THE UNIVERSITY OF HULL

Fisheries Management Plan for the Yorkshire River Derwent

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By

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Executive summary

The European Union's (EU) Water Framework Directive (WFD) necessitates that all Member States must aim to reach good ecological status or potential within inland and coastal waters by 2027. The River Derwent catchment is under substantial pressure (ecological and water quality) from developments such as urbanisation and agricultural intensification. As a consequence, specific reaches of the system are failing to comply with WFD. Surveys and data analysis was undertaken to gain full understanding of the ecological importance and functioning of the River Derwent catchment to determine where and why the system is failing. Major issues were identified and proposals for rehabilitation were planned to help bring the River Derwent and its tributaries to good ecological status or potential.

An overview of the historical status of the catchment found that the River Derwent is under enormous pressure, specifically from barrier structures that are now obsolete in terms of their original purpose; and agricultural land drainage associated with channelisation. A walk-over survey of the majority of the River Derwent and its main tributaries was undertaken to determine and evaluate, specific anthropogenic pressures such as localised land use (farming, industry and aquaculture) specifically in riparian areas and the potential issues that arise from these activities. Areas were identified where potential rehabilitation projects could be implemented.

Analyses of fisheries abundance and diversity, as well as the impact of environmental characteristics and physico-chemical elements on the fish populations, were undertaken to deduce the overall status of the fisheries in the catchment and the influence of ecological change on these fisheries. The predominant impacts on fisheries were from: in-channel structures (barriers to migratory species) causing habitat fragmentation and impoundment of waters, thus altering the flow dynamics; considerable diffuse and point source pollution; increased sediment accumulation; channelisation and disconnection from floodplains altering the flow carrying capacity and decreasing riparian habitat; and riparian degradation reducing the fundamental habitats for the riverine ecosystem, as well as degraded natural processes (sediment trapping). Various solutions and potential projects were outlined that could be delivered by a variety of stakeholders.

In conclusion, partnerships and collaborations between stakeholders, government and non-government organisations are essential for the delivery of practical and active habitat development and improvements. The development of long term solutions by statutory agencies is vital for the mitigation of issues that arise and that will continue to occur if further action is not taken. This research study investigated the prospective for catchment-wide river rehabilitation and the creation of new management strategies to provide successful methods and mechanisms that will help to achieve good ecological status or potential. The main projects proposed were: improve agricultural (and riparian) management and awareness through the installation of buffer strips and erection of stock proof fencing; increase catchment-wide connectivity by modifying in-channel structures or through the addition of a fish pass; and to reinstate natural processes through the setting back or breach of embankments. Finally, the most fundamental project should be the preservation of already existing natural habitats through protection and conservation.

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Abbreviations and acronyms

ALC – Agricultural Land Classification

AONB – Area of Outstanding Natural Beauty

AV - Average

BAP - Biodiversity Action Plan

BOD – Biological oxygen demand

CaBA – Catchment-based Approach

CAMS – Catchment Abstraction Management Strategy

CAP – Common Agricultural Policy

CFMP – Catchment Flood Management Plan

CPUE – Catch per unit effort

CRF – Catchment Restoration Fund

CSF – Catchment Sensitive Farming

DAG – River Derwent Catchment Action Group

Defra – Department for Environment, Food and Rural Affairs

DO – Dissovled oxygen

EA – Environment Agency

ES – Environmental Stewardship

EU – European Union

EYRT – East Yorkshire Rivers Trust

FAO – Food and Agriculture Organisation

FDC – Flow duration curve

FMP – Fisheries Management Plan

GAEC – Good Agricultural and Environmental Conditions

GEP- Good ecological potential

GES – Good ecological status

H' - Shannon-Wiener diversity

HLS – Higher Level Stewardship

IDB – Internal drainage board

INNS - Invasive non-native species

J - Pielou's measure of evenness

JNCC – Joint Nature Conservation Committee

MDS - Non-metric multi-dimensional scaling ordination plot

NGO – Non-Governmental Organisation

NNR – National Nature Reserve

NYMNPA – North York Moors National Park Authority

NVZ – Nitrate Vulnerable Zone

RBMP – River Basin Management Plan

RPA – Rural Payments Agency

ONS - Office for National Statistics

S&TA - Salmon & Trout Association

SAC – Special Area of Conservation

SPA – Special Protected Area

SS – Suspended solids

SSSI – Site of Special Scientific Interest

WFD – Water Framework Directive

WTW – Water treatment works

YWT – Yorkshire Wildlife Trust

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1 Introduction

Inland and coastal waters are a fundamental natural resource which provide potable water, key ecosystems for a diversity of aquatic and terrestrial species and are of importance providing services for industry and recreation. Many rivers, lakes and coastal waters have suffered, or are under risk from, environmental degradation. It is vital to achieve sustainable exploitation of inland and coastal waters by protecting and improving the environment for future generations (JNCC, 2010).

One action supporting this goal is the EU Water Framework Directive (WFD - Directive 2000/60/EC), which came into force at the end of 2000 (EU, 2000; EA, 2013e). The main purpose of this Directive is to address the interests and demands of stakeholders from a local to a national level through the establishment of a framework for the protection and improvement of inland surface waters (rivers and lakes), transitional waters (estuaries), coastal waters and groundwater. The WFD is in place to ensure that the aquatic environment, as a whole, as well as terrestrial ecosystems and wetlands, meet 'good ecological status' (GES) or 'good ecological potential' (GEP) by 2027. GES has been defined as 'a slight variation from undisturbed natural conditions' (EA, 2013e), whereas, GEP is used to define artificial or heavily modified water bodies not able to reach GES because of their unnatural or heavily modified condition (EA, 2013f).

All EU Member States must have obtained full compliance of WFD by 2027. Consequentially, a standardised and sustainable environmental level of water resources within the EU will be achieved (EU, 2000). WFD examines the ecological health of aquatic systems along with their hydromorphology. It also deals with anthropogenic pressures such as diffuse pollution, which subsequently still remains a major issue, following general improvements for most point source discharges.

The WFD requires the establishment of river basin districts. The Yorkshire River Derwent is one such district and each must have their own river basin management plan (RBMP). RBMPs are prepared, implemented and reviewed every six years with the first published in 2009 (Defra, & EA. 2009). There are four different fundamentals to any river basin planning cycle: characterisation and assessment of impacts on river basin districts; environmental monitoring; the setting of environmental objectives; and the design and implementation of the programme of measures needed to achieve them (JNCC, 2010). The EA is currently reviewing and updating plans for England, which are to be published in 2015.

1.1 River Derwent and its tributaries

The River Derwent, East Yorkshire, is a large tributary of the River Ouse (Figure 1.1). The River Derwent is designated as a Site of Special Scientific Interest (SSSI) under the Wildlife and Countryside Act (1981) (as amended), a Special Area of Conservation (SAC) under the EU Habitats Directive (1992), and a Special Protected Area (SPA) under the EU Birds Directive (1972). These EU Directives form the cornerstone of Europe's nature conservation policy; Natura 2000 (EC, 2013; McLeod *et al.,* 2005). The Habitats Directive aims to promote the maintenance of biodiversity through the protection of natural habitats and species listed on the Annexes within the Directive (JNCC, 2010b). The primary reason for the designation of the River Derwent as a SAC is the presence of river lamprey (*Lampetra fluviatilis* (L.)), which are listed as a primary species in the Habitats Directive Annex II. Additional qualifying features are bullhead (*Cottus gobio* L.), sea lamprey *Petromyzon marinus* (L.) and otter *Lutra lutra* L. (all Annex II species), as well as being a "water courses from plain to montane levels with the presence of *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation" (JNCC, 2013; JNCC, 2013c).

The Lower Derwent Valley (Sutton-Upon-Derwent to Menthrope) contains diverse species-rich flood meadows, fens, swamps and wet woodlands (Figure 1.1). It is a SAC specifically for lowland hay meadows, being the highest quality site in the UK (JNCC, 2013b; JNCC, 2008). A high abundance of the rare narrow-leaved water-dropwort (*Oenanthe silaifolia* (Bieb)) makes it a distinguished conservation area (JNCC, 2013b). Wheldrake Ings forms a part of this area which is designated as an SPA for wild avian fauna. The Lower Derwent Valley also has qualifying features for the presence of alluvial forests with alder (*Alnus glutinosa* (L.) Gaertn.) and ash (*Fraxinus excelsior* L.). Between Canal Head and East Cottingwith, the 11.1 km long Pocklington Canal is also designated as a SSSI because it supports the nationally rare soft hornwort (*Ceratophyllum submersum* L.) (JNCC, 2013b; Figure 1.1). The majority of the River Derwent and its species are currently in an 'unfavourable condition' which is to be rectified by achieving GES or GEP by complying with the WFD (Nunn *et al.,* 2008; Shannon, 2012).

There are 86 water bodies, one lake and one canal located within the Derwent catchment of which 34 are artificial or have been heavily modified. Currently 10% of these rivers (61 km) achieve GES or GEP, 44% are of poor biological status and 5% at bad status. There are only three water bodies which have been assessed to having good chemical status (Defra, & EA, 2009).

There are a number of issues having dramatic consequences on the River Derwent. These include, but are not restricted to: physical modification caused by land drainage, flood protection, barriers to fish migration, impoundment and urbanisation; pollution from rural areas, specifically from mixed agricultural run-off, forestry and bank erosion by livestock; and pollution from waste water such as sewage discharge and industrial or trade discharge (EA, 2013d).

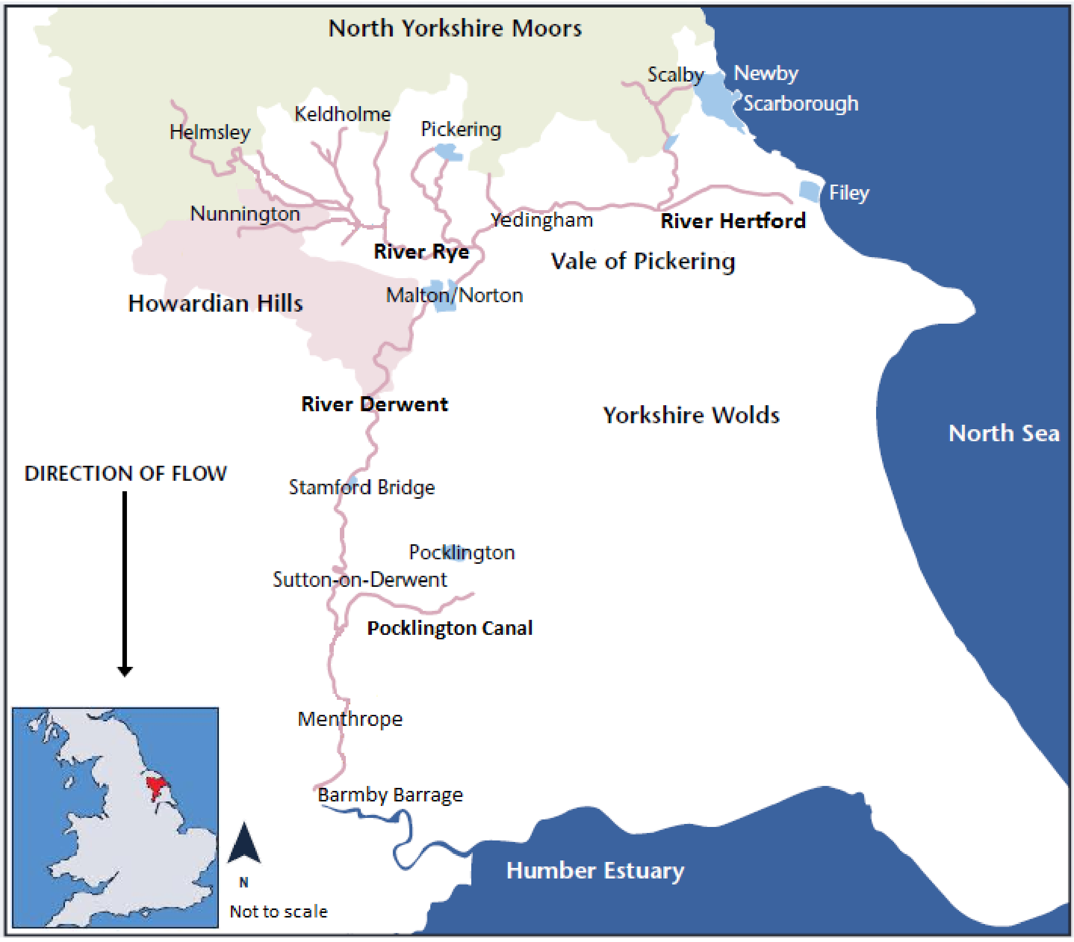


Figure 1.1 Overview map of the River Derwent and its tributaries (adapted: EA, 2007)

1.2 The current study

It is vital to understand the importance and functional ecology of the River Derwent catchment with regards to fish assemblages, fisheries, as well as pressures that impact on these vital resources to support the 2nd River Basin Management Plan (RBMP), which is to be released in December 2014. The purpose of this study is to develop a Fisheries Management Plan (FMP) that, along with the newly established 2nd RBMP, will provide actions to improve the overall status of the River Derwent catchment specifically regarding the fishery. Due to the national importance of this river catchment, measures are needed to remediate the degraded status and contribute towards meeting the Government's Public Service Agreement targets (95% of the SSSIs in England being favourable or recovering condition), as well as meeting GES or GEP as a part of the WFD by 2027.

The overall aim for this study is; 'To provide a plan to restore and rehabilitate the River Derwent catchment towards a more natural functioning and un-constrained system which ensures that ecological, socio-economic and sustainable development is achieved by 2027.'

Chapter 2 is the collation and analysis of available literature and other information on environmental features. Overall exploitations within the catchment, including non-fishery utilisation, socio-economic benefits and status of the aquatic ecosystem from the River Derwent catchment, provides an understanding of the system and its constraints. Environmental characteristics and physico-chemical elements (water quality, hydrology and temperature) were investigated to understand potential relationships and influences that they may have on existing fish populations.

Chapter 3 identifies and examines the major issues within the River Derwent catchment. The information gathered from the review and a walk-over survey was used to identify the location of the major issues impacting on the sustainable development of the River Derwent catchment and its fisheries.

Chapter 4 investigates the comparative fish assemblages in the River Derwent catchment to understand abundance and diversity of fishes. Further analysis was undertaken on angler catch data, specifically species abundance, catch per unit effort and percentage success. This analysis provides another element to the overall data set potentially adding clarification of fisheries survey data.

Chapter 5 describes the institutional framework and identifies the organisations (government, non-government and other agencies) present within the River Derwent catchment which have a potential impact on the system as a whole. These key stakeholders are essential for the development and delivery of the action plan. This chapter also uses the previous information to develop a fisheries management plan for the River Derwent including: (i) issues affecting the catchment; (ii) past and present performance of the fisheries within the catchment; and (iii) stakeholders involvement and institutional framework. It identifies the management options and projects for the River Derwent catchment with regards to wider ecosystem issues and the stakeholders present.

