discussion between various groups, so improving communication and helping to identify better future solutions. The ability to explore issues within a 'What If?' visualisation framework encourages communities in directing their own future and so assists in creating longer term management goals."

The NRT and the UEA team developed and trialled a unique approach to catchment scale planning. The UEA research team adapted a visualisation framework to engage stakeholders in the issues which their catchment faces now and in the future. Working with the UEA enabled the 9 Chalk Rivers project team to apply a customised tool for community engagement and ensured that the UEA visualisation research was trialled in a real world situation.

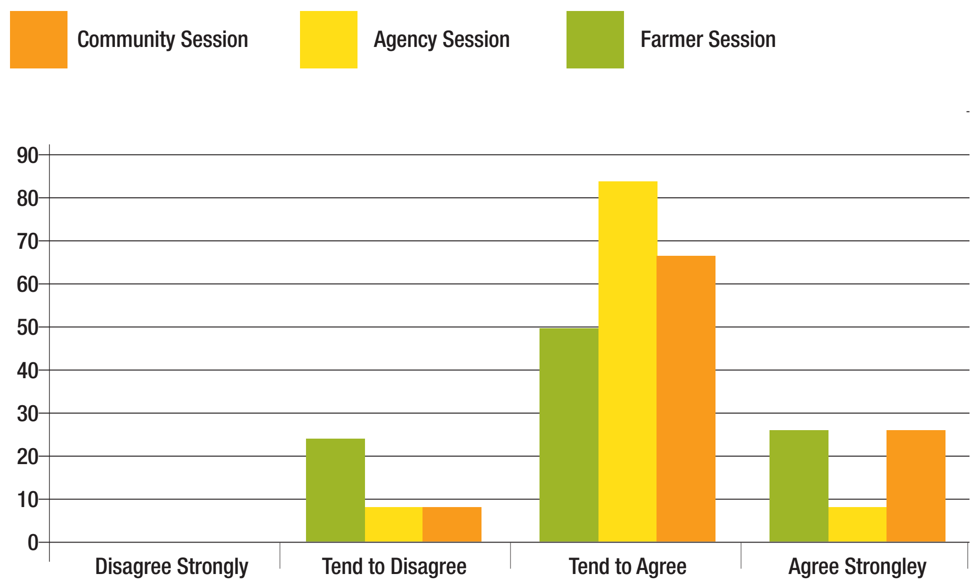
Engaging catchment stakeholders

Using local knowledge from the Norfolk Rivers Trust areas of the catchment which could be improved by sensitive river restoration were identified prior to stakeholder workshops. The most important current issues identified in the Stiffkey catchment were:

- Silt runoff and build up requiring in river dredging
- Lack of river function due to canalisation, the river also being detached from its floodplain
- Low flow, seasonal flooding and lack of buffering (no wetlands) impacting in-channel habitat
- Lack of access for community to enjoy the recreation potential of the river area

Using 3D computer models and maps current and future visualisations were created by the UEA team and shown at workshops to gather feedback on the issues within the Stiffkey catchment. Three sessions were held in March 2013 for stakeholder groups (**landowners/farmers, agencies** and **community**), data gathered was shown at a second open day in May 2013 to give feedback and to allow additional contact with a wider community focus. Stakeholder attendance at the March workshop sessions was excellent (around 40 attendees); the response to a survey developed by the UEA was good (82% completion). Workshop participants were asked whether they felt the Stiffkey catchment would benefit from a change in land use – see graph below.

Results from the UEA survey indicated unanimous agreement across all three workshop sessions that priority should be given to the reduction and mitigation of silt runoff into the river network. Improving the habitat along the river and reducing damaging flooding were considered equally important. Recreational access to the river was a lower priority for all groups.



FEEDBACK from stakeholders (March 2013 WORKSHOPS)

Feedback from the March workshops suggests a good response to the idea of restoring sections of the River Stiffkey. In particular comments were noted on the potential for improved water quality, better quality habitat, and the more natural aesthetics of the restored land form and possibility of improved access. There was also interest in the increased water storage of the river proving longer abstraction period for irrigation of this area.

Alongside the UEA survey additional comments were documented during the first round of workshops. This information has been condensed; comments in *italics* are those from workshop participants. Please note that due to the ethics process which the UEA team abides by it has not been possible to include comments which would identify a particular stakeholder.

DIRECT QUOTES FROM UEA SURVEY - COMMUNITY

- All other improvements depend on improving water quality
- Farmers do not like their land to be flooded - difficult to gauge but also want water for irrigation and cattle during drier periods
- River access & water quality key priority
- Improving water quality to improve habitats
- Improving water quality and reintroducing meanders will in turn help to improve habitat, alongside the improved flood management scheme
- The starting point should be improving access, e.g. Footpaths. I feel this would create more interest in environment and nature.

During the community event particular interest was shown in the history of the river – *"why did the river change course? And when?"* enquires were made about whether the old maps could be brought into the computer model and shown alongside the current landscape and the possible future landscape – this is indeed something which could be done with the UEA tool.

DIRECT QUOTES FROM UEA SURVEY - FARMERS

- Because the nature of rivers means that they are inherently shared by wildlife and humans there needs to be good understanding of the dynamics to reach sustainable solutions to pressures
- Abstraction for irrigation [when asked for additional info on most important consideration]
- Reducing diffuse pollution in order to improve the ecosystem, but also maintain flows of water which is another important resource
- If we improve water quality by mitigating runoff then we will increase wildlife value

COMMENTS DURING FARMER WORKSHOP

- *"Absolutely 'for' restoring the river and Binham stream but requirement to water stock and allow crossing points, what would be the most conservation friendly way to do this?"*
- *little or no support for land use change if quality grazing areas become wet (liver fluke)*
- *"Would wetland buffers reduce the amount of flooding in Stiffkey village which has suffered lately with the wet weather?"*
- *Will the wetland buffers remain vegetated if water was allowed to stand on them for long periods of time? What maintenance would be needed and who would take responsibility for that? What would the overall bankside vegetation look like, would trees be encouraged or discouraged? To what degree would stock have access to graze these areas and at what times of the year?*
- *Particular interest shown by farmers in the creation of wetland silt traps*
- *"Whether new access/footpaths being permitted by the landowners would be a prerequisite to the work on the river being carried out by the Norfolk Rivers Trust?".*

Overall the session with the farmers and landowners was positive and the feedback was constructive. It was also noted that the river currently forms the boundary of many tenancy and land ownership agreements and any changes to those boundaries would have to be investigated further.

DIRECT QUOTES FROM UEA SURVEY – AGENCY STAFF

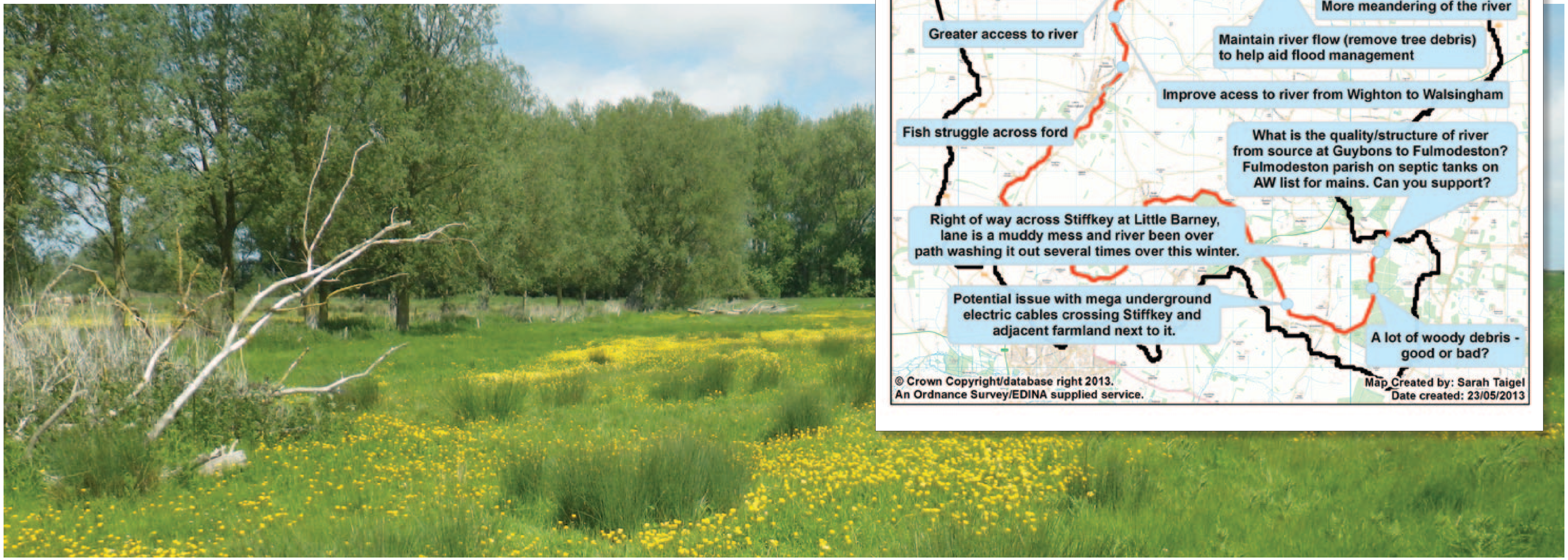
- Sustainable drainage and water quality & reuse are key
- Preventing runoff is the first step towards improvement
- Must tackle issues at source, I believe silt traps etc are an interim measure. The long term aim has to be to manage the entire catchment sustainably to allow farming to be profitable
- To bring community, landowners, businesses along we need to ensure that we all recognise the benefits of improving the Stiffkey catchment
- Flooding can cause major problems to people's homes, and highway users which may endanger lives
- Improving water quality will improve biodiversity, this coupled with channel improvements will ultimately create a sustainable watercourse both from an ecological and flood conveyance view
- Silt, nutrient runoff reduction seems to be the first priority to me, habitat improvement may be ineffective without this e.g. Spawning gravel introduction
- Water quality is a necessity but not sufficient condition to achieve good ecosystem services - habitat is primary

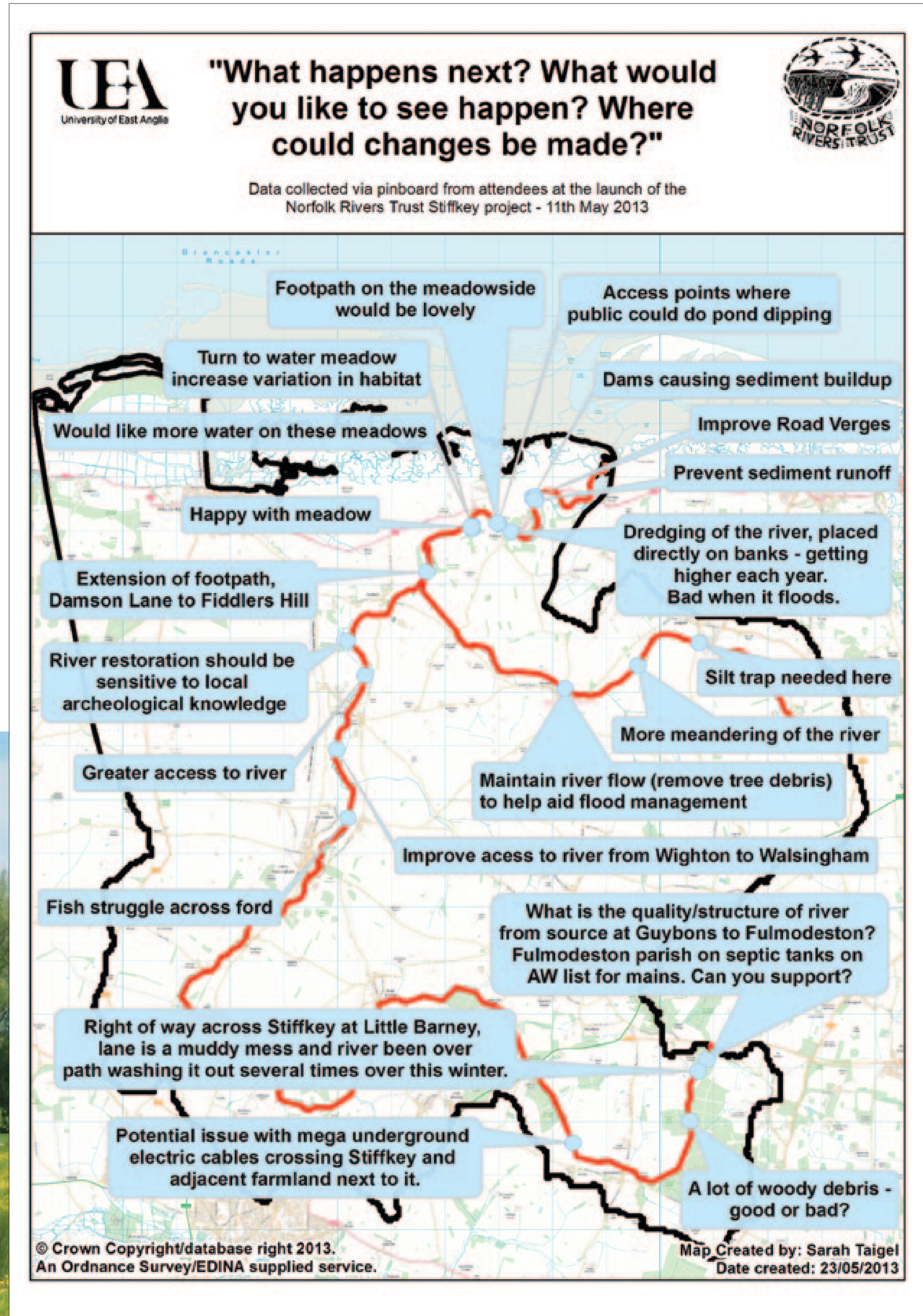
Summary

This combined Norfolk Rivers Trust and UEA research project successfully increased awareness of the river and its issues using cutting edge visualisation tools and by bringing together a representative sample of stakeholders to gather feedback on the issues in the Stiffkey catchment, the possible solutions and the visualisation tools themselves. The visualisation framework was designed to be transparent and replicable in other catchments. By applying a visioning framework the engagement process was successfully completed in a short time frame.

Credit

This research has been developed as part of a PhD based at the UEA to develop tools to enable the visioning of future catchment landscapes. Sarah Taigel's research is being conducted as part of ESRC PhD Studentship No. ES/I022139/1





SECTION 2 THE PROBLEMS AND SOLUTIONS

MORPHOLOGY – THE IMPORTANCE OF RIVER FORM AND FUNCTION

The diversity of life associated with chalk streams is reliant on the health and diversity of the habitats in and around the streams themselves. Lowland chalk streams such as the Stiffkey typically meander across their floodplains. Due to its low gradient and small size the Stiffkey is not powerful enough to cut deep channels through the land, but instead responds to subtle changes in gradient and substrate resistance by flowing round, rather than through. Naturally, the channel would meander greatly, and would be incapable of cutting deep into the bedrock. Bends in the river create a gradient of water velocities and depths, exposing clean gravels where the water flows faster and depositing silt in the slower areas. This variety of flows and substrates creates habitats for a variety of life. Over the centuries, the Stiffkey's channel has been straightened and re-directed, and much of its variability lost. Straightening creates a uniformity of flow, and the faster flowing areas from which silt would naturally be scoured disappear, allowing silt deposition along the whole river bed. Creatures adapted to uniform flows and silty substrate thrive in such conditions, but those requiring pools and riffles, clean gravels, or fast or slow water do not. Slowly the make-up of the plant and animal communities changes, and diversity is lost.

Much of the Stiffkey has been straightened and marginalised, from the headwaters to the sea, and very little of the river retains a "natural" form. Meanders do remain, most notably between Great Snoring and Little Walsingham, pictured below.

Meander restoration is now recognised as valid method of partially restoring river function, re-creating habitat diversity and allowing improved silt management. The technique has been globally (and locally) to great effect, and restored meanders on the neighbouring Rivers Glaven and Wensum are now delivering habitat and biodiversity benefits.

FLOODPLAIN CONNECTIVITY

As the river has been repeatedly dredged over many centuries, the channel has deepened to the extent where in many places it is now many feet below ground level. The material taken from the river bed has been used to create embankments on the sides of the channel and the river now very rarely spills over its banks. In its natural state a chalk stream would spill over onto its floodplain frequently, the floodwaters carrying with them silt, nutrients and seeds which are deposited in the riverside woodlands and meadows. This system allows the river to export excess silt, phosphate and nitrate, and delivers valuable seeds and nutrients to the floodplain. The soil in the valley bottom benefits from regular (but short-lived) floods, rather than the rare but prolonged inundations that occur when embankments prevent groundwater floods draining away into the river. The sequence of prolonged flood and drought conditions seen on the floodplains of embanked rivers kills microbial and invertebrate life in the soil, leading to a loss of plant and insect diversity, which in turn affects the mammal and bird populations. Snipe, avocet, lapwing and woodcock in particular are sensitive to soil degradation, as are the shrews, voles and other small mammals which in turn feed the owls, kestrels and harriers.