Chapter 6 integrates the knowledge gained from the previous chapters and provides recommendations for further studies**.**

2 Yorkshire Derwent catchment

2.1 Overview

The River Derwent, East Yorkshire, (Figure 1.1) is comparatively one of the larger rivers in the UK with a total length of 115.1 km and a catchment drainage area of 2,057 km^2. The River Derwent catchment has received considerable designation for conservation status, with over 40 SSSIs, two National Nature Reserves (NNR) and an Area of Outstanding Natural Beauty (AONB) (EA, 2006a). The river arises on Fylingdales Moor (SE916994) (approximately 260 m above sea level) and runs southwards across the North York Moors to its confluence with the River Ouse at Barmby Barrage (SE680286) (EA, 2006a; Figure 1.1). There are several in-channel structures located along the River Derwent for managing waters, these are migration barriers for the various species of diadromous or anadromous fishes as well as locally resident potadromous species. Fylingdales Moor is surrounded by the coniferous Langdale Forest (Figure 1.1). The stream then travels southwards towards the heather covered Langdale; here the river is roughly 6.5 km from Scarborough. A part of the river still flows towards the coast and into the sea near Scalby (TA015904) alleviating high flooding pressures on the adjacent agricultural land, towns and villages. The flood alleviation sea cut has its own catchment of 33.2 km^2 (EYRT, 2012; EA, 2012a; Kelman, 2001;Figure 1.1).

Forge Valley Woods (SE985871), just north of the confluence with the River Hertford (Figure 1.1), is a NNR for approximately 2 km; this area is owned and conserved by Scarborough Borough Council in concurrence with Natural England. This ancient woodland is nationally recognised for its broad range of mixed deciduous species, the low wet valley provides suitable conditions for alder and willow species. Numerous species of flora cover the ground such as opposite-leaved golden saxifrage (*Chrysosplenium oppositifolium* L.), yellow flag iris (*Iris pseudacorus* L.), and pendulous sedge (*Carex pendula* Huds.). There is also a great abundance of different species of fauna such as characteristic woodland birds, as well as the iconic protected species white-clawed crayfish (*Austropotamobius pallipes* (Lereboullet.))(Figure 2.1).

The River Hertford (Figure 1.1), a tributary of the River Derwent, flows westwards from Filey (TA115806). A Corallian limestone aquifer supplies overlaying river water to the River Hertford’s highly modified channel (Carey & Chanda, 1998). The River Derwent descends through the Vale of Pickering which is generally flat with slight undulations and was formerly a post–glacial lake. Consequently, it acts as a drainage sink for the moors and here many calcareous aquifers give rise to springs such as Keldholme (SE787845) (Natural England, 1997b; Figure 1.1). Heavy modifications for land drainage continue from the confluence of the River Hertford until roughly Yedingham (SE892794), subsequently resulting in impoundment and channelisation restricting the rivers hydromorphological dynamics.

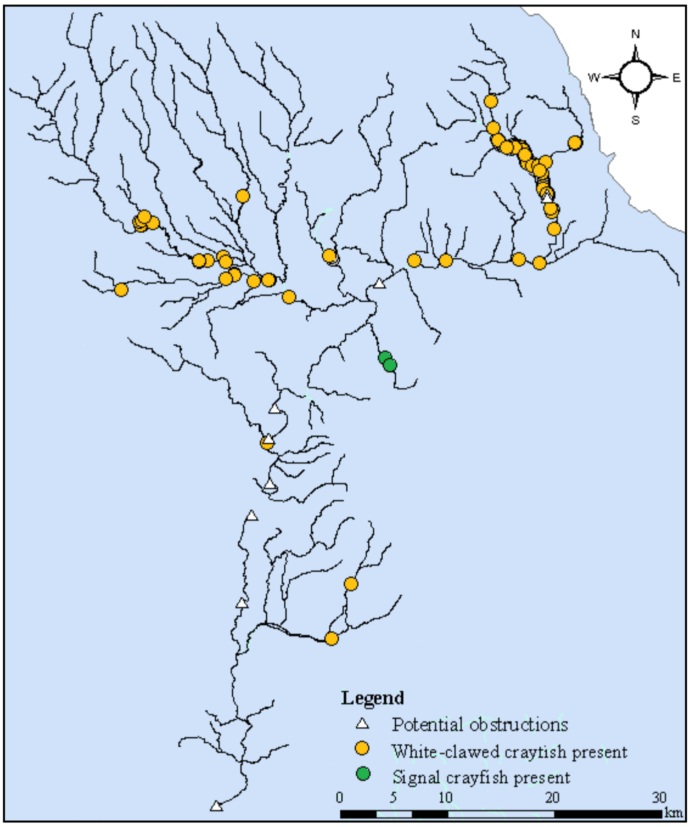


Figure 2.1 White clawed crayfish and signal crayfish presence in the River Derwent, Yorkshire (adapted: Nunn *et al.,* 2007)

One of the main tributaries of the Derwent, the River Rye (Figure 1.1) and its various tributaries, flow south before joining the course of the River Derwent just north of Malton (SE988714) at Rye Mouth (SE822757) (Figure 1.1). The towns of Malton and Norton are separated by the Derwent which flows south towards Kirkham Gorge. This gorge is a deep, meandering dale carved into the rocky landscape from the historic Lake Pickering, where water had been forced in a south-westerly direction because of the once North Sea ice sheet. Henceforth the course of the River Derwent follows this path (Natural England, 1999c).

As the Derwent meanders southwards towards Stamford Bridge (SE712552) the river channel starts to increase in size (Figure 1.1). The lower reaches of the River Derwent comprise large expanses of wetland known as ings. This area covers approximately 665.42 ha and was made a SSSI in 1975. The Derwent Ings are located between Sutton-upon–Derwent (SE703469) and Menthorpe (SE705339) and these freshwater habitats are also linked to the Pocklington Canal (Figure 1.1).

The Pockington Canal (Figure 1.1) is 11.1 km long and was built to provide transportation for the trade of farming goods to the rest of Yorkshire. The canal has designated status under three SSSIs: Pocklington Canal SSSI; from Canal Head (SE799473) to Church Bridge (SE758444); downstream from this both the Melbourne & Thornton Ings SSSI and Derwent Ings SSSI. These flooded hay meadows are traditionally managed due to their seasonal flooding (PCAS, 2011; Figure 1.1). These SSSIs are currently categorised as declining unfavourable condition although, some areas have started to recover specifically Melbourne & Thornton Ings (Natural England, 2013). The canal has nine locks which contribute to the Lower Derwent Valley SPA; it also flows into the lower reaches of the Derwent SSSI and SAC. The canal has fallen into disrepair although restoration works are being undertaken for much of its length. The canal is protected for nationally rare flora such as soft hornwort (*Ceratophyllum* spp.), lesser water-plantain (*Baldellia* spp.), flowering rush (*Butomus umbellatus* L.) and water-crowfoot (*Ranunculus fluitans* L.).

The Derwent Ings (Figure 2.2) are one of the most outstanding, agriculturally unaltered flood meadow environments and species-rich alluvial flood habitats in Britain. Unfortunately, the distribution of these abundant grasslands is very restricted due to agricultural advancements. The Derwent Ings are of international significance and have been designated as a SSSI, NNR, a Ramsar site, SPA for avian fauna and SAC for an array of species and habitats including the alder woodlands amongst the floodplains and lowland hay meadows (EA, 2010). These sites are protected because of the diverse range of flora and fauna present and specifically because they provide a vast breeding habitat for wetland wildfowl and waders. Rich diversity is apparent in the Ings, with nationally rare and scarce species inhabiting the area including, greater water-parsnip (*Sium latifolium* L.), flat-stalked pondweed (*Potamogeton friesii* Rupr.), water violet (*Hottonia palustris* L.) and round-fruited rush (*Juncus compressus* Jacq.). There is also a high abundance of invertebrates found among the wetlands, these species being particularly important to each habitat together with 16 different species of dragonflies, damselflies and three nationwide rare species: viz. snail-killing-fly (*Sciomyza dryomyzina (*Zett.))*,* a freshwater snail (*Omphiscola glabra* (Müller.)) and a ptilid beetle (*Acrotrichis cognata* (Matthews.)) (Natural England, 1992).

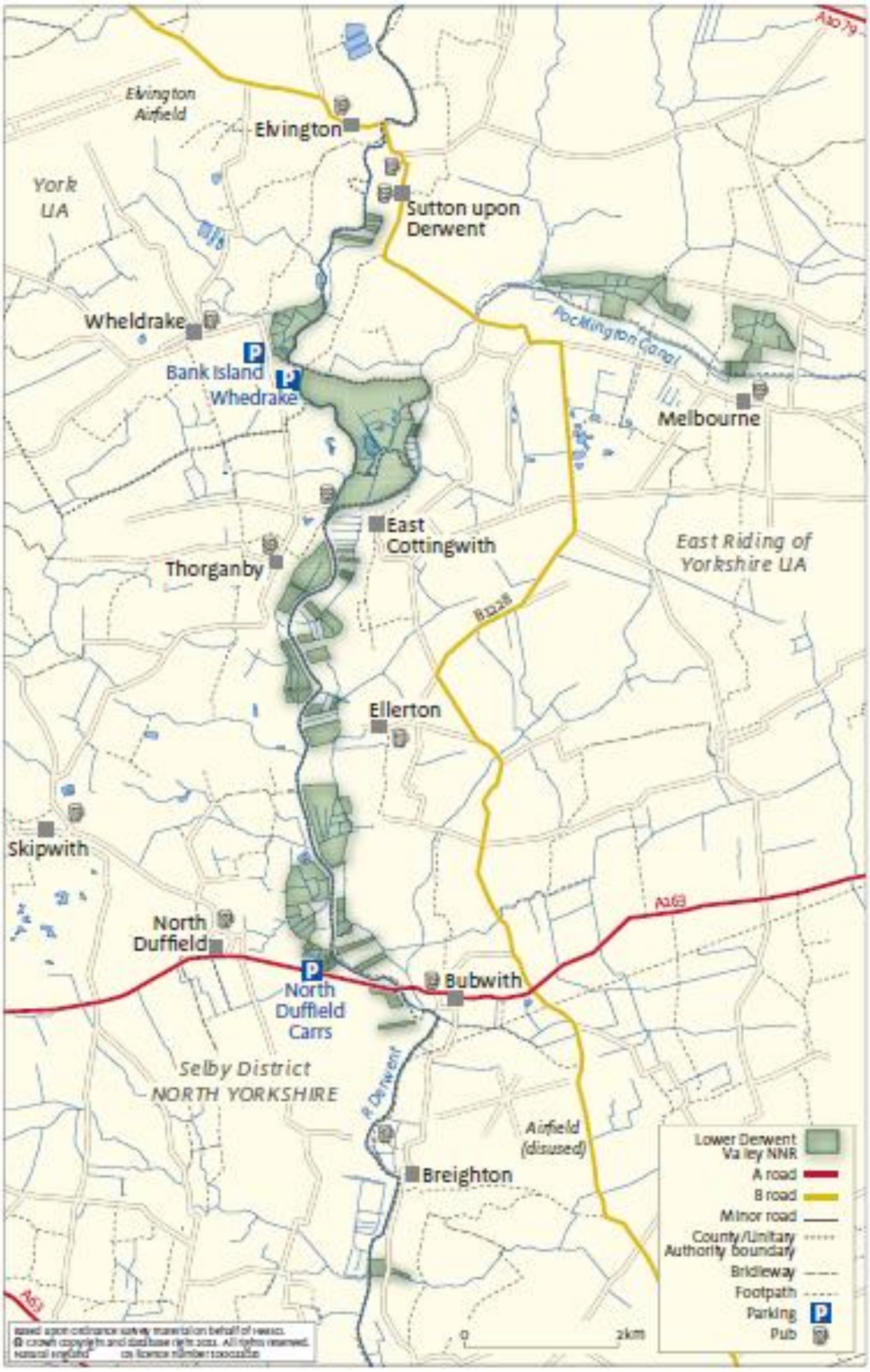


Figure 2.2 Lower Derwent Valley Ings with reference to the designated conservation areas (source: Natural England, 2012e).

At the downstream end, the Derwent reaches Barmby-on-the-Marsh (SE690286); the tidal confluence of the River Ouse (Figure 1.1). Barmby Barrage is located here, it was constructed in 1975 comprising two vertical lifting gates in a concrete structure. An additional lock system added in 2011 allows boaters and migratory fish species to pass upstream (EA, 2006b; EYRT, 2012). This structure was inaugurated and made operational for several purposes; ensuring waters from the tidal River Ouse does not enter the lower River Derwent, thus preventing the spread of pollutants; to guarantee water depths are adequate for abstraction at Loftsome Bridge and Elvington Water Treatment Works (WTW) and to create water levels that are deep enough for boats to pass safely. This is required under the Barmby Tidal Barrage Order (Clause 13), which enables access to boats (EYRT, 2012; EA, 2006b).

The River Derwent flows primarily through a rural landscape; the human population of the catchment is approximately 249,000 (NYCC, 2011; EROD, 2012). The catchment has a number of small industrial units amongst the small populated towns and villages. Scarborough Parish (TA036884) is the biggest of these with an approximated population of 108,800 (ONS, 2011; Figure 1.1).

2.2 Geomorphology of the River Derwent catchment

The River Derwent catchment has a diverse geology (Figure 2.3). It is the most northern point in Europe to have an underlying Jurassic limestone platform (Jarvie *et al.*, 1997). This is mainly exposed at more southern lower locations along with Oxford clay (Evans *et al.,* 2005, 1997). Other rock types are present in the North York Moors, such as shale and sandstone (EA, 2006a). The current landscape of the North York Moors has been uplifted and eroded by a variety of geological processes including glaciation and river action. These ice-age melt waters have caused geologically important features such as glacial tills with many miscellaneous glacial deposits (Morley, 1997). Distinctive habitats are associated with the different rock types; the limestone gives rise to a calcareous soil while the shale and sandstone gives rise to acidic soils which support large expanses of upper grasslands and bogs. This Jurassic sandstone soil is also free draining thus supporting possibly the largest continual area of lush heath moor in Britain (Natural England, 1999a; Morley, 1997).

Three major aquifers are located within the River Derwent system: Corallian limestone, chalk and Sherwood sandstone (Figure 2.3). The Corallian limestone aquifer is situated underneath the foothills of the Vale of Pickering (EA, 2006b; Figure 1.1). Further downstream, the regions youngest rock type - Kimmeridge clay - can be found, a vast proportion of which is buried beneath stratum of glaciolacustrine deposits consisting of peat beds, littoral and deltaic gravels & sands and also lacustrine glacial clays (Jarvie *et al.,* 1997; Natural England, 1999b). Consequently, the soil is very dark and nutrient rich. Intensive agricultural practices use the fertile and productive arable landscape (Natural England, 1999b).