The straightening of the river and disconnection from the floodplain has been so complete that very little marginal habitat between river and meadow now exists, the near-vertical banks forming a definitive cut-off between river and bank. This marginal habitat, the transitional area between water and land, is essential habitat for a wide diversity of wildlife, including water-voles, amphibians, insects and water forget-me-nots, marsh marigolds, hemp agrimony and flag iris.

Restoration works can successfully restore these floodplain and river-side habitats, as has been shown on the Glaven, where University College London research is now showing that where a river is once again allowed to spill into (and back out of) a meadow the plant diversity in the meadow very rapidly doubles.

Floodplain restoration can highlight the potential conflict between the need for ecological improvement and the need for agricultural production. In the Stiffkey valley much of the valley floor is valuable grazing land, and in other areas arable land approaches the river, so farmers may be understandably see increased flooding as a threat to their land, and the areas in which this can work successfully are limited. However, even where full floodplain function cannot be restored, it is possible, and beneficial, to bring back the banks and create wet-shelves within the existing channel, creating marginal habitat for a variety of wildlife.

FLOW

Although the ecological consequences of a reduced flow are difficult to demonstrate, and over a prolonged period of time the flora and fauna of the river will adapt to the amount of water available, the human impacts on the Stiffkey river channel make the river particularly vulnerable. The straightening and repeated dredging of the channel have left the river bed overly wide, and what flow there is tends to dissipate across the river bed, allowing for very little water depth. The pools and backwaters that should act as refugia in times of drought are mostly gone, and the drainage of the floodplains and wetlands means the capacity of the catchment to buffer the river in dry periods is all but gone.

Work to restore habitat heterogeneity in the channel can recreate low-flow refugia and restore deeper, narrower channels, making maximum use of the available water. Allowing the river to spill onto the floodplain allows the floodplain to act as a sponge, as the original wet woodlands, mires and meadows would have done, releasing water slowly but continually back into the river.

PHOSPHATES, NITRATES AND NUTRIENT BALANCE

The wildlife of the Stiffkey, and other chalk streams, has evolved to exploit the levels of nutrients and minerals naturally found in the chalk-filtered water and the run-off coming through wet meadows and woodlands. An increase in the levels of nutrients in the river (typically phosphates and nitrates) allows the growth of an alternative biota in the river, leading to an increase in algal growth and a shift in the plant community to more nutrient-hungry species. The increased plant and algal growth can deplete the oxygen levels in the water, threatening the natural chalk stream animals and plants. Persistent and high nutrient input can lead to a complete domination of the stream by a very limited number of species, and an exclusion of the iconic higher plants, insects and fish.

Excessive algal growth, mid catchment, a result of an excess of nutrients and reduced flow in the overly-wide channel.

In the Stiffkey the vast majority of the nutrient input comes from two sources: agriculture and sewage. Although crop fertilisers are now generally used much more sparingly and intelligently than in past decades, and the Stiffkey is protected by a nitrate sensitive zone, some leaching into the river still occurs, and high nitrate levels persist in the aquifer and groundwater, a legacy of generations of use.

The vast majority of phosphates now found in UK rivers come from human sewage. The Stiffkey is particularly vulnerable to this problem, due to the high number of septic tanks (particularly in the Fulmodeston and Saxlingham areas) and the size of the existing sewage treatment works, generally too small to warrant phosphate removal from the effluent.

Fiona Wood, of Anglian Water
writes on the importance of clean water and nitrate management, below.

Looking after water quality

The quality of the water in our rivers and groundwater can have a profound effect on wildlife, people's enjoyment of the river, and the economy. The impact of poor water quality can range from unsightly algal growths to chemicals in the water that require lots of energy and treatment to remove.

Phosphate and sediment

Too much phosphate in the river can stimulate excessive growth of algae or aquatic plants which are not only unsightly, but also clog up fish spawning gravels and smother more diverse vegetation. When the algae eventually dies and decays, it uses up oxygen in the water, reducing what's available for fish.

A significant source of phosphate in the Stiffkey is actually from households. It's found in foodstuffs, food additives, laundry powder, and dishwasher tablets. This can then enter the river in discharges from sewage treatment works or septic tanks. There has been a significant amount of investment at the large sewage treatment works in the region to remove phosphate from the water, however, removing phosphate through water treatment is expensive and it has a high carbon footprint. Although new technologies are being developed, it's more efficient and environmentally friendly to tackle the problem, particularly in smaller villages, by focussing on reducing the quantities at source.

Trials are ongoing in the region to encourage people to cut down on products containing phosphate and replace them with alternatives like phosphate free laundry powder and dishwasher tablets. Initial results look very promising with phosphate levels in water substantially reduced and seemingly without an increase to customers' shopping bills.

Alongside this work, continued investment in conventional phosphate removal (and treatment for other pollutants) will be carried out by Anglian Water at sewage treatment works around the region. Agreements are made every 5 years between the Environment Agency, water companies and Ofwat, the water industry regulator, about what investment needs to be made to maintain or improve river water quality.

Local water quality monitoring can play a part in picking up early indications of phosphate or nitrate changes in streams. Working with the EA, in the Wissey catchment for example one resident has indeed picked up likely elevated phosphate levels in one of the tributaries.

Surprisingly, phosphate is actually added to drinking water at source, in the form of a very dilute acid, to prevent lead from old household plumbing pipes dissolving into drinking water. Ten percent of the phosphate in waste water is believed to come from this source, though as pipes are gradually replaced, it will eventually be possible to stop this dosing.

Another major source of phosphate is misconnected drains that cause foul sewage to enter the surface water system. It's estimated around 300,000 homes in England and Wales have misconnected drains, generally because of poor quality building works and plumbing mistakes. The Stifffkey region is no exception and therefore encouraging homeowners to use approved plumbers and builders for any renovations is key to tackling the problem.

Phosphate also gets into the water when livestock are able to dung in the river and through uncontrolled soil and river bank erosion. Whilst erosion is a natural process, too much of it, especially that from farmland and road verges, will wash phosphorous-rich fine sediment into the river after rain. On top of that, as with heavy algal growth, lots of sediment going down the river will clog up fish spawning gravels.

Nitrate

In England, we enjoy drinking water that is amongst the best in the world. It is treated to extremely high standards and tested to make sure that it is clean and safe to drink. In the Stiffkey catchment , only groundwater is used for public water supply and the main chemical in the raw water requiring treatment is nitrate. Groundwater is abstracted from three Chalk sources to supply local towns such as Wells and Fakenham.

Nitrate is essential for growing crops so it's a key component in fertilisers and manures used on farmland. This can easily leach through the soil into groundwater supplies when it rains.

Farmers have long worked to rules such as the Nitrate Vulnerable Zone regulations that limit the amount of nitrate that can be applied on their farms and govern other activities like the management of manure heaps - another source of nitrate.

Water can be drawn from tens of metres below the surface, and groundwater moves down through the ground very slowly, meaning that any change on the land would take around 20 or 30 years to be seen as better water quality in public and private boreholes. However, the land use and geology above an aquifer has an enormous effect on the amount of nitrate leaching down into groundwater.

Anglian Water computer models of the catchment combined with other evidence suggest that where nitrate levels in groundwater are significant, they will continue to increase for several years as the effects of farming practices in the last part of the last century come through, before levelling off.

There is some uncertainty about what will happen after that. If groundwater nitrate levels mirror those seen in river water, they will show a partial decline as the effects of improvements in farming practices feed through from the late 1980s onwards.

Where it is needed, water companies reduce nitrate in raw water before it goes into public supply through ion exchange or by blending high nitrate raw water with waters from a different source with less nitrate. Within the Stiffkey catchment both of these solutions are carried out. However, these are high energy processes and the knock-on effect for customer bills mean that simply building additional water treatment is not a sustainable option long term. Furthermore, legislation (the Water Framework Directive) aims for no further deterioration of groundwater quality, and indeed expects a reversal of any current deteriorating trend.

However, groundwater nitrate is likely to remain relatively high in those locations where there is a high proportion of agricultural land and little cover over the chalk. Nevertheless, reducing nitrate in groundwater to the lowest level consistent with productive farming will bring benefits to everyone. This can be achieved by continued development and uptake of improved farm practices.


Photograph: © Jack Perks

SILTATION

Due to its low gradient, historic straightening and disconnection from the floodplain, the Stiffkey is particularly vulnerable to siltation, as once the silt enters the system it is evenly distributed across the whole river bed and cannot be exported onto the floodplain. The landuse in the catchment also poses a particular threat, as potato and sugar-beet farming in particular can leave large areas of ground bare during periods when heavy rainfall is likely. The increasing use un-cropped field boundaries and more latterly the use of cover crops to minimise the areas of earth left bare over winter have reduced the direct input from fields, however, large quantities of silt still enter the river. Much of the silt now entering the river now comes from roads, fords and farm access tracks, and the increasing volume and size of traffic in the catchment's narrow lanes is exacerbating the problem. Recent research shows that although the majority of silt entering British rivers is still agricultural in origin, an increasing proportion is coming from road verges, and it is this material which poses the greater threat due to its high organic content, and its traces of hydrocarbons, heavy metals and other chemicals.

A 2013 APEM Ltd report for Natural England examined 44 silt entry points on the Stiffkey and found the highest number of points, and those which deliver the most silt to be in the middle reaches of the catchment. Recent work by Norfolk Rivers Trust on the Nar is showing how these problem points can be addresses relatively easily and cheaply, either by diverting rain-flow away from the river, or by trapping silt in the river close to its point of entry. The headwaters of the river contain a number of old on-line ponds which once trapped large quantities of silt but are now full – these can be excavated to good effect and will continue to trap silt for some years. Work in the Glaven is now helping farmers re-locate field entry points and beet storage pads which can release lost of soil onto access tracks and eventually to the river. The catchment sensitive farming initiative has taken great steps to prevent top-soil being washed from fields into rivers, and is described below.

Catchment Sensitive Farming

Practical and Cost Effective Solutions to Protect Water Quality

The DEFRA funded Catchment Sensitive Farming (CSF) initiative has been operating in the North Norfolk area since 2006. The River Stiffkey has been one of the main focus points throughout this time, along with the River Glaven, River Burn and areas surrounding boreholes used for public water supply, as CSF is trying to protect water quality both to enhance the ecological interest of rivers and for purity of drinking water supplies.

CSF aims to increase awareness of the effects that agriculture can have on surface and groundwater quality and the contribution that good farming practices, like restricting cropping in the most vulnerable locations, can make to improving both types of water resource. Its approach is by voluntary engagement with farmers to identify where changes to farming practice beyond those required by regulations will bring real benefits, but without compromising farming efficiency. In fact, good practice often gives the opportunity to make efficiency savings also, for example through reduced fertiliser use or reducing the volume of dirty water that needs special treatment.


Good planning of crop cultivations and timing helps to reduce problems of high risk crops like sugar beet and outdoor pigs

To ensure that the best informed and most practical advice is available, CSF has used specialist advisers to talk to farmers at locally held events or to visit them individually on farm. The range of subjects covered and which have been taken up by many in the Stiffkey valley has included:

Nutrient Management Planning – to optimise nutrient application rates and minimise any surplus that might be washed or leached away

Soil Husbandry and water management – examining soil health problems and looking at the best approach to rectify them to ensure good crop growth and reduce runoff that carries valuable nutrients away with it

Pestcide handling – best practices for safe filling, emptying and washing out to prevent any contamination of runoff.

Tracks can provide an easy route for sediment laden runoff to get from fields to watercourses, but increasingly farmers have found that they can use simple methods like bufferstrips, gate relocation and crossdrains in tracks to intercept the flow.

Farm infrastructure – design of buildings, yards and trackways to prevent water contaminated with farm wastes from reaching watercourses.

CSF has given incentives to implement some of the recommendations from specialist advice reports through its own grant scheme that can fund up to 50% of the cost for items particularly appropriate to the Stiffkey catchment area, among them - : track resurfacing, crossdrains and gate relocation to control runoff; concrete renewal and roofing in yard areas to separate clean and dirty water sources; pesticide sprayer washdown areas and biobeds to treat contaminated sprayer washings.

CSF advisers are employed by Natural England (NE) and so have also been able to make use of land management options available through NE's Entry and Higher Level Schemes which have a very high coverage around the River Stiffkey . Areas in fields with soil particularly susceptible to erosion can be taken out of cultivation altogether and sown with a mix of grasses that will slow water movement across the surface. Bufferstrips around field edges reduce sediment, nutrients and spraydrift from cultivated fields getting into ditches, while much of the pasture land near to the river is managed particularly sensitively with very few inputs, also benefiting characteristic species like the lapwing that nest there and wildflower rich wet grassland.

Text and photographs by Roger Gerry, Natural England

FISH PASSAGE

The Environment Agency identify ten barriers to fish passage on the main body of the Stiffkey with a further four on the Binham Stream, ranging in severity from easy to hard, but also note that fish populations in the catchment are good. The highest priority obstacles are the sluice gates at the river's end and the gauging weirs at Little Walsingham and Warham. While none of these barriers are likely to be completely impassable to a fit adult sea trout or an elver, each one will hinder a proportion of fish, probably expose all fish to an increased risk of predation and require unnecessary energy expenditure. As noted above the presence of flounder high in the catchment suggests these obstacles are all passable but they may nevertheless hinder fish productivity significantly and should be addressed. Furthermore it is possible that these obstacles, particularly the sluice gates, may hinder the passage of species which have not been recently recorded in the Stiffkey, but are found in coastal waters and may re-produce in the river if permitted to do so, such as sea lamprey, shad, smelt and possibly occasional salmon.

INVASIVE SPECIES

The Stiffkey, probably due to its relative isolation from main roads, railway lines and large towns, lack of major fishing interest and lack of public access has not yet been victim to invasive species to the same extent that other British rivers have. There are as yet no records of signal crayfish or Japanese knotweed, and mink populations seem to be minimal, possibly as a result of the successful otters. Himalayan balsam has been recorded in the lower catchment and *Crasula helmsii* in a pond close to the river. However, the threat is serious, as signal crayfish are now in the Wensum, Glaven and Great Ouse, and knotweed is also in the Glaven and Burn. Mink are widespread throughout the country, and a whole variety of non-native invasive plants are found in neighbouring catchments. Killer shrimp are now present in the Broads and are likely to spread quickly to other English catchments. The threat of the crayfish in particular is extremely serious, as an invasion of signal crayfish would not only wipe out the recently re-introduced native crayfish but would also diminish insect, fish and plant productivity, and undermine the river banks, increasing the siltation problem dramatically.

Norfolk County Council are currently preparing a North Norfolk Biosecurity Plan which will provide guidance on the control and eradication of these species. Biosecurity is now a critical issue, and anyone visiting or working on the river should be aware of the requirements to cleanse and dry all clothing and equipment which may have been used at other sites.

TREES, SHADING AND LIGHT, AND WOODY DEBRIS

Over the past two decades the importance of trees to rivers, as a nutrient source, habitat, and architect of channel morphology has become increasingly apparent.

Recent research has highlighted the threat that climate change poses to aquatic ecosystems through changing water temperatures, and small streams such as the tributaries of the Stiffkey are particularly vulnerable. The recent Environment Agency project "Keeping Rivers Cool" highlights the need to protect rivers from warming and the role that strategic tree planting can play in providing shade. There is a need for careful planning and planting however, as too much shade can prevent macrophyte growth, hinder in-stream productivity and drain wetlands, as is apparent in parts of the Stiffkey where dense woodland dominates, or plant growth inside riparian fencing has not been controlled.

Very few areas of the Stiffkey achieve the balance between light and shade, as trees are almost totally absent from the river banks for long stretches of river but dominate completely in others. The problem of over-shading is greatly exacerbated where the river is incised, as on the barely visible Binham Stream, below.

In the wet woodland that would have been widespread thoughout the catchment the river would have flowed at ground level, and regular breaks in the canopy would have appeared when trees toppled in waterlogged ground or trees lost boughs.

To achieve a balance of light and shade, strategic fencing and planting of alders, willows and other native water-tolerant species should be considered in the areas where trees are currently absent. Where possible planting on northern and eastern banks will still allow maximal light to reach the stream. As the small stands mature, falling leaf litter will provide an additional habitat and food source, and falling limbs and trees will encourage the development of a more diverse, dynamic river channel.

Management of current plantations should be carefully considered, as in some areas plantations are draining former wetlands, and in others shading has become complete. Where appropriate whole trees may be pulled into the river, to encourage the formation of meanders and backwaters, and provide shelter for fish and invertebrates, as demonstrated by the National Trust on the River Bure. The pulling, rather than felling of trees, leaves craters where the roots were, ideal habitat for amphibians and invertebrates, and areas of weakness into which the river may eventually meander.