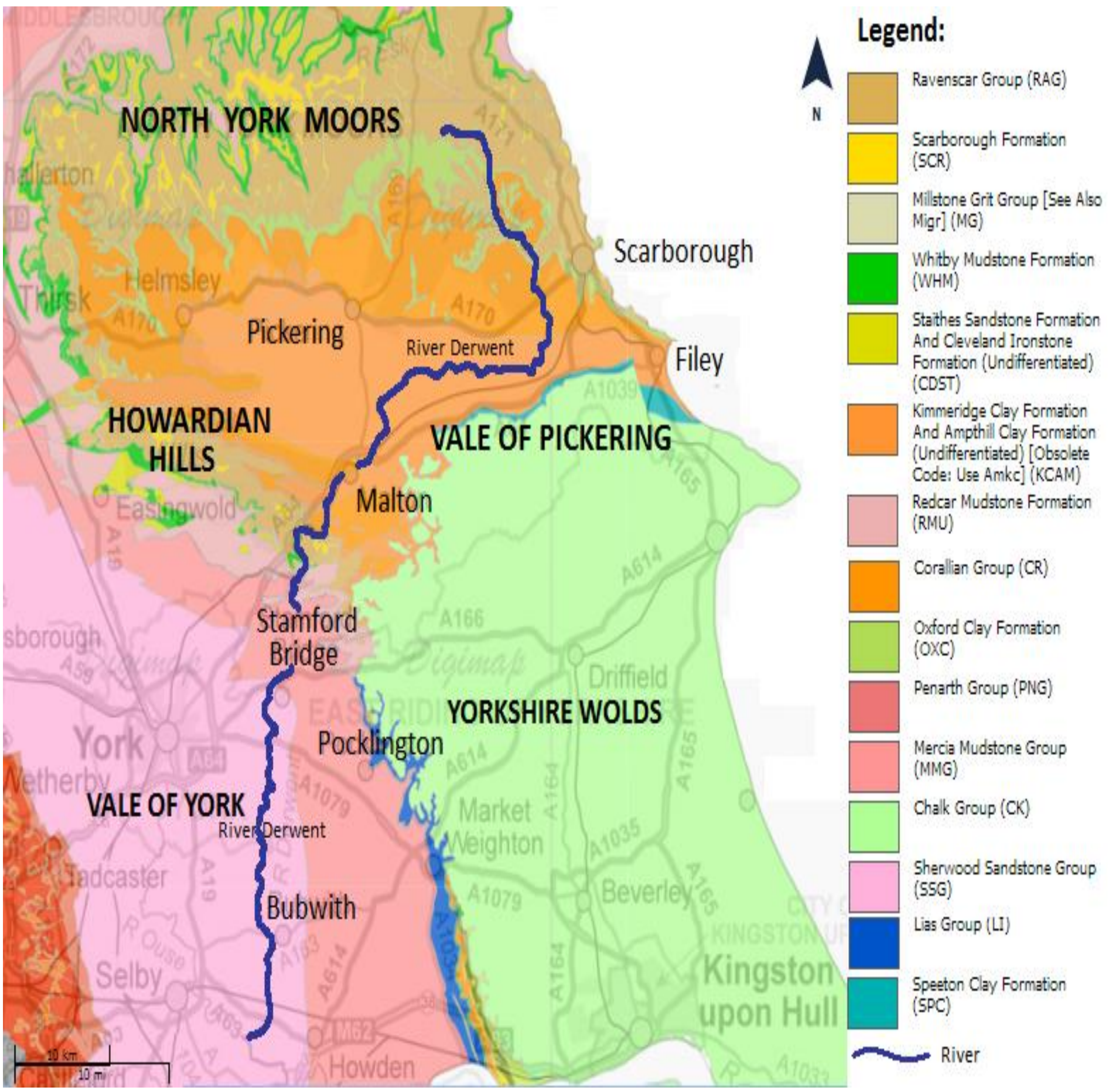


Figure 2.3 Geological map of the River Derwent catchment (adapted: digimap.edina.ac.uk)

The preglacial Lake of Pickering was formed as a result of the North Sea glacial ice sheets preventing drainage from the eastern and western sides and thus impoundment occurred. Extensive water build up caused the lake to overflow carving through the now Kirkham Gorge, ultimately characterising the present course of the River Derwent (Jarvie *et al*., 1997). Anthropogenic activities such as large scale land drainage schemes, following the passing of the Drainage Act 1800, have caused massive habitat loss but subsequently have improved the productivity of the land for agricultural use through a large web of drainage ditches (Natural England, 1999b).

West of Malton is the Howardian Hills - this AONB rises about 170 m above sea level and consists of Jurassic lime and sandstones (Figure 1.1; Figure 2.3). These layers cause contour banding depending on the soil type which consist of three distinctive types of soil. Large proportions of this region's soil are composed of well drained, coarse, loamy soil which lies upon a sandstone bed. There are also shallow, well-drained with fine loam matter which is situated on limestone and finally, fine loamy – clay soils that are slowly permeable and are highly vulnerable to seasonal water-logging (Carter, 1995; Falloon *et al.,* 2001).

The Yorkshire Wolds (Figure 2.3) range from 50 to 200 m above sea level and comprise steep sided and deep valleys with very few areas of shallower valleys (Harrison, 2000). They make up the northern most chalk banding in Britain from the Cretaceous period (80 to 100 million years ago). Distinct shallow calcareous soils are found within the Wolds supporting vast lush chalk pastures (Natural England, 1997b). As the River Derwent travels south downstream through undulating lands, the rivers course continues into a small part of the Vale of York where the geology is mainly dominated by Triassic sandstone, as well as Triassic and Jurassic mudstone. Glacial deposition provides high-quality loamy soils that are ideal for agricultural practices. Generally arable farming occurs here but some open areas of grassland are left for flood meadows (Natural England, 1999d; Shand *et al.,* 2002).

2.3 Hydrology and flow regime of the River Derwent

Human activities have subjected and affected river drainage basins in many ways for thousands of years, thus primarily having an impact on the hydrological flows. The main activities in the Derwent include, but are not limited to, irrigation and/or land drainage for agriculture and discharge or abstraction of surface and ground waters for domestic and industrial consumption (Ward & Robinson, 1999; Bulu, 2010).

Highly permeable chalky rock aquifers are located deep under the Derwent which work as a buffer when rain falls. This decreases the immediate effect of the base flows. Although, in times of extensive rainfall these aquifers become saturated and with an increase in surface run-off can cause the Derwent to flood.

There is a narrow range of discharge in the Derwent spring-dominated channels, a typical characteristic of a spring subjected channel is that it will be flowing at the bank full 'mark' or above by at least 20% of the time whereas, on the other hand, run-off-dominated channels are typically at 2-4 % capacity (Whiting & Stamm, 1995).

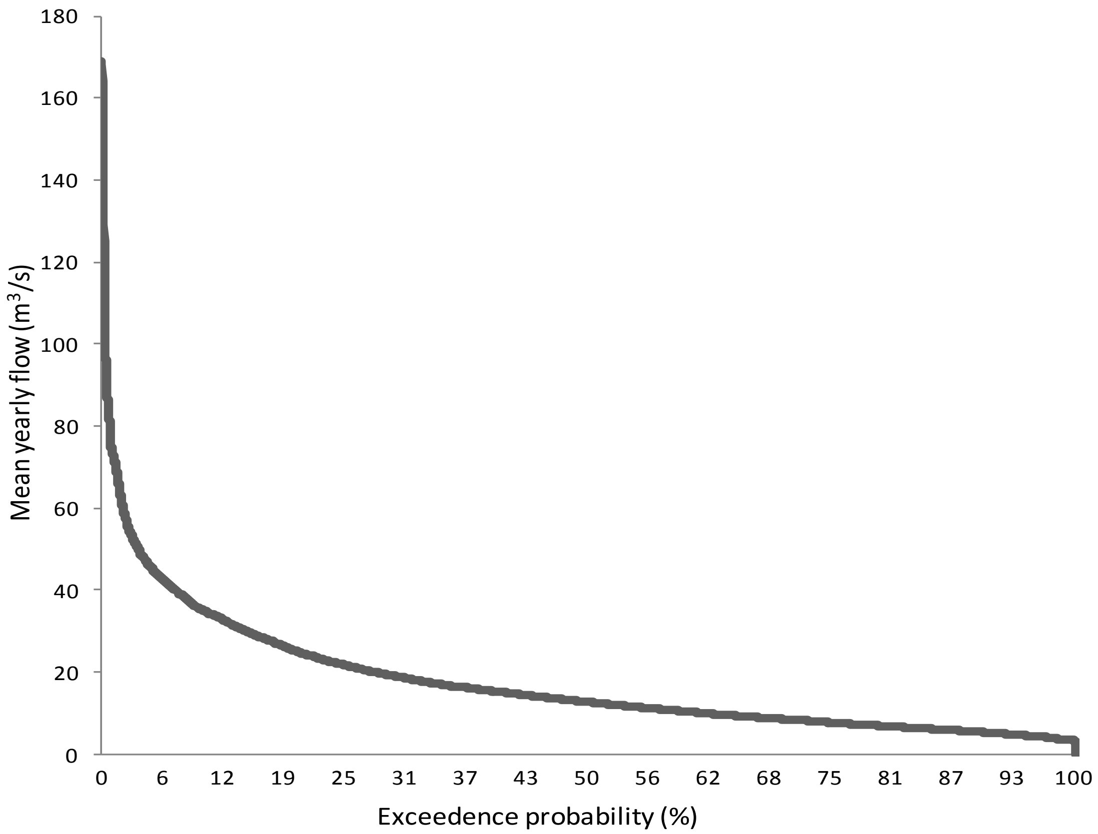


Figure 2.4 Flow duration curve for Buttercrambe gauging station (1992 – 2012), River Derwent (source: Environment Agency database)

A gauging station located at Buttercrambe on the Derwent provided data regarding to flow rates (m^3/s) from 1992 until 2012. The mean annual flow pattern for the River Derwent at Buttercrambe is demonstrated by a flow duration curve (FDC) and a hydrograph (Figure 2.4; Figure 2.5). FDC indicates that flows above Q20 are ~ 20 m^3/s and flash flooding is the likely cause for this due to the large upper catchment drainage area of the River Derwent from the North York Moors. The River Derwent's catchment has predominantly a 'flashy' flow regime (Q80 is ~ 6 m^3/s) reflecting the greater range of flows that occur in this catchment. Subsequently, there are more severe high and low flows within the River Derwent catchment (Figure 2.4). The overall yearly mean flow was 17.44 m^3/s. The highest mean annual flow being in 2000 (26.27 $m^{3/}s$); 2006 was just above average (17.67 m^3/s) and the lowest annual mean flow was in 1997 (10.69 m^3/s) (Figure 2.5).

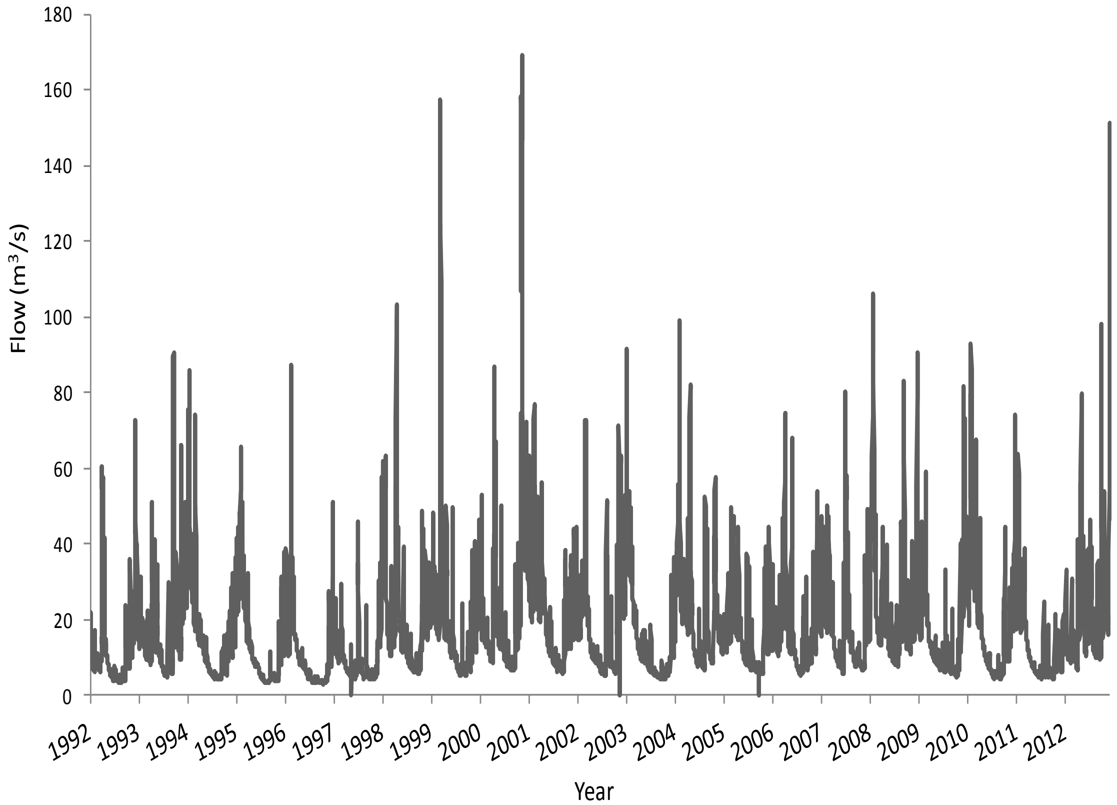


Figure 2.5 Hydrograph of the mean flows (m^3/s) at Buttercrambe gauging station (1992 to 2012) (source: Environment Agency database)

2.4 Chemical water quality

Historically, the River Derwent has had problems with high concentrations of nitrate (NO_3^-) and smaller concentrations of ammonia (NH_3) as ammonium (NH_4^+) (Neal *et al.,* 1998). In 2009, the entire River Derwent was designated a Nitrate Vulnerable Zone (NVZ) despite being a moderately clean river (Mian *et al.,* 2010). NVZ status was given to this catchment due to the risk from diffuse agricultural nitrate pollution where contaminants leach through the soils, thus increasing the overall nitrogen concentrations within the River Derwent. These increases are a probable consequence of intensive agriculture units.

Previously, large concentrations of phosphate found within the River Derwent were connected with suspended particles, soluble reactive phosphorus and total dissolved particles. The most credible cause for this is related to sewage discharge which commonly reduces in concentration with amplified flows (Neal *et al.,* 1998); these high concentrations are generally concentrated around industrial and domestic areas. The concentration levels of suspended solids are specifically linked to high flows, the faster the flow, the greater the turbidity.

Many other factors exacerbate small clusters of high concentration suspended solids, from pollutants within soil, geological aspects (bed rock), the use of fertilisers for agricultural practice and the mixing of saline water which enters from the estuary (Neal *et al.,* 1998). At the mouth of the Derwent, the Barmby Barrage retards the tidal flow of the River Ouse towards the lower reaches of the Derwent. It does this by trapping water thus almost entirely impounding the tidal re-suspension effect from affecting the River Derwent. This is a key issue affecting the river.

Chemical quality analyses were undertaken between 1990 and 2012 at three different sites located on the River Derwent; Forge Valley represents the upper catchment; Howsham Bridge represents the middle catchment and Loftsome Bridge represents the lower catchment.

The largest mean nitrite concentration was recorded at Loftsome (4.79 mg/l); with lowest mean concentration at Forge Valley (2.56 mg/l); the mean concentration at Howsham was 4.33 mg/l. This follows a downstream trend, with the highest concentration of nitrite nearer to the mouth of the River Derwent (Figure 2.6). The greatest mean ammonia concentration was recorded at Howsham (0.10 mg/l); followed by Loftsome (0.08 mg/l) and lowest mean concentration at Forge Valley (0.07 mg/l). The trend has to some extent decreased throughout the sampled years, with a few minor fluctuations (Figure 2.7). The greatest mean phosphate concentration was recorded at Howsham (0.11 mg/l); followed by Loftsome (0.09 mg/l); with the lowest at Forge Valley (0.03 mg/l). In recent years, phosphate concentrations have decreased dramatically and started to plateau, again the upper most recorded site had the lowest readings with a sporadic nature from the other sites (Figure 2.8).

The highest mean suspended solids concentration was recorded at Howsham (17.45 mg/l); followed by mg/l); followed by Loftsome (16.8 mg/l); and Forge Valley (10.05 mg/l). There is no relevant trend to the relevant trend to the sporadic nature of the concentrations although, in recent years, an increase an increase occurred (Figure 2.9). The largest mean biological oxygen demand concentration was recorded at Howsham (1.83 mg/l); next was Loftsome (1.60 mg/l), and closely followed by Forge Valley (1.51 mg/l). Concentrations have been relatively stable with spikes in 1996 and 1997 at Howsham (Figure 2.10). Mean dissolved oxygen concentration is relatively stable and high at all sites (

Figure 2.11). Maximum temperatures recorded increase further downstream in the River Derwent. The most extreme high temperature was in 1995 at Loftsome Bridge (23.2°C). The lowest temperature was recorded in 1992 at Forge Valley (1.2°C) (Figure 2.12).

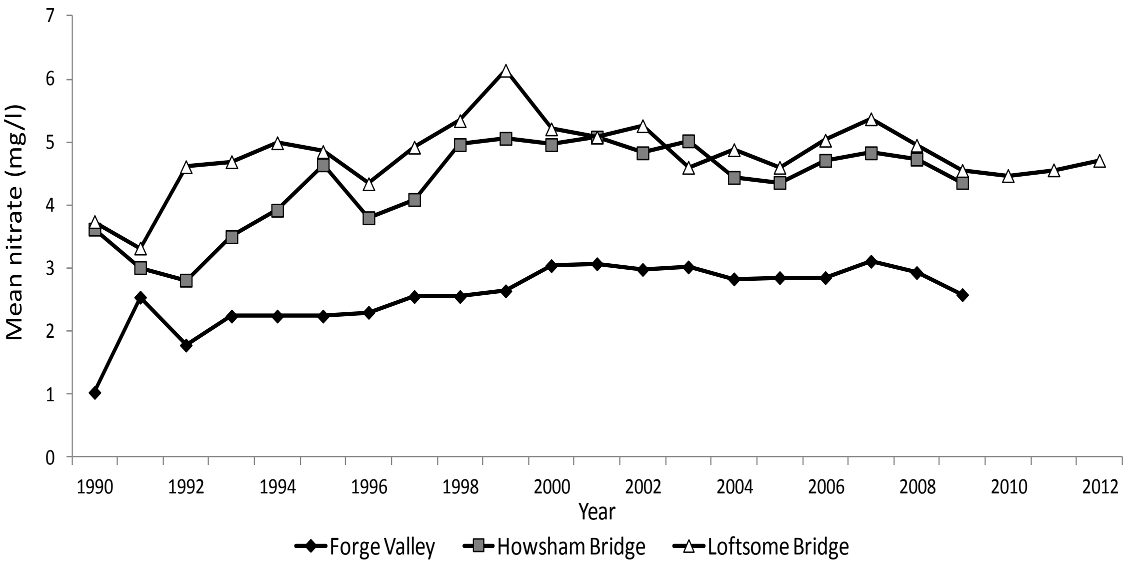


Figure 2.6 Mean nitrate (NO_3^-) concentrations (mg/l) in the River Derwent (1990 to 2012) (source: Environment Agency database)

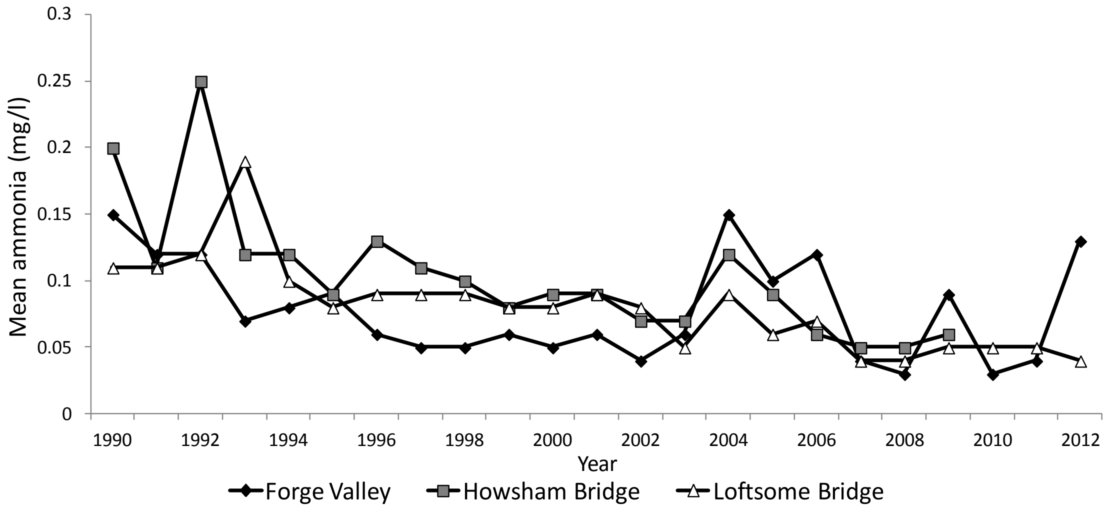


Figure 2.7 Mean ammonia (NH_3) concentrations (mg/l) in the River Derwent (1990 to 2012) (source: Environment Agency database)

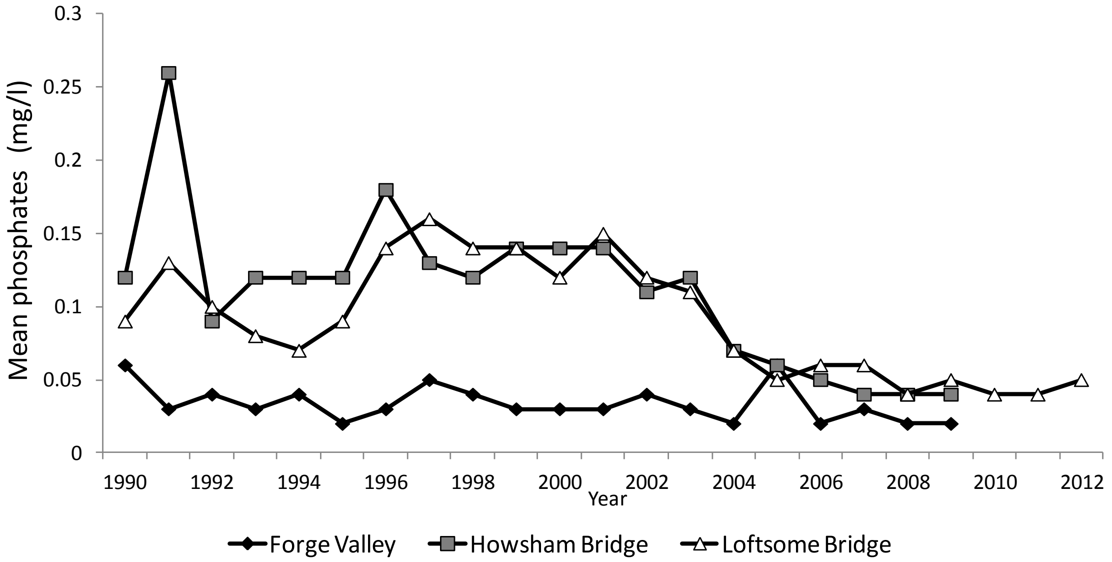


Figure 2.8 Mean phosphate (PO_4^{3-}) concentrations (mg/l) in the River Derwent (1990 to 2012) (source: Environment Agency database)

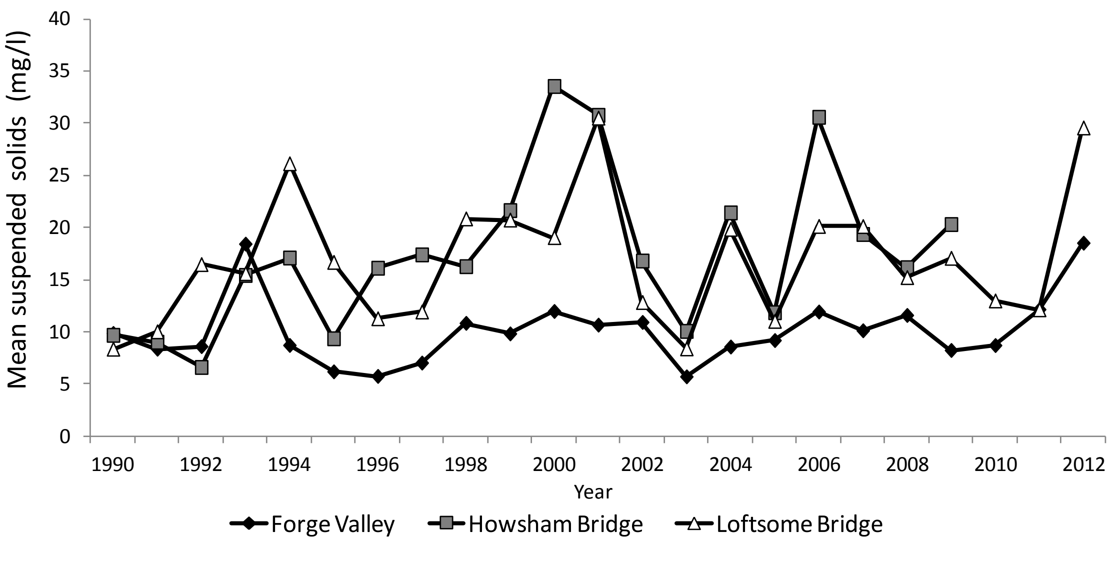


Figure 2.9 Mean suspended solid (SS) concentrations (mg/l) in the River Derwent (1990 to 2012) (source: Environment Agency database)

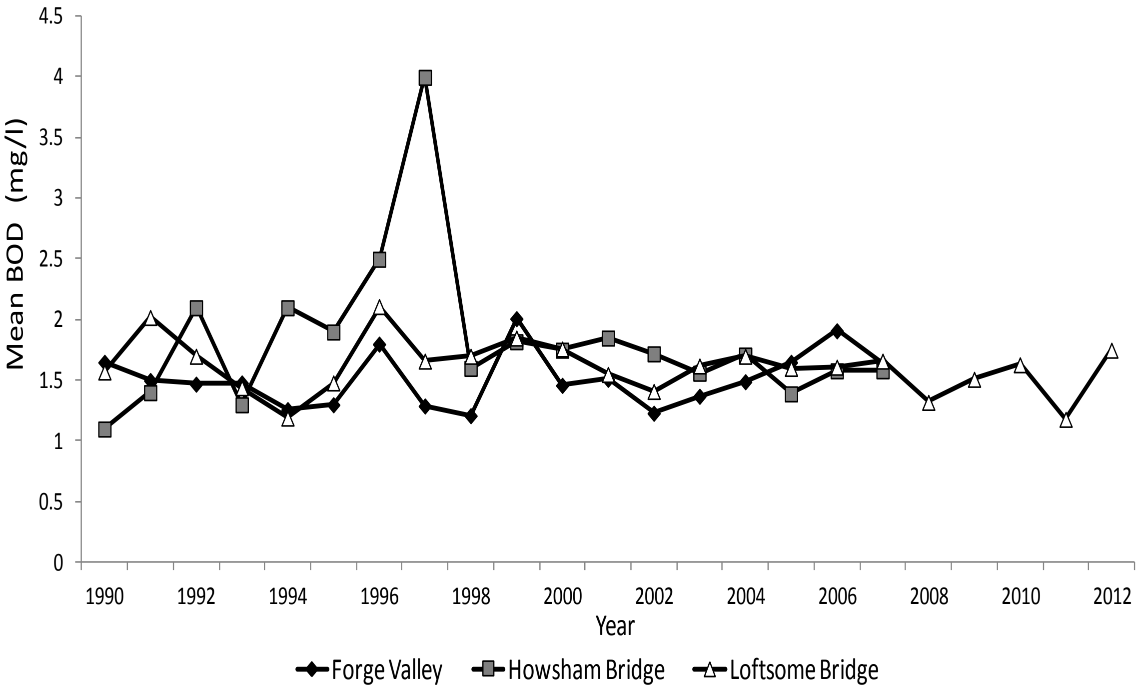


Figure 2.10 Mean BOD concentrations (mg/l) in the River Derwent (1990 to 2012) (source: Environment Agency database)

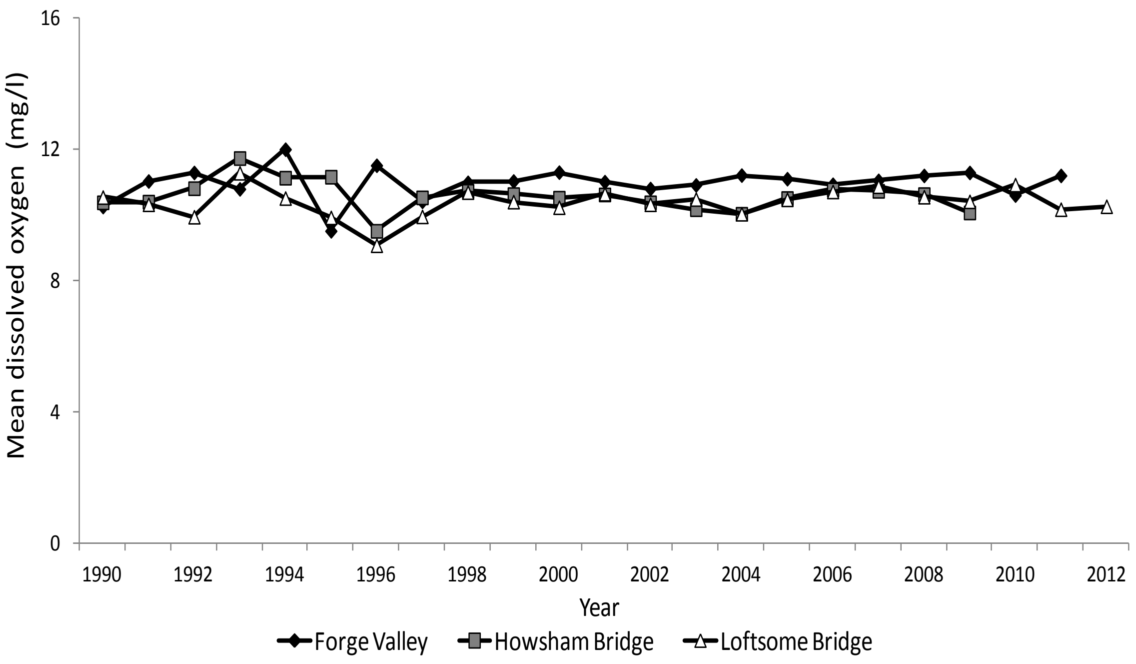


Figure 2.11 Mean dissolved oxygen (DO) concentrations (mg/l) in the River Derwent (1990 to 2012) (source: Environment Agency database)