Wholesale felling may be appropriate where trees (particularly poplars and pines) have been planted in particularly wet areas unsuitable for agriculture. These areas, easily identifiable particularly around Field Dalling and Hindringham, would once have been major springs contributing to the main river.

An overgrown section of the Binham Stream. The channel is five feet deep below this vegetation and no light penetrates.

SECTION 3 AN ACTION PLAN

In 2013 Norfolk Rivers Trust ran a series of meetings and workshops to discuss the possibilities of river restoration with farmers, landowners, various agencies and the general public. We would like to continue this process and would especially like to engage farmers and landowners in the catchment to ascertain where work on the river may be undertaken. The plan provides a basic overview of the ecological requirements of the river and floodplain, but restoration is constrained by valuable agriculture and owners' consent. In reaches where agricultural land abuts the river, or the banks and floodplain have archaeological value a realistic target may be to work within the channel creating small wet terraces and miniature meanders rather than full re-meandering and floodplain re-connection.

This plan will be distributed throughout the catchment, and Norfolk Rivers Trust would be delighted to hear from river owners who may be interested in working with us.

For the purposes of planning future catchment management, the catchment has been divided into subsections. The subdivisions have been made according to river character and work required. The actions suggested are based on those identified by the Environment Agency and those described in this plan

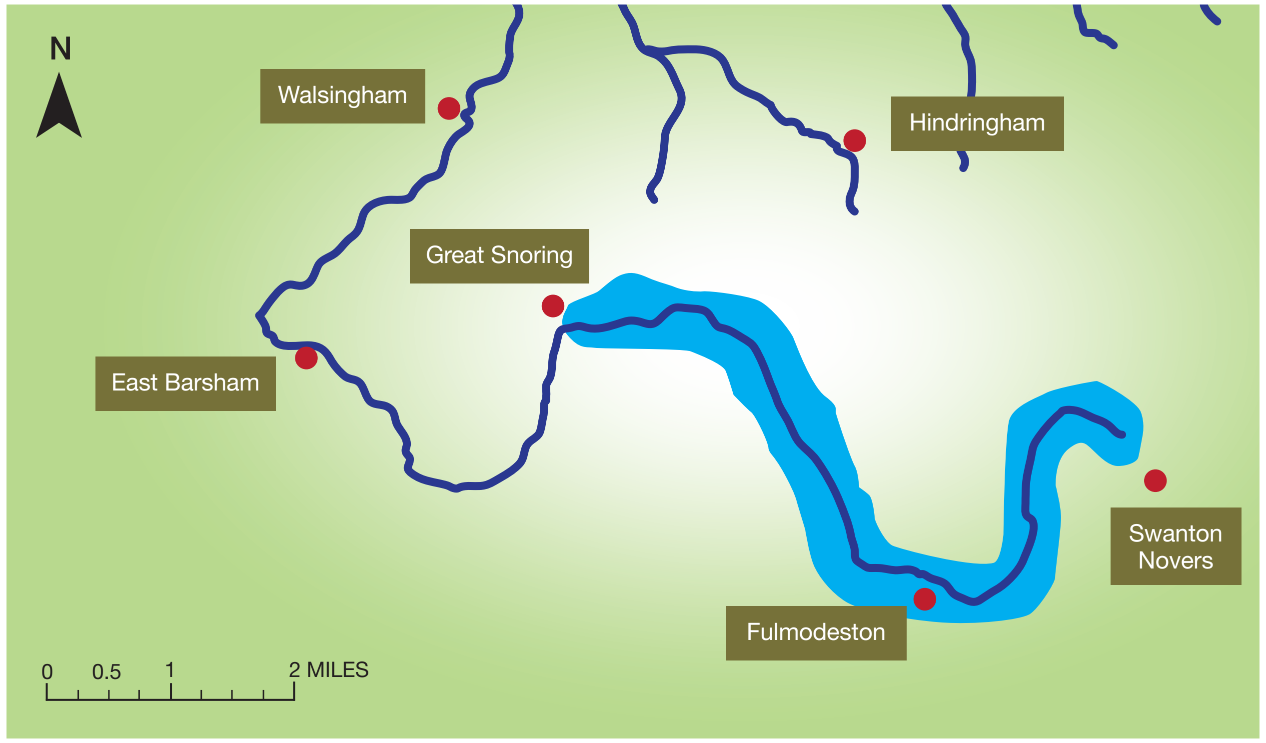
ZONE 1: MAIN RIVER HEADWATERS

Length: 10 km

Problems: The river is incised and straightened as far up as the source in Swanton Novers woods. Where the stream is incised it is frequently also overgrown with little light penetration. Many houses in Fulmodeston parish have aging septic tanks rather than mains sewerage and sewage is occasionally reported in the stream. Sewage treatment works at Thursford lacks phosphate stripping.

Suggested Actions: Although the stream may benefit from filling of its current dykes and the creation of a new channel, this would be costly and it may be that allowing (or encouraging) trees to fall and block the channel forcing morphological change may be more realistic and less disruptive. Further investigation of the sewage output is a priority.

Constraints: The SSSI woodland in the headwaters is of great ecological value in its current state



ZONE 2: BINHAM STREAM HEADWATERS

Length: 13 km

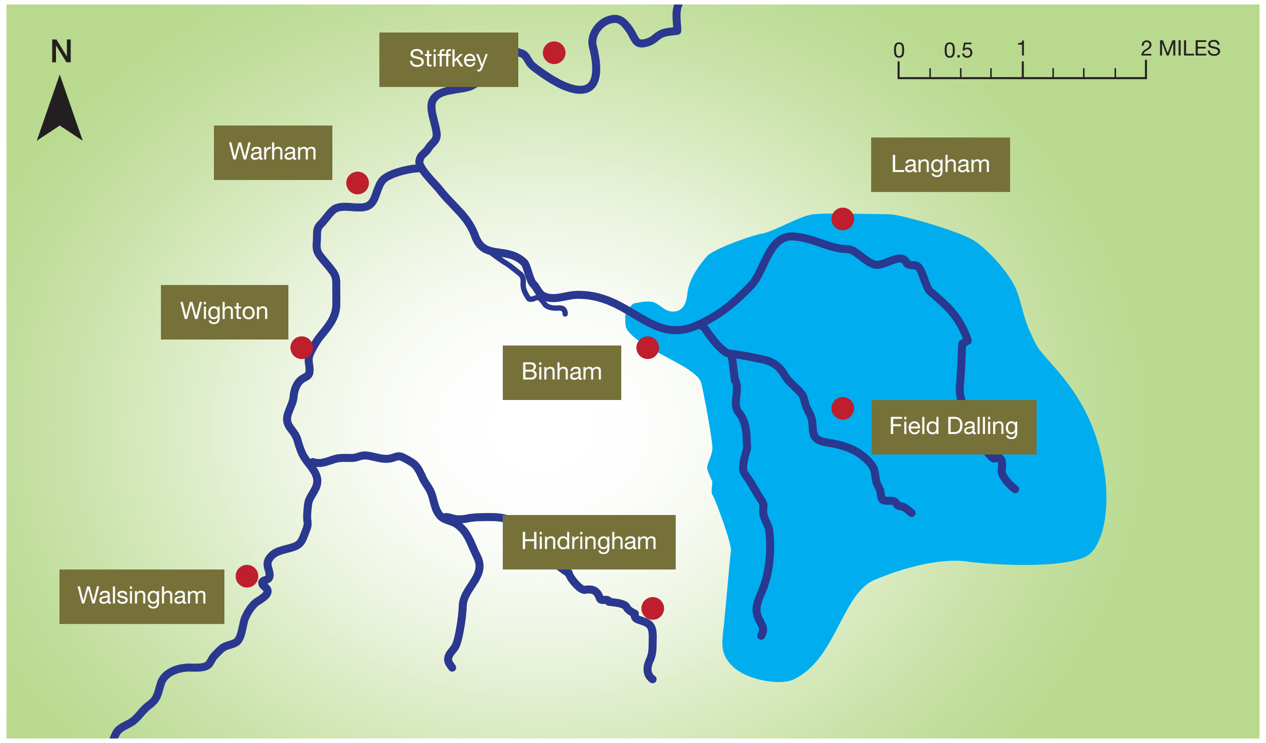
Problems: The channel is straightened and incised in places, although relatively natural in other reaches. Stands of poplars and pines have been planted draining headwaters. Siltation from many small ditches draining agricultural land is a problem in this zone and downstream. Septic tank leakages reported. Little floodplain connectivity or wet ground except in occasional meadows where some natural function is retained. Meanders remain upstream of Binham.