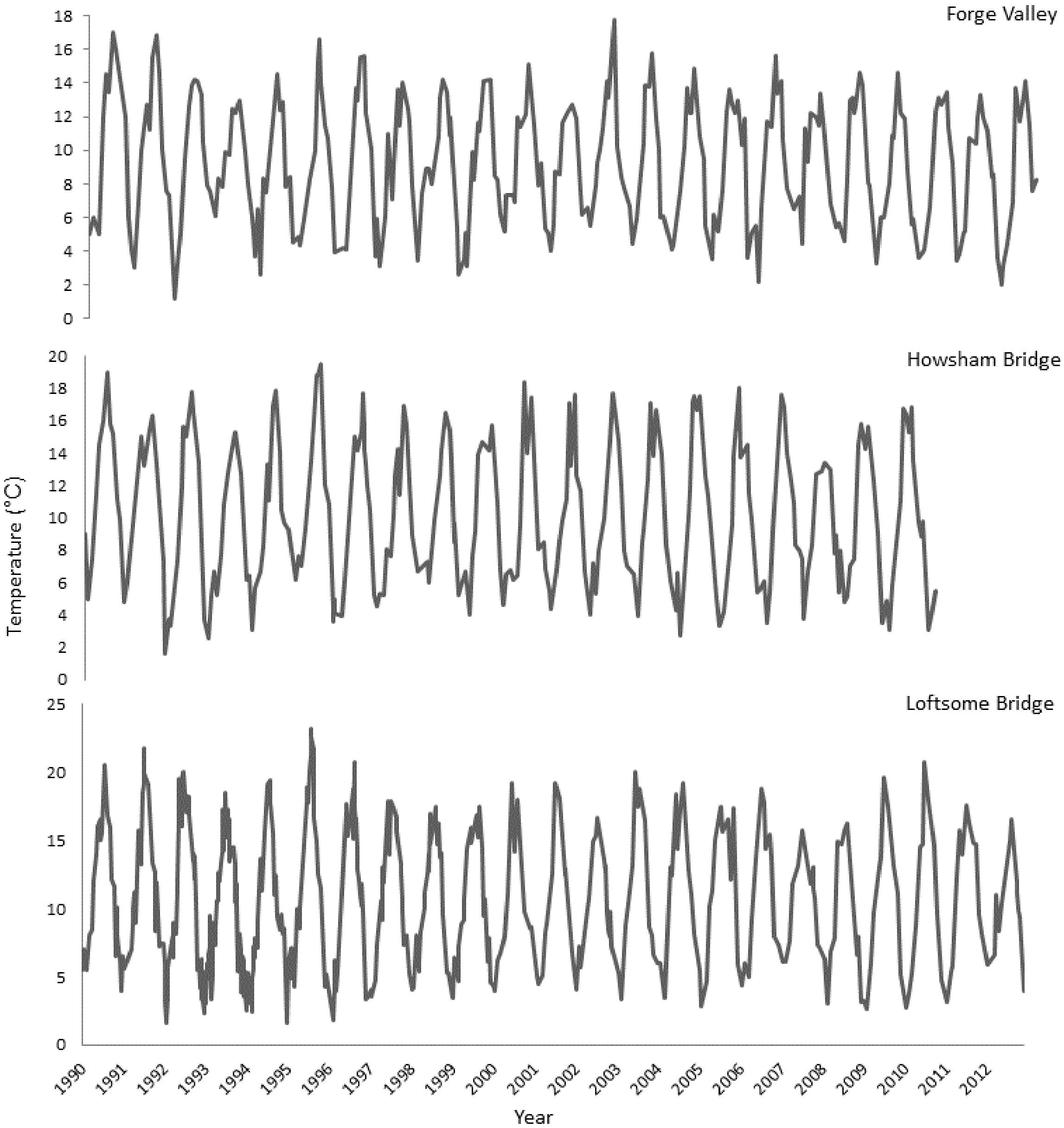


Figure 2.12 Yearly temperatures (°C) in the River Derwent (1990 to 2012) (source: Environment Agency database)

2.5 Uses and impacts on the River Derwent catchment

2.5.1 Industry

There are many historical and modern day industrial influences in the River Derwent catchment including sand and gravel extraction, forestry, tourism, milling and brewery practices. This area has been heavily reliant on these practices throughout its history. Even though the landscape has been heavily used and modified for industrial needs it can be considered semi-natural (Morley, 1997).

Historically, the local economy of the River Derwent catchment heavily relied on mining and quarrying for raw materials. Of all the excavation practices the largest was iron ore mining; the Industrial Revolution in the 19th Century saw a boom in iron ore extraction subsequently causing a mass increase in population on the North York Moors (NYMNPA, 1999; Morley, 1997).

Forestry and silviculture takes place throughout the catchment but is more concentrated in the upper reaches, specifically the North York Moors spanning over 18,500 ha of Forestry Commission owed land covered by trees. These practices alter the habitat of the woodlands and have potential affects on the river catchment in several ways; sediment being the main threat due to the ground being damaged causing soil erosion as a result of harvesting. This is a key issue within the Derwent catchment (FCE, 2007; McKay, 2011).

2.5.2 Agricultural practices

The countryside surrounding the catchment consists primarily of tilled farmland (arable and mixed;Figure 2.13) with interspersed grass fields used for livestock grazing, boundaries segregating these lands with hedgerows and general drainage ditches with steep sides. The higher elevated North York Moors are located at the northern most point of the upper reaches of the River Derwent; the large open areas of heather moorland support traditional livestock grazing (sheep) as well as regular slash and burn maintenance for game shooting (red grouse) (Morley, 1997; Table 2.1). The variation in climate at the higher altitudes and the shallower, poorer quality and stonier soil than in the valley makes the more elevated areas somewhat incompatible for arable cultivation (Jarvie *et al.,* 1997).

A mixture of livestock production with larger spaces of grassland used for dairy production is found on the western side of the river in the Vale of Pickering where denser clay soils are found. Although these are not completely traditional activities, the Vale of Pickering is heavily grazed more so now by cattle rather than sheep and pig (Natural England, 1999b; Table 2.1). These methods of farming can have detrimental repercussions such as water quality contamination and habitat issues. Farms that have riparian vegetation can cause unintentional effects with direct cattle access to the river potentially causing poaching of riparian vegetation and banks. This can lead to loss of diversity in the marginal habitat, and sedimentation and eutrophication. The Vale of Pickering also holds the most northerly watercress (*Nasturtium officinale* R. Br) cultivation beds. Cultivation methods require the application of fertilisers, which in turn can be flushed into the external waterways when the water is discharged. The harvesting of watercress can also cause disturbance to the silts and sediments affecting suspended solids (Cox, 2009).

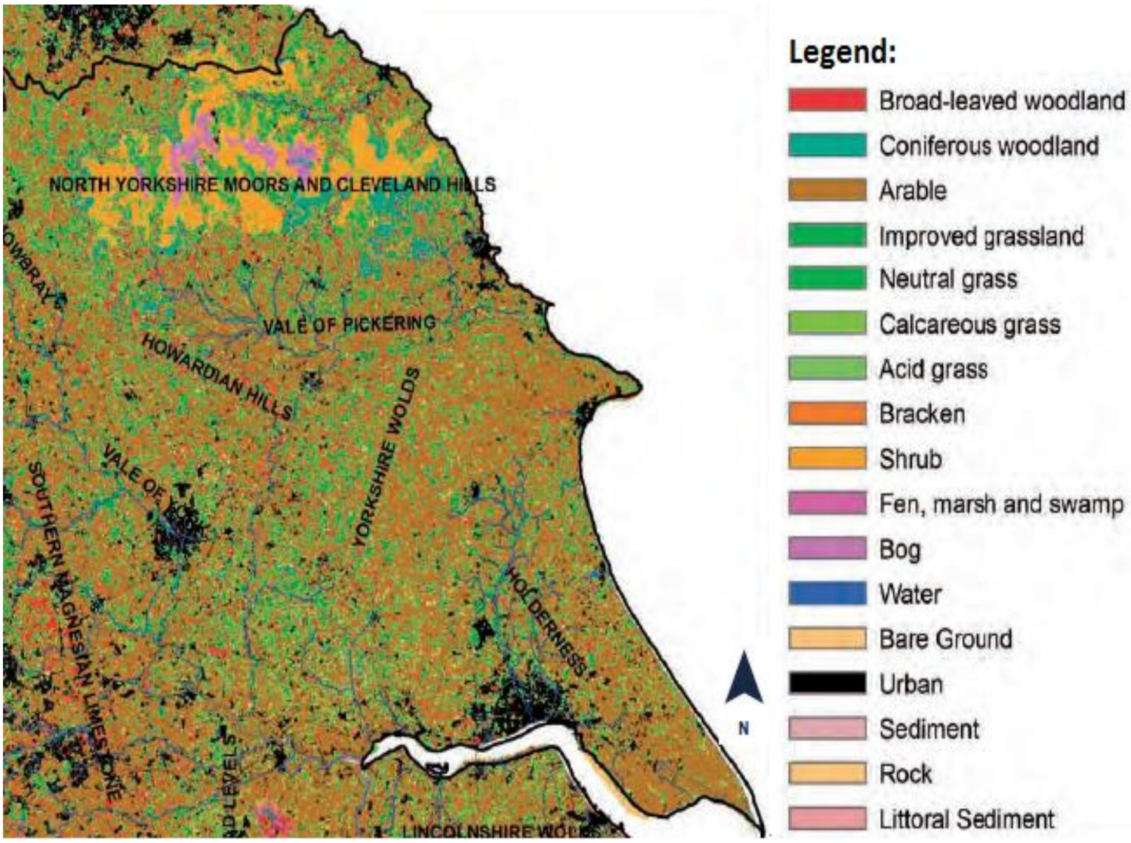


Figure 2.13 Map of agricultural land use within East Yorkshire (source: Boardmeadow & Nisbet, 2010).

The majority of the cultivated land in the River Derwent basin has been sustained with numerous organic and inorganic fertilisers; additionally the use of pesticides to control the susceptibility of crops to pest and diseases has occurred which can have large detrimental affects on the adjacent environment. Specific native endemic fauna and flora are in decline as a consequence of the heavy use of fertilisers and herbicides on agricultural land (Natural England, 1997b).

Table 2.1 The River Derwent agriculture and livestock land use [ha & (%)] (source: Fezzi *et al.,* 2010)

Land use ha (%)	**Derwent**	**Upland (North)**	**Lowland (East)**
Urban	7,520 (5.1)	1,890 (2.9)	2,540 (7.0)
Woodland	19,140 (13.0)	10,480 (16.3)	3,925 (10.9)
Cereals	42,425 (28.7)	10,550 (16.4)	13,945 (38.6)
Potatoes	2,810 (1.9)	625 (1.0)	1,050 (2.9)
Oilseed rape	6,320 (4.3)	1,005 (1.6)	2,420 (6.7)
Sugar beet	1,950 (1.3)	170 (0.3)	700 (1.9)
Other arable	2,430 (1.7)	560 (0.9)	875 (2.4)
Vegetables	150 (0.1)	35 (0.1)	90 (0.3)
Set aside	6,770 (4.6)	1,645 (2.6)	2,360 (6.5)
Grassland	52,575 (35.8)	35,240 (54.8)	7,150 (19.8)
TOTAL	147,010 (100)	64,330 (100)	36,130 (100)
Livestock (No.)			
Dairy	7,060	2,670	1,550
Beef	50,310	21,350	14,080
Sheep	248,940	161,950	34,410
[a] Includes both temporary grassland and rough-grazing areas.			

2.5.3 Tourism – (leisure and recreation)

The different landscapes of the Derwent catchment are essential in attracting such a varied range of tourists. The landscape and quaint towns and villages of the Derwent basin provide a beautiful back drop for a variety of activities from walking to sightseeing, cycling to angling through to boating and golfing (EA, 2007). Many golf courses are located in the Derwent catchment, having dramatic affects on the landscape with the potential to cause run-off from fertilisers (Natural England, 1997a).

2.5.4 Aquaculture

The clean, clear chalky head waters of the Derwent and its catchment provide ideal grounds for fish farming and other aquaculture establishments such as watercress cultivation. There are several aquaculture units in the Derwent catchment including: Willowdene Watercress & Trout Farm Ltd (SE 7818183978) and Costa Spring Hatcheries Ltd (SE 77808400). These are both located on the Oxfold and Costa Becks within a few 100 metres of each other. The Becks connect further south to the River Rye which is a confluence to the River Derwent at Rye Mouth. Costa Spring Hatcheries Ltd produce rainbow trout (*Oncorhynchus mykiss* (Walbaum.)) as well as the native brown trout (*Salmo trutta* L.). These are all produced for growing on and stocking (CSFish, 1999).

In addition, Moorland Trout Farm (SE 799385848253) is located on the Pickering Beck to the east. The presence of aquaculture units on the Becks draining into the River Derwent have a number of influencing factors on the overall ecological and chemical status of the Derwent SSSI and other protected areas. Although they negatively impact the status of the river, the aquaculture units provide economic value to the local area through employment.

3 Issues threatening the River Derwent and its tributaries

3.1 Introduction

Anthropogenic pressures, such as transportation, water supply, flood alleviation, agriculture and power generation have enormous environmental and socio-economic impacts on rivers catchment (Poff *et al.,* 1997). A great deal is known about anthropogenic pressures on freshwater aquatic ecosystems, specifically in-channel structures (Marmulla, 2001; NSW, 2006; Lucas & Frear, 1997); sedimentation and pollutants (Vörösmarty *et al.,* 2003; Wood & Armitage, 1997; Amisah & Cowx, 2000; Harvey *et al.,* 2004; van Rijn 1993; Neal *et al.,* 1998); channelisation and disconnection from floodplains (Brooker, 1985; Jurajda, 1995; Baattrup-Pedersen *et al.,* 2005; Copp, 1989; Peirson *et al.,* 2008; Cowx *et al.,* 2004; Bolland *et al.,* 2012) and riparian habitat degradation and destruction (Baattrup-Pedersen *et al.,* 2005; Pysek & Hobbs, 2007; Barling & Moore, 1994; Martin & McIntrye, 2007; Kauffman & Krueger, 1984; Platts & Wagstaff, 1984) but not enough is known about specific anthropogenic pressures with regards to the River Derwent catchment. The Yorkshire Derwent catchment overview in Chapter 2 provides some understanding on the potential impacts that could arise within the Derwent catchment.