More natural stretch of the same stream with wet margins and returning sinuosity around trees

Straightened, deepened tributary of the Binham Stream with no riparian margin

Suggested Actions: Selective fencing and tree planting or immediate installation of large woody debris would help improve channel morphology in this reach, while felling of non-native trees in formerly wet areas would help restore small wetlands and improve flows. Blocking the existing channel at selected points could improve floodplain connectivity. This is a key zone for silt management, so silt traps should be installed where appropriate and buffer zones re-assessed. Sewerage outputs need investigation.

Constraints: Valuable arable land.



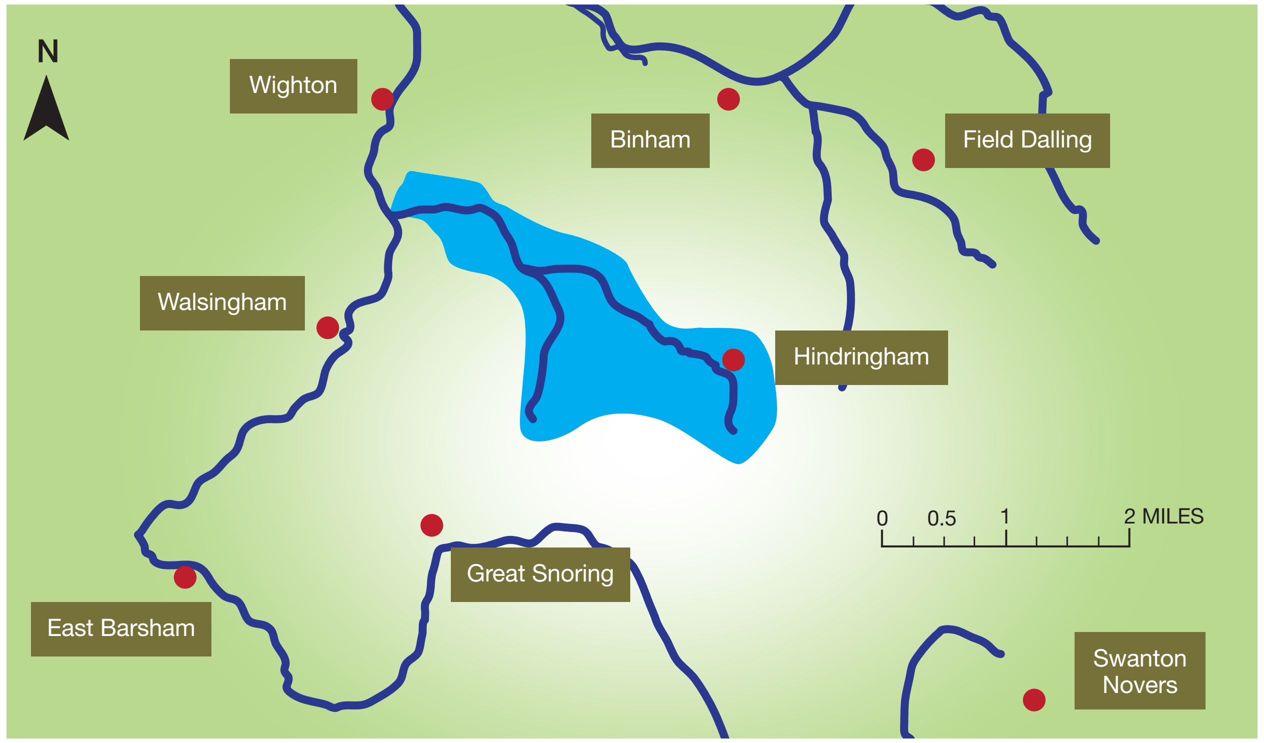
ZONE 3: HINDRINGHAM STREAM

Length: 7 km

Problems: The channel is deeply incised even through the local nature reserve and county wildlife site. Very little floodplain connectivity, and even the wet meadows are heavily drained. Good native tree cover in places.

Suggested actions: Re-meandering the channel to improve morphology and floodplain connectivity may be a good option in this zone. Ensuring fallen woody debris remains in the channel will improve in-channel habitats.

Constraints: Valuable grazing land, graziers may not want wetter meadows.




Photograph: © Jack Perks

ZONE 4: LOWER BINHAM STREAM

Length: 5 km

Problems: The channel is incised and straightened through most of this reach, and suffers greatly from siltation. There is no connectivity between river and floodplain. Some areas lack trees and very little woody debris can be seen in the channel. Sewage treatment works at Langham does not strip phosphate from effluent. The weir at the Binham gauging station is not listed as an obstacle to fish passage but requires assessment.

Suggested Actions: The channel would benefit from re-meandering in this reach. Where possible flood plain re-connection would benefit in-river and riparian ecology. Where neither of these actions are possible it would be beneficial to bring back the river banks in places, creating wet shelves and improved bed profiles without increasing flood risk or threatening agriculture or archaeology.

Constraints: This stretch is of great archaeological interest and this may be a barrier to river channel restoration. The stretch also provides good grazing and in places there is arable land adjacent to the river.

Photograph: © Jack Perks

ZONE 5: UPPER MAIN RIVER, Great Snoring to Walsingham

Length: 10 km

Problems: Although this reach retains more of the characteristics of a naturally functioning chalk stream than the rest of the river, presumably due to the extreme difficulty of draining it, and the vast majority of bank side fields are grazed rather than cropped, the channel is still incised through long stretches and connectivity with the floodplain is limited. Despite the remnants of a natural channel this stretch still suffers from siltation in what should be one of the most productive areas for spawning fish. Large quantities of silt may be delivered from the many ditches and field drainage pipes that enter the river in this stretch. Sewage treatment works at Thursford and East Barsham do not strip phosphate from effluent.

Suggested Actions: Although the river maintains some of its meandering character it would benefit from channel restoration in the many places where the river currently sits well below the level of the floodplain. The meadows bordering the river are mostly well drained, and a raised channel and strategic blocking of drainage channels would improve floodplain habitat and decrease siltation. The many drainage ditches and channels need assessing for silt delivery, which needs managing either at source or prior to entering the river. A study of the more natural stretches of river would inform restoration in other parts of the catchment. Strategic planning and felling would be of benefit in this stretch, as would a change in approach to the removal of woody debris.

In 1996 The National Rivers Authority produced a plan to restore sections of the river in the Barsham area. These plans are still valid and Norfolk Rivers Trust retains copies.

Constraints: This stretch is mostly rich grazing land.

Remnants of wet woodland, Walsingham

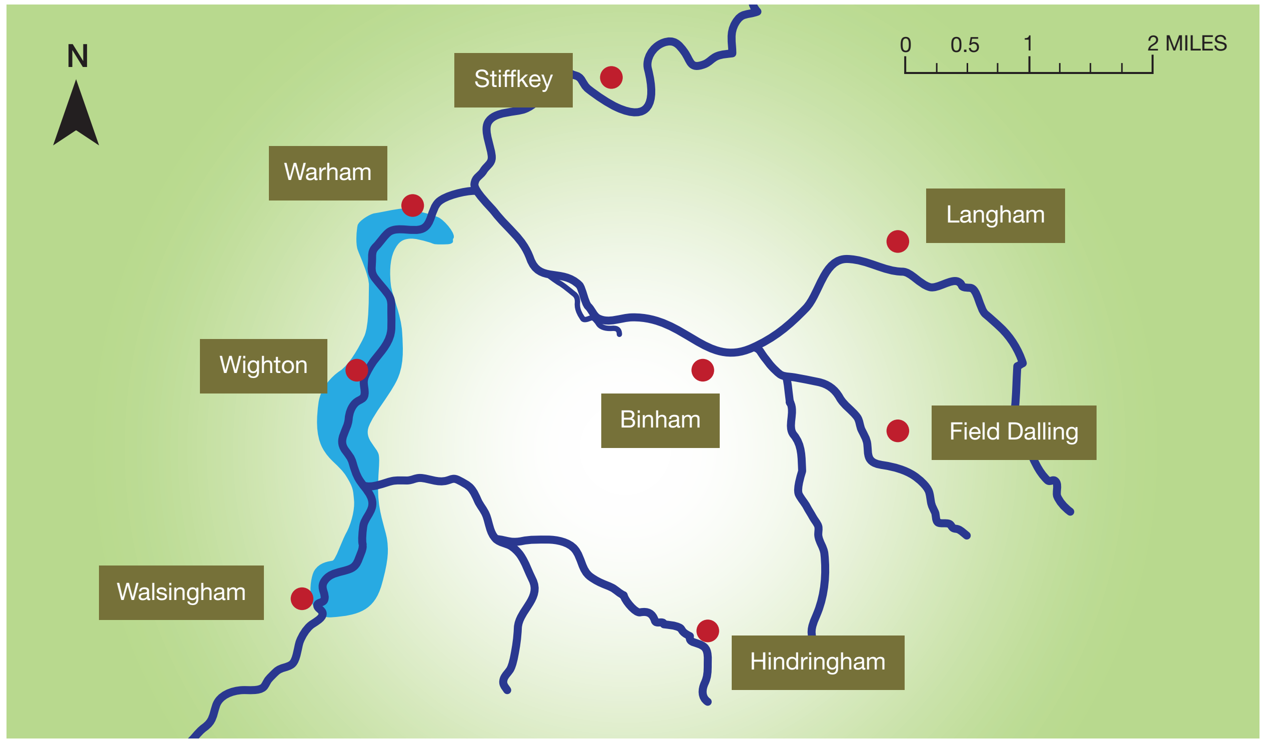
ZONE 6: MIDDLE MAIN RIVER, Walsingham to Warham