The objective of this chapter is to document the major issues within the River Derwent catchment. These are: in-channel structures; diffuse and point source pollution, channelisation and disconnection from the floodplains, riparian habitat degradation and destruction. Highlighting these major issues will facilitate in a better understanding of the affects these issues have on the Derwent catchment, with regards to biological and hydromorphological influences. The identified issues and pressures influence the River Derwent catchment in many ways, specifically: inappropriate in-channel structures causing habitat fragmentation; water quality issues occur due to diffuse and point source pollution from agricultural run-off which are exacerbated by sedimentation and siltation; channelisation and disconnection from the floodplains cause concerns about the flow regime as well as flood defence works; and lack of riparian management causes degradation and destruction to these unique habitats. Other pressures transpire from different sources including aquaculture (fish farming and stocking) and agricultural land drainage and associated irrigation (EA, 2010).

To understand the status of the Derwent ecosystem, assessments were completed through a variety of methods. A broad range of publications and literature were reviewed together with consultations to source information directly from specialists and stakeholders. Finally, a walk-over survey was carried out on the catchment (5 – 9 April 2013) to assess anthropogenic activities, impacts and potential issues. Access to some areas of the rivers catchment was not possible due to private land ownership or limitations due to protected areas. The analysis was split into the following reaches:

Upper Derwent from the North York Moors, the 'Sea Cut', River Hertford downstream to Rye Mouth;

River Rye Basin and its tributaries;

Middle to lower Derwent (Malton down to the mouth at Barmby Barrage) also including the Pocklington Canal.

Also noted was how the pressure affects the catchment or specific location whether there are any particular spatial trends and/or if there are any locations where the issues are significantly worse.

3.2 In-channel structures

There are roughly 254 barriers located throughout the River Derwent catchment; this section will be only dealing with the major ones. In-channel structures have many causes with different uses but were generally constructed across the channel to reduce flooding of the surrounding areas, as well as impound water for industrial or agriculture uses (Figure 3.1). Engineered modifications to a riverine environment, such as weirs, sluices, grills and hydropower units have a vast array of impacts and issues all of which occur in the River Derwent catchment (Figure 3.1). These issues and impacts arise as an effect of an in-channel structure which includes: acting as a physical barrier inhibiting migration, altering fish community dynamics and fish genetic integrity, and causing habitat fragmentation (Lucas & Frear, 1997; Mills, 1989; Figure 3.1). In-channel structures also alter the natural hydrological processes through changing the morphology of the channel as well as cause impoundment of waters upstream which slows flow rates (increasing sedimentation) (Poff *et al.,* 1997; Mistak *et al.,* 2003; Doeg & Koehn, 1994; Figure 3.1) whereas, downstream channel dynamics are drastically distorted increasing flow rates (increased turbulent flows and localised erosion) (Mistak *et al.,* 2003; Figure 3.1), thus altering prey availability changing the predator-prey interactions in the system (Jansen *et al.,* 1996; Figure 3.1).

The main influencing in-channel structures on the River Derwent are: Kirkham Weir and Sluice, Howsham Weir, Buttercrambe Weir, Stamford Bridge Weir, Elvington Sluice and Sutton Lock, and Barmby Barrage (Figure 3.2). There are also water abstraction points located at Loftsome Bridge and Elvington water treatment works (Figure 3.2; Table 3.1).

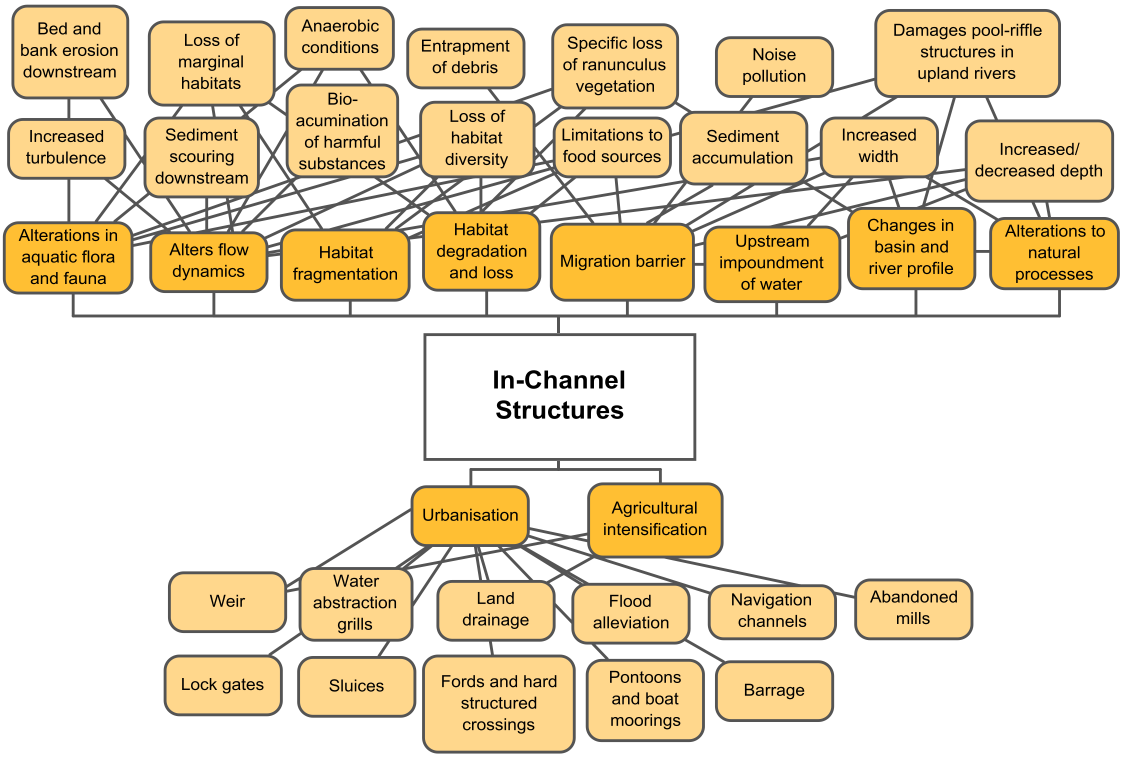


Figure 3.1 Problem diagram relating to in-channel structures. At the very top are the outcomes from the affects below, causes are located at the bottom.

Fish passes have been installed at Buttercrambe and Kirkham weirs (Figure 3.2), although it is not sure how affective these fish easements are. There are a few locks in the Derwent that prevent upstream migration. Stamford Bridge weir (Figure 3.2) is a major barrier for migratory species such as lamprey (Harvey *et al.,* 2006; Nunn *et al.,* 2007; Nunn *et al.,* 2007b), although downstream of Stamford Bridge weir is one of the few important breeding locations for lamprey on the lower Derwent (Jang & Lucas, 2005; Nunn et al., 2008). There is only an eel pass on the Barmby Barrage (Figure 3.2) which is passable to other species when the flow regime is high and specific operating times can be instated to ensure safe fish passage but, when the Derwent has a low discharge, the barrage may be closed impeding migration of salmon, lamprey and eel (Nunn *et al.,* 2007a: Nunn *et al.,* 2007b).

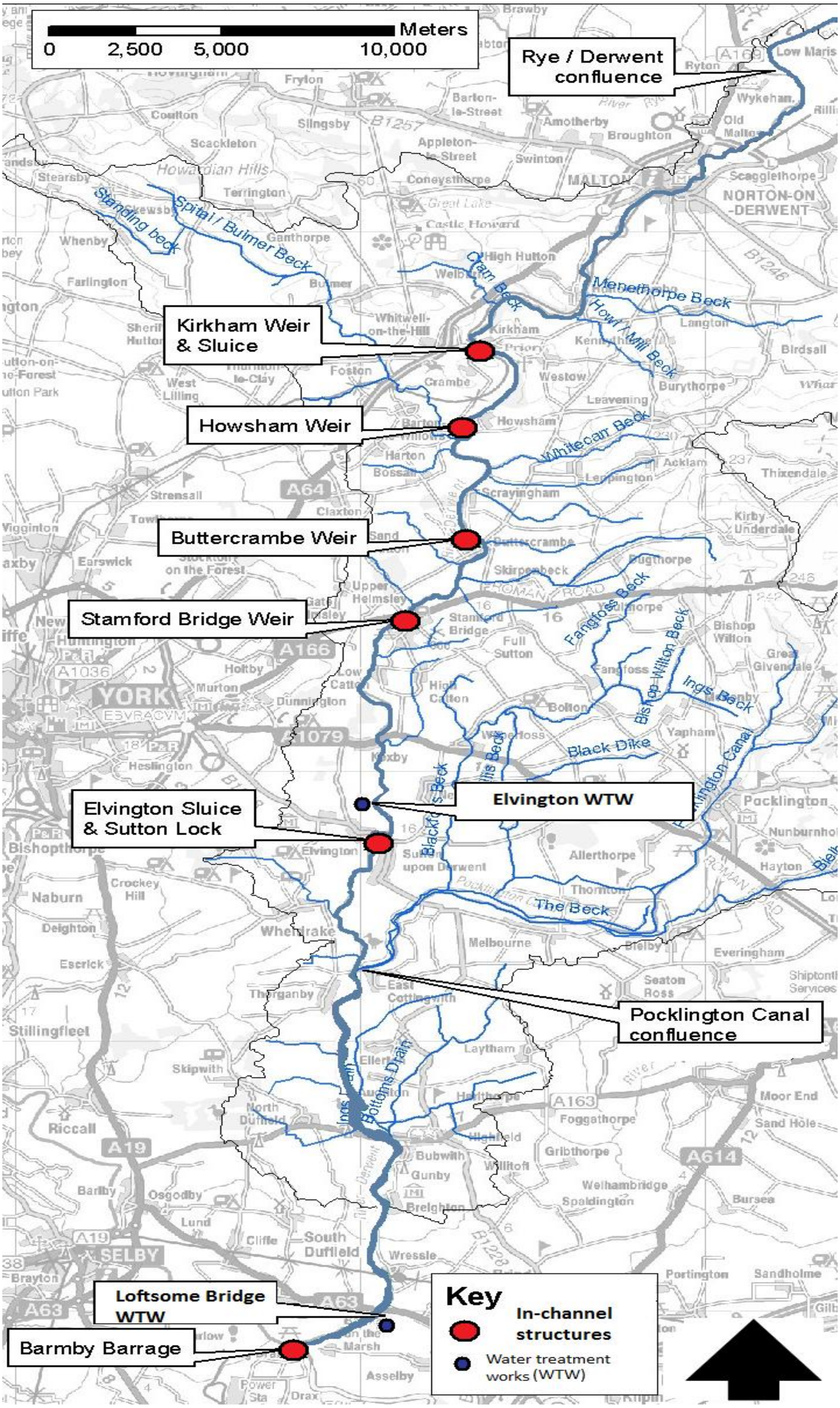


Figure 3.2 Lower River Derwent locations of in-channel structures (adapted: EA, 2010)

Table 3.1 In-channel structures within the River Derwent catchment

Site name	National Grid reference (NGR) and location	Description	Comment
Upper Derwent from the North York Moors, the 'Sea Cut', River Hertford downstream to Rye Mouth			
Weir head (near fisheries site 4)	SE 97298 88392 Diversion channel from the River Derwent and the Sea Cut.	Sluice limiting flows (Figure 3.5a).	Sluice full of detritus and had not been cleared for some time.
Sea Cut	SE 98624 88763 Runs towards the North Sea via Scarborough. Upstream Whitby Road.	Impassable stepped weir with a large straight drop at the bottom.	Barrier to upstream migration (Figure 3.3a, b).
Forge Valley Weir and West Ayton Weir (fisheries site 7)	SE 98868 85719 Transition between moorland riverine characteristics and heavily engineered section.	Altering natural riverine processes (flow, sediment loading etc.) (Figure 3.3c).	Increased sediment was observed above the weir. Sluice channel has not been used for some time as it is completely silted over.
River Rye Basin and its tributaries			
Nunnington Weir	SE6779 Middle reaches of the River Rye.	Crested weir acting as barrier to salmonids (Figure 3.3d).	Salmon redds recorded up and downstream but juveniles have only been recorded downstream.

Site name	National Grid reference (NGR) and location	Description	Comment
Middle to Lower Derwent (Malton to Barmby Barrage), including the Pocklington Canal			
Kirkham Weir and Sluice (near fisheries site 13)	SE 73400 65700 Derwent splits into two channels, weir channel with an established fish pass (Figure 3.3e).The other houses two sluice doors.	Owned by the EA for operation as part of flood alleviation scheme. Sluice doors do not incorporate a fish pass, thus it is expected that they are restricting upstream migration for lamprey.	Royal Haskoning (2011) suggested the preferred option is 'complete removal of all structures' with the second option being 'removal of sluices, lower weir crest and lower fish pass'. Due to environmental impacts, it has been recommended that further geomorphological surveys are undertaken to clarify every outcome.
Howsham Weir (near fisheries site 14)	SE 73000 62800 Howsham Mill.	Small structure. Mill screen meshes in-situ (entrapment possible). Archimedes screw hydropower turbine situated on it. Large neglected lock and swing-bridge (Figure 3.3f). Completely overgrown with large oil slick and high turbidity apparent.	Mill under complete refurbishment. No point source pollution associated with the mill although negative effects could still be occurring.
Buttercrambe Weir (fisheries site 15)	SE 73200 58700	Large concrete structure used as a gauging weir. Large wide impoundment upstream, turbulent flow produced by the weir as well as shallower, faster flowing waters downstream with vast areas of gravel and stones scoured clean.	Bottom baffle fish pass constructed along with an elver pass. There is speculation of a new hydropower scheme to be installed. Flow velocity very high thus substrate scoured leaving larger gravel, cobbles and boulders; bank erosion rife.
Stamford Bridge Weir (fisheries site 16)	SE 71400 55700 River channel splits into two, one of which is the weir with the other a navigation cut, with a guillotine sluice (Figure 3.3 g, h).	Straight drop off concrete structure once used to increase the water level for the mill. Denil fish pass situated next to the weir, which is rarely used by fish. This is likely to be due to the flow over the pass being too strong. Many different old screen grills used to trap detritus from entering the mill (entrapment possible).	Royal Haskoning (2011) suggested the preferred option is 'complete removal of all structures', with the second option being 'remove sluice and reduce weir'. However, due to environmental impacts, it has been recommended that further topographical surveys are undertaken to clarify every outcome, as well as analysis on sediment deposition using ADCP and bathymetric survey equipment. Stamford Bridge flood alleviation scheme finished in 2004, consisting of lock gates around the mill isolating any potential flood waters.

Site name	National Grid reference (NGR) and location	Description	Comment
Elvington Sluice (Figure 3.3i) and Sutton Lock (near fisheries site 18)	SE 70501 47435 Two counter-balanced concave steel gates. Sutton Lock consists of a guillotine sluice and a standard lock gate. Pool & weir fish pass.	Main purpose is to preserve a significant level of water for Elvington WTW, just upstream. Pool & weir fish pass ideal for coarse species but poor in efficiency for eel (Clay, 1995; Nunn *et al.,* 2007). Ranked medium priority for mitigation action (Defra, 2010b)	High amounts of detritus and debris blocking fish pass. Royal Haskoning (2011) suggested the preferred option is to 'refurbish radial gates and maintain the existing case', with the second option 'replace existing weir with rock chute'. However, due to environmental impacts, it is unfeasible because of the length of a rock chute and the shape of the channel is too small, it may also interfere with the bypass channel.
Pocklington Canal	SE 75334 44443 Nine locks located along its stretch with various lift gates and culverts.	15 km long which was disregarded and fell into disrepair.	Restoration works are being undertaken for much of its length.
Loftsome Bridge WTW	SE 70159 29463	Large grills (entrapment possible) (Figure 3.3j).	
Barmby Barrage (fisheries site 22)	SE 68100 28600 Tidal barrage situated at the tidal reaches of the Derwent with the River Ouse, it consists of two vertical lifting gate sets and a lock for boat passage (EA, 2010) (Figure 3.3k).	Operational for different purposes: prevention of tidal waters entering the lower Derwent ensure water depth is sufficient for abstraction at Loftsome Bridge WTW; to provide boat pass upstream. Ranked high priority for mitigation action (Defra, 2010b).	Normally closed at high tides, passable for many fish species, can be a significant barrier (Nunn *et al.,* 2007). Elver bristle fish pass on one of the gates, high velocity around entrance (unlikely that it has been used) (Figure 3.3l) Lamprey pass has been damaged.

	
a) Weir located on the Sea Cut, just north of the Whitby Road Bridge (looking upstream)	b) Newly installed fish pass on the Sea Cut just before conjoining with Scalby Beck
	
c) West Ayton weir and sluice gate (fisheries site 7)	d) Weir located on the grounds of Nunnington Hall in the AONB Howardian Hills
	
e) Kirkham weir Denil fish pass	f) Disused lock of Howsham Mill

	
g) In take from the River Derwent through the old mill at Stamford Bridge	h) Stamford Bridge guillotine sluice
	
i) Elvington Sluice	j) Abstraction point for the Loftsome Bridge WTW
	
k) Barmby Barrage	l) Elver fish pass located at Barmby Barrage, the tidal confluence with the River Ouse.

Figure 3.3 Various in channel structures in the River Derwent catchment

3.3 Diffuse, point source pollution and sediment

There are many different activities that cause diffuse, point source pollution and sediment within the Derwent catchment. These mainly derive from agricultural intensification, aquaculture, urbanisation, flood alleviation and restrictions of natural processes (Figure 3.4; Table 3.2). Poor management of agricultural activities has been acknowledged as the foremost contributor to environment stress within the River Derwent catchment, affecting all ecological components, through various aspects specifically, sediment erosion (Figure 3.4). Sediment is a natural and essential feature of river systems and plays a key function in the hydrological, geomorphological and ecological functioning of rivers.

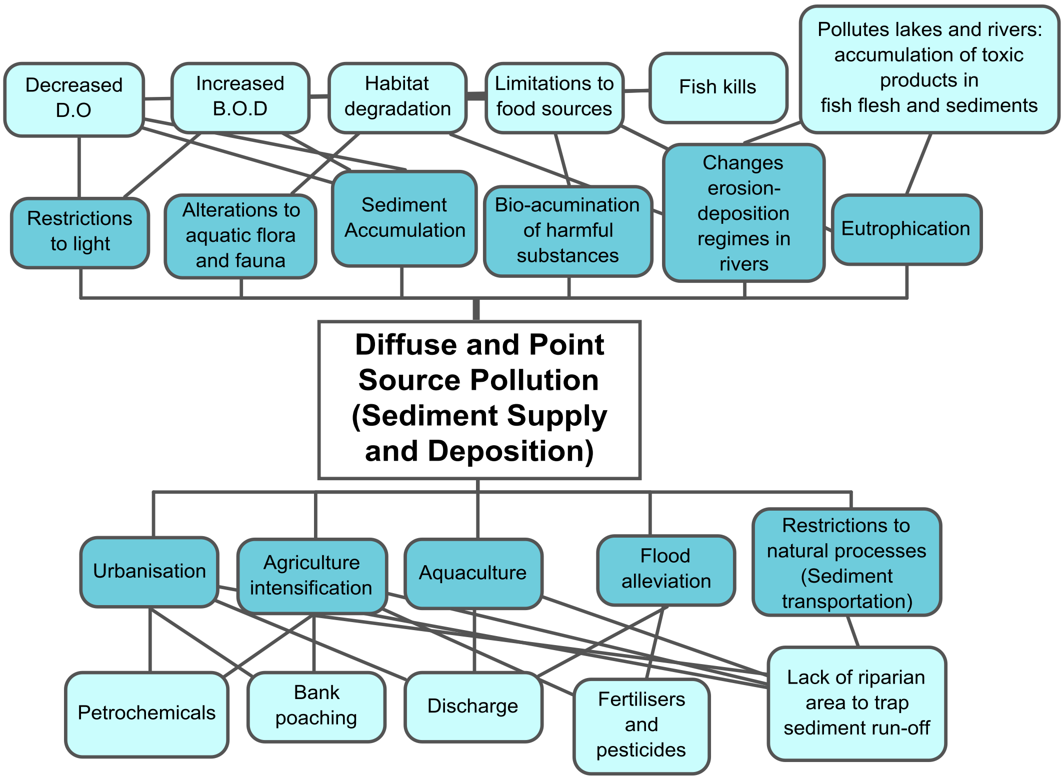


Figure 3.4 Problem tree relating to diffuse and point source pollution. At the very top are the outcomes from the affects below, causes are located at the bottom.

Agricultural tilled land is catchment-wide and these fields are directly linked to a vast array of agricultural drainage ditches that feed sediment directly into the Derwent (Figure 3.4). The majority of the sediment that arrives in the River Derwent, and its tributaries, is the result of catchment run-off - this is due to the erosive nature of the sediment soils within the catchment. As well as arable farming, there is considerable livestock grazing within the River Derwent catchment. A large proportion of these grazing pastures have direct access to the river; the livestock can, therefore, freely graze on the riparian vegetation and, while doing so, bank-side poaching occurs, which exacerbates bank-side erosion, thus increasing sedimentation (Figure 3.4). This occurs catchment-wide. Furthermore, machinery tracks were observed near to the river bank in some areas, causing slumping and, in a few instances, large chunks of the bank fall into the river (Figure 3.4).

When excessive nutrients enter a system phytoplankton blooms are more than likely to occur, thus limiting photosynthesis and decreasing oxygen concentrations (FAO, 2008; Figure 3.4). Aquatic flora benefit from plant fertilisers, proliferating and causing drastic increases in the amount of oxygen that is consumed from the water therefore, reducing dissolved oxygen levels for aquatic life (Waite, 2011; Figure 3.4). Consequently, reduction in the abundance of macrophytes will have a detrimental effect on the higher food chain (Figure 3.4). There are several macrophyte species that are protected under SAC and SSSI; a few specific species are under substantial threat from excessive sediment, especially water-crowfoot and shining pondweed (*Potamogeton lucens* (L.)) due the entirety of the plant being coated.

Accumulation of sediment and detritus occurs behind the majority of the key weirs and sluices on the River Derwent due to the slower flowing waters (Figure 3.4). These weirs consequently limit the downstream transfer of sediments, although, there has been an increase in bed levels in the lower reaches since 1998. Yorkshire Water is licensed to abstract water from the Derwent from Elvington (SE 70294 48558) and Loftsome Bridge (SE 70159 29463) Water Treatment Works (WTW) which provides water for North Yorkshire, but needs to remove 20,000 – 25,000 tonnes of silt a year from below Elvington WTW.

Urbanised areas can also have a considerable amount of storm drain run-off which can potentially contain harmful chemicals and nutrients (Figure 3.4). Several main roads cross or run near to the river and its tributaries; this subsequently can cause an issue with road run-off sediment and chemicals such as petroleum. Hydrocarbons can have drastic effects on aquatic ecosystems. It was noted that, underneath the A1079 at Old Kexby Bridge, a large oil slick was present that had drained directly from the road into the river via a drainage pipe.

Table 3.2 Potential diffuse, point source and sediment pollution regions in the River Derwent catchment.

Site name	NGR and location	Description	Comment
Upper Derwent from the North York Moors, the 'Sea Cut', River Hertford downstream to Rye Mouth			
Near weir head (fisheries site 4)	SE 97298 88392	Sluice limiting flows (Figure 3.5a).	Sluice full of detritus and not been cleared for some time.
Forge Valley Gauging Weir (fisheries site 6)	SE 98868 85719	Channel restrictions upstream due to siltation (Figure 3.5b).	An island has formed and plants have started to colonise.
River Rye Basin and its tributaries			
Moorland Trout Farm (Pickering)	SE 79941 84839	Discharged effluent waters contain high suspended solids.	Proposed local development – dry forested reservoir to help alleviate local flooding.
Costa Spring Hatchery Ltd	SE 78024 83933	Diverted waters from Keldhead spring.	Costa Beck suffering from high suspended solids.
Willowdene Watercress & Trout Farm Ltd	SE 77701 83833	Discharged effluent waters contain high suspended solids.	Costa Beck suffering from high suspended solids. Herbicides and pesticides are used to protect crops.
Sinnington Trout Farms Ltd	SE 73864 84244	Discharged effluent waters contain high suspended solids.	Located on the River Seven.
Caravanning and camping sites.	SE 62271 88093	Sewage effluent discharged directly into waterway. Increasing BOD and SS in the summer months.	Winterbourne becks (River Riccal) are frequent within this reach. Accumulation of hazardous substances is likely.

Site name	NGR and location	Description	Comment
Middle to Lower Derwent (Malton to Barmby Barrage), including the Pocklington Canal			
Duncombe Sawmill	SE 61640 8326	Wood shavings and other leachate could enter the water course.	Toxic pollutants clog fish gills, decreased light penetration leading to smothering restricting macrophyte growth and chemicals from treating wood can cause water quality spikes leading to fish kills (Airmoro *et al.,* 2006).
Malton & Norton Golf Club (near fisheries site 11)	SE 77959 69953	Green maintenance (rolling) compacting soils causing harder surfaces decreasing entrapment of sediment and increasing run-off.	Pesticides and fertilisers; (nitrogen (N), phosphorous (P) and potassium (K)) on tees, greens and fairways can run-off (England Golf, 2013; Wong *et al.,* 2004).
The Oaks Golf Club (Aughton) (near fisheries site 20)	SE 72137 37785	Green maintenance (rolling) compacting soils causing harder surfaces decreasing entrapment and increasing run-off.	Pesticides and fertilisers; (nitrogen (N), phosphorous (P) and potassium (K)) on tees, greens and fairways can run-off (England Golf, 2013; Wong *et al.,* 2004),
Mixed & arable agriculture including lawn & turf farming.	Catchment-wide. Turf & lawn farming. SE 70724 34946	Can have drastic impacting effects on a system. Increase suspended solids and sedimentation (Figure 3.5 c, d).	Fertilisers not always necessarily absorbed by the plant compaction thus leading to run-off into neighbouring lands. Can cause illness and death to any live organisms nearby. Specifically heavily decreases light availability for aquatic macrophytes thus limiting photosynthesis, as well as reducing microphyte communities through directly covering.
Breighton (fisheries site 21)	SE 70654 33876	Leisure boating activities including moorings (Figure 3.5e, f).	Vessels cause re-suspension of particulate sediment and bank side erosion. Turbidity is consequently intensified. Reach suffering from high suspended solids.

a) Weir Head (site 4), the confluence between the River Derwent and the Sea Cut has clearly been swamped with detritus and silt

b) Downstream Forge Valley Gauging Weir (site 6), weir has clearly started to become over grown with sediment and aquatic flora

c) River Seven running through intensive agricultural lands clear indication of bank poaching from cattle

d) Drainage ditch in the middle reaches of the River Derwent

e) Leisure boats located near site 21 (The Breighton Ferry Public House)

f) Near Breighton (site 21) clearly indicating an issue with bank erosion most likely from the high level of power boating just upstream

Figure 3.5 Diffuse and point pollution sources in the River Derwent catchment

3.4 Channelisation and disconnection from the floodplains

Channelisation and disconnection from the floodplains is a major reason why the Derwent is failing to comply with WFD. The main causes for this are: agricultural intensification, navigation, aquaculture, urbanisation, flood alleviation and water resource development (Figure 3.6; Table 3.3). The majority of the middle and lower Derwent has been straightened and dredged thus increasing the capacity of the channel, elevating pressures of the interconnecting land drainage system and flood waters from the localised agricultural land (Figure 3.6). As a result of channelisation, meanders and connectivity to flood plains has been restricted or completely cut off (Figure 3.6).

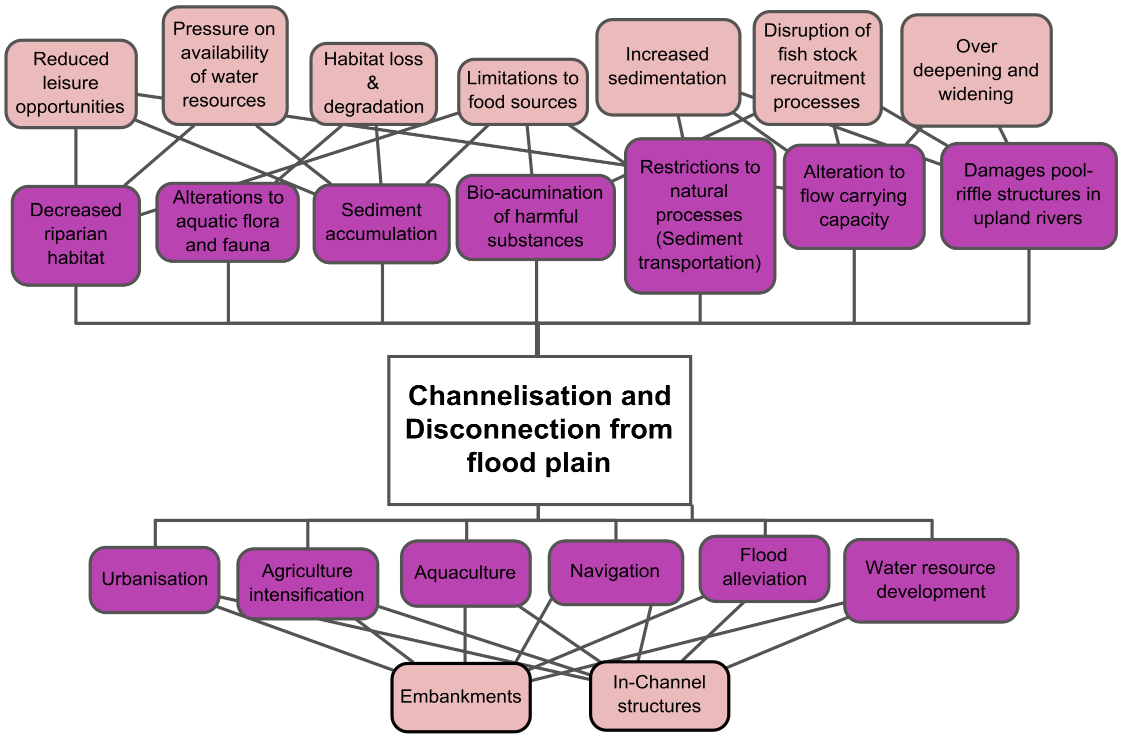


Figure 3.6 Problem tree relating to channelisation and disconnection from flood plains. At the very top are the outcomes from the affects below, causes are located at the bottom.