Length: 6 km

Problems: Obstructions to fish passage at gauging weirs at Warham and Walsingham. River straightened and embanked through the majority of the reach. Little or no floodplain connectivity. Major siltation problems, partly from delivery from upstream but also from many major point and diffuse sources in this zone. Sewage treatment works at Wighton does not strip phosphate from effluent.

Suggested Actions: Many opportunities for channel restoration in this zone UCL have identified the shapes and locations of many old meanders which may inform future restoration. Where agriculture limits the scope for re-meandering and re-connection embankments may be brought back and in-channel improvements may be made, particularly with wet shelves and channel narrowing. The channel lacks woody debris and shade, and would benefit from strategic planting and management of fenced areas. The channel is dredged and cleared in places - the Environment Agency are currently reviewing best practice. Silt management, particularly at the major point sources identified in the APEM / Natural England report is a priority.

Constraints: Grazing and agricultural land. Area of great archaeological interest.



Photograph: © Jack Perks

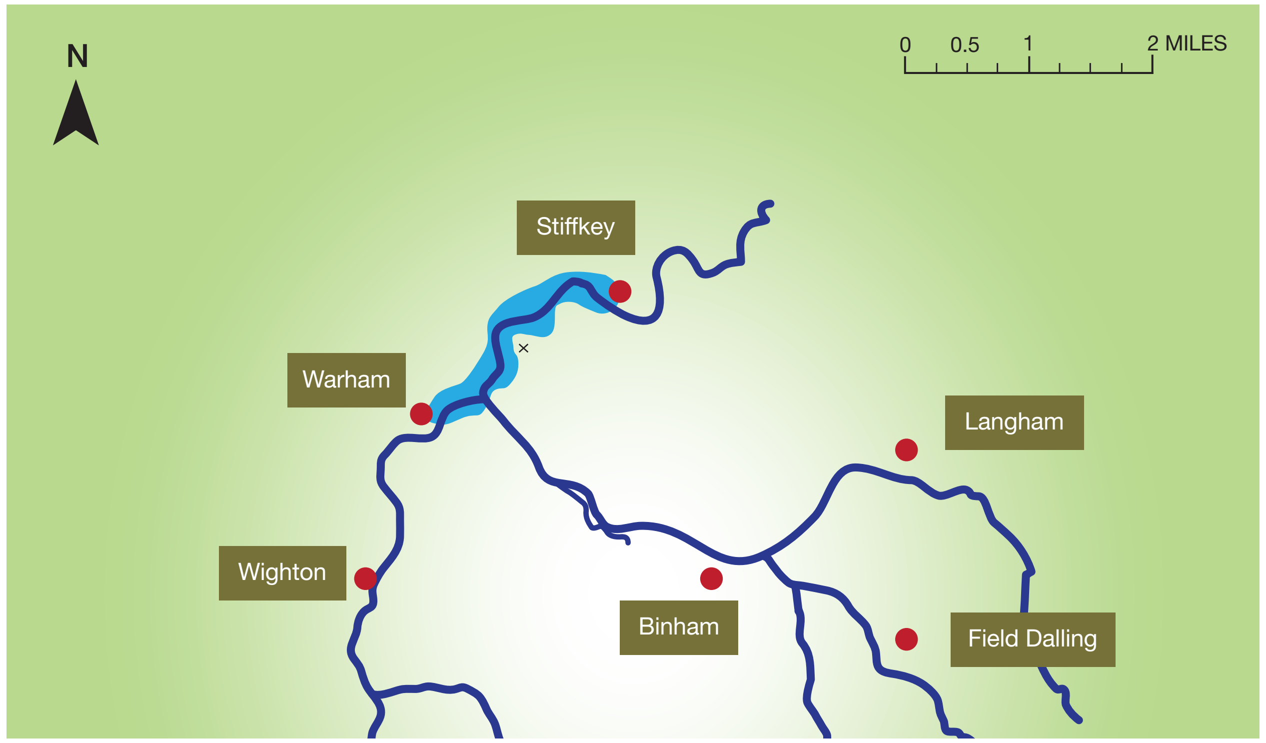
ZONE 7: LOWER RIVER, Warham to Stiffkey

Length: 3.5 km

Problems: The river is straightened and embanked with no floodplain connectivity. Riparian fencing has been very effective in this stretch, allowing plant communities to regenerate and the river to begin to restore natural function. These benefits will be limited by dredging, weed clearance and the removal of woody debris. Siltation of the river bed and gravels is a problem, and several point sources can be found in this zone. Sewage treatment works at Stiffkey does not strip phosphate from effluent.

Suggested Actions: The river and floodplain would benefit from re-meandering and re-connection to the floodplain in this reach, and a change in management of woody debris and in-stream vegetation. If full-scale channel restoration is not achievable work within the existing channel would be beneficial.

Constraints: This zone contains valuable grazing land and the residents of Stiffkey are very wary of flood risk.



Riparian vegetation inside bankside fencing, lower Stiffkey

ZONE 8: STIFFKEY MARSHES AND SSSI

Length: 2.5 km

Problems: The river is straightened, embanked, and several feet below the level of the floodplain. The channel lacks habitat diversity. The river and floodplain are disconnected, so when the valley bottom floods the land remains waterlogged for prolonged periods, and conversely the soil is prone to drought in dry periods. Bank-side trees are present, but the channel lacks woody debris.

Suggested Actions: Norfolk Rivers Trust is currently in consultation with the Buxton Conservation Trust, Natural England and other riparian owners over a plan to restore the river and floodplain.

Constraints: The land is grazed, and managed for bird conservation.

Photograph: © Jack Perks

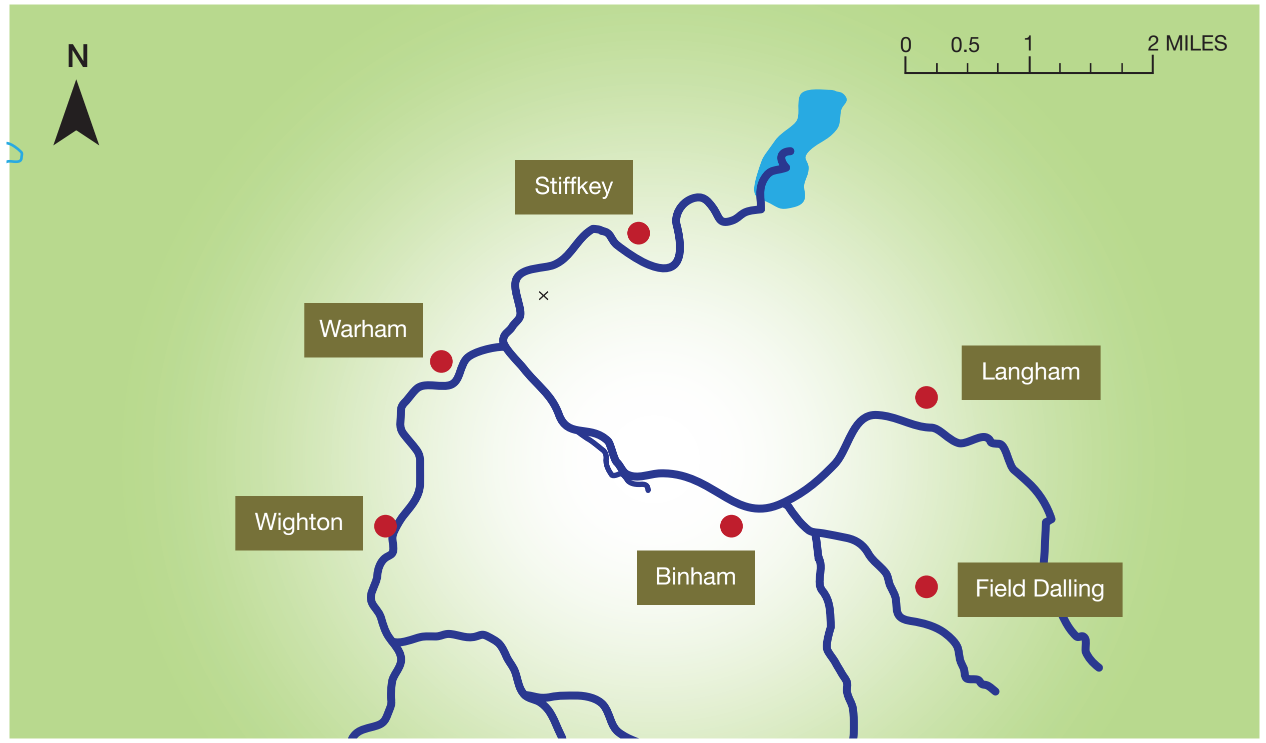
ZONE 9: ESTUARY

Length: 1 km plus side channels

Problems: The saltmarsh and estuarine waters are affected by the quality of water and quantities of silt coming down the river. The environment downstream of the sluice gates remains in a relatively natural state, although little is known about the nature or health of the estuarine flora and fauna.

Suggested Actions: Further research into the ecology of this transitional zone is required.

Constraints: Unknown.



COSTS AND TIMELINE

The Water Framework Directive objective for the Stiffkey Catchment is to reach Good Ecological Potential by 2027, and each of the actions set out above will assist in achieving that goal.

The river, including main tributaries, is approximately 58km long. Of these 58km, approximately 35km can be considered headwaters and estuary and 23 km main river. A minimum of two-thirds of the length of the river would benefit from restoration work, and approximately one half of the main body of the river would benefit from major morphological alteration.

In terms of priorities, the vast majority of the river cannot achieve good ecological health in its current straightened and deepened state. The river is unable to manage its silt and lacks habitat diversity. As identified by the Environment Agency, morphological change is a priority, restoring floodplain connectivity and sinuosity where possible.

Fish passage and channel maintenance regimes should be addressed quickly and may be improved by 2015. Measures are currently being considered by the Environment Agency.

Tree planting (and felling, where appropriate) can commence where can commence when funding permits, and the middle reaches where shading can be effective and woody debris is largely absent should be prioritised.

As described by Anglian Water above, work to control nitrate input is on-going, although groundwater levels are very slow to respond. Although further research is required into the origins of phosphates within the river, it is likely that the vast majority comes from sewerage rather than agriculture, and this should be addressed urgently.

Management of silt input from agricultural ditches and highway sources is required throughout the catchment. Norfolk Rivers Trust has identified several sites throughout the catchment that would benefit from in-ditch silt traps or wetlands, and it is realistic to suggest that the river would benefit from silt trapping in well over 40 locations.

The restoration of small headwater springs and wetlands can realistically be achieved in 10 to 15 locations, with the majority of sites identified in the upper Binham Stream catchment.

Action	Number of kilometres / sites	Predicted cost	Achievable timeline
Channel morphology work	20 km (main river and headwaters)	£2,000,000 based on £100 per metre	On going to 2027
Fish passage	3 priority sites	£100,000	2013 to 2021
Riparian tree work	30 km	£250,000	On going to 2027
Silt management (ditches)	40 sites	£40,000	On-going to 2021
Silt management (road access points)	10 sites	£20,000	On-going to 2016
Headwater wetlands	15 sites	£15,000	On-going to 2021
Phosphate assessment – sewagte treatment works and septic tanks	Five sewage treatment plants	£5,000,000 for P-stripping or £200,000 for treatment wetlands	On-going to 2021
Non-native species man-agement	Whole catchment	£25,000	On-going

FURTHER INFORMATION

Environment Agency - Keeping Rivers Cool report
Rivers by Design - rethinking development and river restoration
World Wildlife Fund - Why are chalk streams special?
Norfolk Wildlife Trust
River Restsoration Centre manual of river restoration techniques
River Rehabilitation for Eastern England Rivers
Environment Agency homepage
Introduction to the Water Framework Directive
The North Norfolk Catchment Abstraction Management Strategy
The State of England's Chalk Rivers Report

A Norfolk River – The Stiffkey

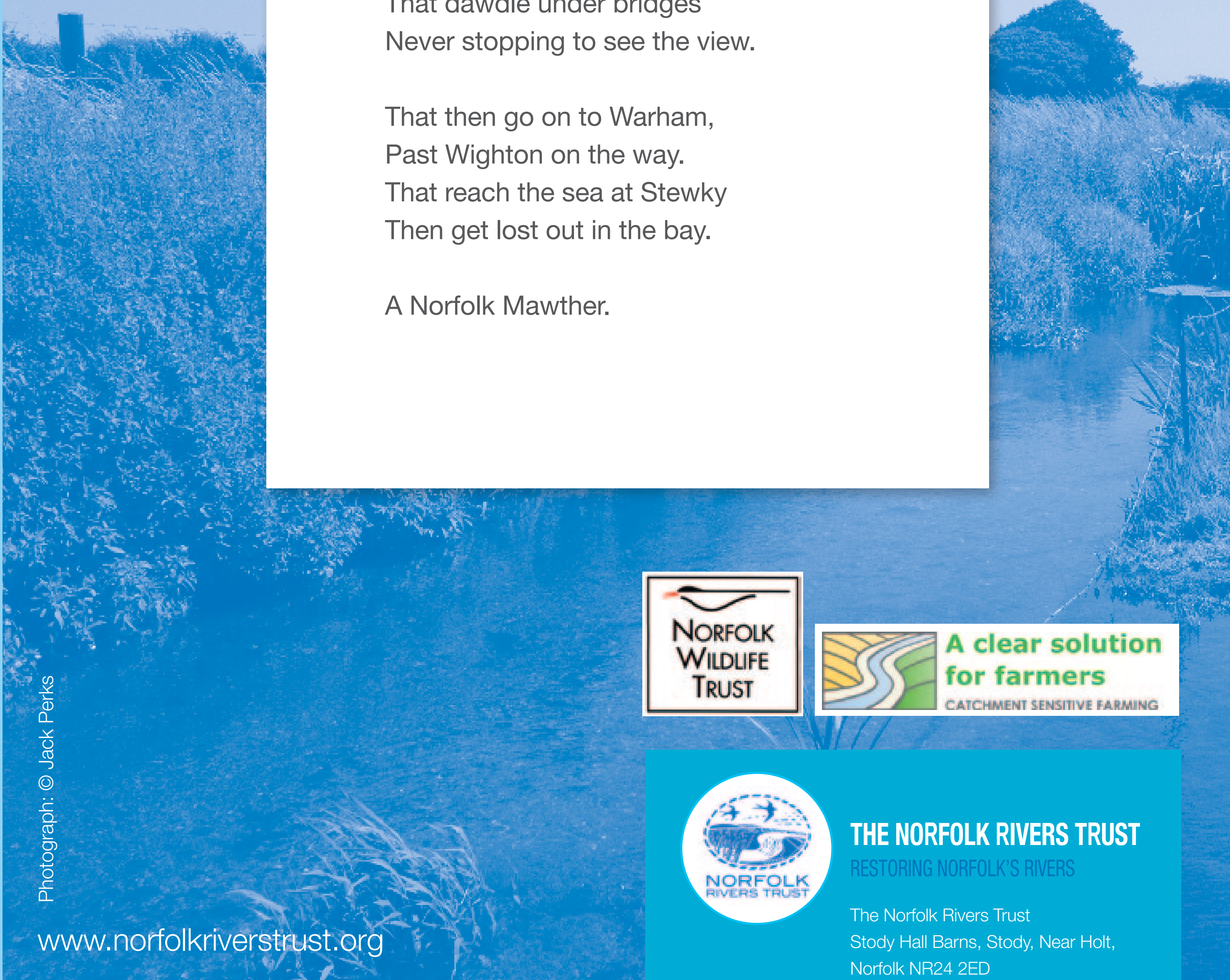
By Mary Sheeky

That run from Swanton to Stewky,
Well, with a name like that that would,
That run across the meders
And then through Thursfer Wood.

Through Snoring, Barsham and Houghton
That go on to Walsingham too.
That dawdle under bridges
Never stopping to see the view.

That then go on to Warham,
Past Wighton on the way.
That reach the sea at Stewky
Then get lost out in the bay.

A Norfolk Mawther.



Photograph: © Jack Perks

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