A large proportion of the Derwent has had flood embankments constructed adjacent to it and over 230 separate flood defences have been put in place to reduce the potential of flooding (EA, 2010b). These structures, although having rather severe environmental impacts have been created to protect over 3000 properties (EA, 2010b).

Embankments are disconnecting the river from areas of natural flooding, consequently, restricting lateral transfer of waters, sediments and nutrients stopping the development of wetland areas crucial for birds (Figure 3.6). Embankments are generally over 2 m in height, subsequently, minimising the diversity of the riparian habitat and completely isolating floodplains, which are crucial for natural process as well as habitats for an array of important species (Figure 3.6). Several meanders within the Derwent catchment have been completely cut off from the main river channel restricting floodplain connectivity.

Channelisation often reduces the river to a single channel that impedes lateral connectivity with floodplains and lentic waters (Bolland *et al.,* 2012; Ward & Stanford, 1995; Cowx & Welcomme, 1998), this is a common occurrence in the River Derwent catchment (Figure 3.7). The connectivity of floodplains from flood waters allows aquatic organisms to disperse between systems and habitats for spawning, nursery, refuge and feeding (Peirson, Bolland & Cowx, 2008; Figure 3.6). Channelisation was carried out on the Derwent to improve the load capacity of the channel which has helped land drainage, reduced flooding as well as increasing the availability of navigable reaches (Schoof, 1980; Brooker, 1985).

Figure 3.7 Heavily channelised section of the River Derwent with very limited riparian habitat (looking west from Brompton Bridge, downstream)

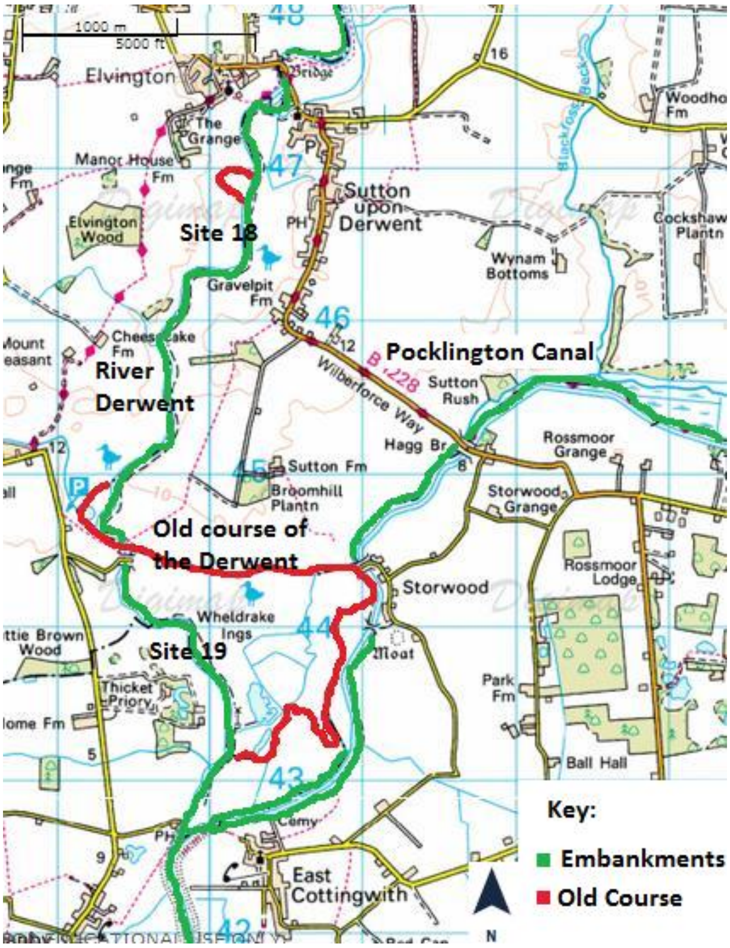
Table 3.3 Potential channelised and disconnected sections in the River Derwent catchment

Site name	NGR and location	Description	Comment
Upper Derwent from the North York Moors, the 'Sea Cut', River Hertford downstream to Rye Mouth			
Sea Cut (Figure 3.8a)	SE 98624 88763 Alleviates flooding pressures from the North York Moors on the Derwent catchment, it still flows towards the North Sea.	Large embankments with minimal riparian vegetation.	During the time of the walk-over survey livestock were grazing and in the river channel.
River Hertford	SE 98326 79058 Embankments are generally over 2m in height over total length on the river.	Agricultural land drainage ditches run parallel both sides. They are deeper than the main river channel completely constraining any movement; the channel was bare, with few macrophytes.	During the time of the walk-over survey, flooded and boggy areas where in many of the arable fields suggesting that the land drainage is not working and potentially causing many problems to both the environment and for agricultural use.
River Hertford confluence to Yedingham (fisheries sites 9 & 10) (Figure 3.7)	SE 89296 79653	Section is highly channelised and completely restricted from any natural flooding processes due to agricultural land management.	Section is under severe threat, proposed rehabilitation commencing. White clawed crayfish present. Riffle and pool sections are rare in this reach.
Brompton Beck (Figure 3.8b)	SE 93606 79503 Falls out into Derwent; culverts constructed underneath them to continue the drainage ditches. Similar is happening on the outlet to Ruston Beck.	Brompton Beck falls over this culvert, which creates an area of faster flow.	The head waters of this beck are in pristine condition with isolated populations of wild brown trout.

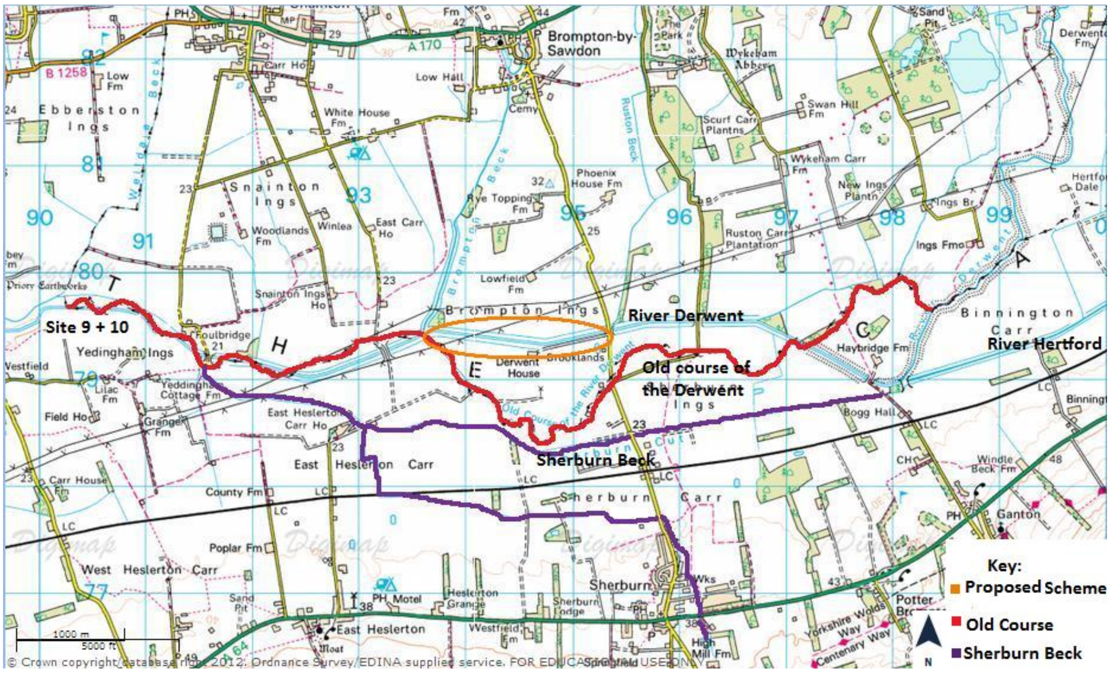
Site name	NGR and location	Description	Comment
Sherburn Beck (Figure 3.8d)	SE 93751 78576 South of the River Derwent. Has been completely cut off from the main channel.	Has been diverted into drainage ditches which are controlled by a flap gate, the drainage ditches are saturated with agricultural run-off.	The head waters of this beck are in pristine condition with isolated populations of wild brown trout.
Middle to Lower Derwent (Malton to Barmby Barrage), including the Pocklington Canal			
Malton Reach	SE 78291 71486 Alleviate the pressures of flooding and protect potential areas of floodplains.	Highly populated area requiring that the river be isolated more due to potential flooding.	Riffle and pool sections are rare in this reach.
Wheldrake Ings (fisheries site 19) (Figure 3.8c)	SE 70214 44020 Lower Derwent Valley	Hay and wildflowers generally cover this expanse which is protected. These ings have dried out thus damaging the grassland habitat. The main reason for protecting these lands is to help alleviate this problem.	SSSI, SAC, SPA, Ramser. Very large abundance of birds. High botanical interest.

a) The Sea Cut just after the confluence with the River Derwent (looking downstream)

b) Brompton Beck confluence to the River Derwent with agricultural land drainage running either side and underneath the confluence



c) River Derwent from Elvington to East Cottingwith (adapted: http://digimap.edina.ac.uk/roam/mapper#)



d) Map of the Vale of Pickering. Red = the old course of the River Derwent. Purple = Sherburn Stream diversion channel. Orange = Location of the proposed rehabilitation scheme – Straightened Derwent Project (adapted: http://digimap.edina.ac.uk/roam/mapper#)

Figure 3.8 Channelisation and disconnection pressures from the floodplains in the River Derwent catchment

3.5 Riparian habitat – degradation and destruction

Riparian habitats are in decline in the Derwent catchment from agricultural intensification as well as aquaculture and urbanisation (Figure 3.9; Table 3.4). Poor management of agricultural activities in the Derwent catchment are linked to the complete removal or degradation of vital vegetation areas; environmental functions can be damaged as well as the services it provides for other species (FAO, 2008; Figure 3.9).

In-stream and riparian flora communities change with flow regime (Baattrup-Pedersen *et al.,* 2005), as well as hydrological, geomorphological and biological features (Jansson et al., 2000) which is predominant within the Derwent catchment (Figure 3.9). In regulated systems, like some areas of the Derwent, such as the Lower Derwent Valley, riparian plant communities have lower abundance, density and diversity of species and less cover than natural systems (Baattrup-Pedersen *et al.,* 2005; Jansoon *et al.,* 2000; Figure 2.2; Figure 3.9).

Phytoplankton blooms are a likely outcome of excessive nutrients and these shade macrophytes from photosynthesis which, in turn, lowers oxygen concentrations (FAO, 2008; Figure 3.9). The wide expanses of degraded riparian areas can cause drastic effects on the designated species in the River Derwent through habitat loss which can lead to decreases in prey (Richardson *et al.,* 2007; Figure 3.9). It must be noted that areas that are over-shaded can also negatively impact riverine habitat from: reductions in biodiversity in river corridors and increase habitat fragmentation; alters heating and cooling of the system (Barling & Moore, 1994) and shading regulates phytoplankton and submerged vegetation from swamping shaded areas (FAO, 2008; Figure 3.9).Also, in the Derwent catchment, there is a high impact from invasive non-native species (INNS) choking native species (Hood & Naiman, 2000; Richardson et al., 2007; Figure 3.9).

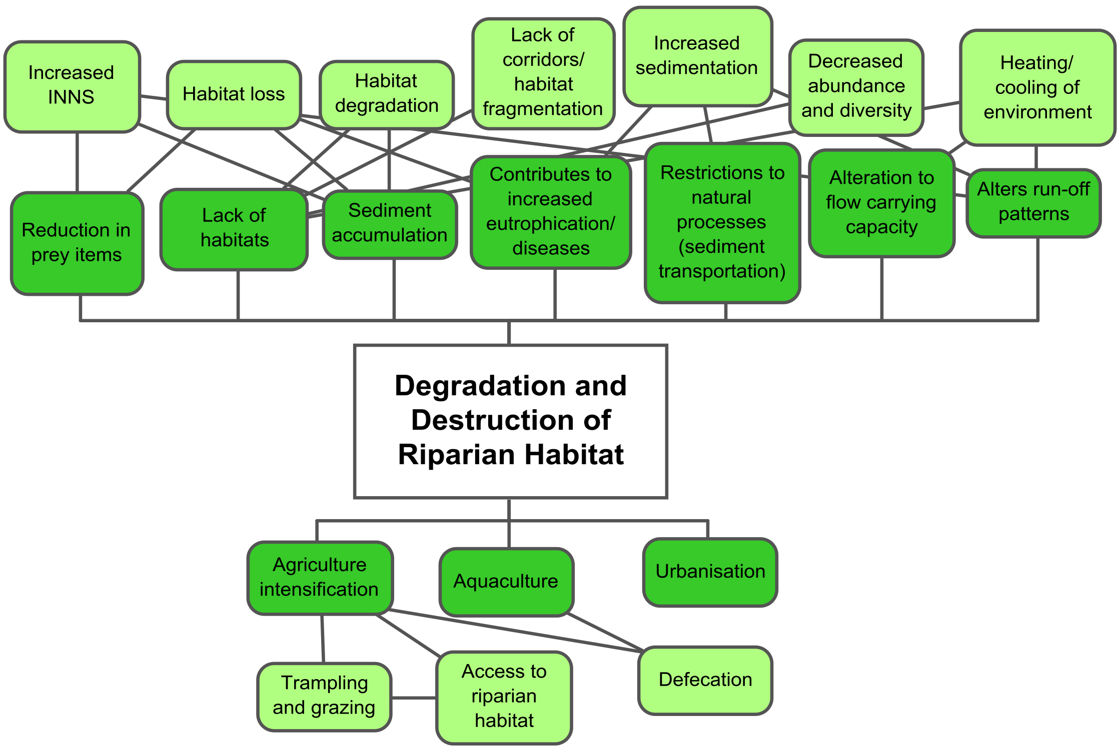


Figure 3.9 Problem diagram relating to the degradation and destruction of riparian habitats. At the very top are the outcomes from the affects below, causes are located at the bottom.

Table 3.4 Potential riparian habitat areas suffering from degradation and destruction in the River Derwent catchment.

Site name	NGR and location	Description	Comment
Upper Derwent from the North York Moors, the 'Sea Cut', River Hertford downstream to Rye Mouth			
Forge Valley Wood NNR (near fisheries site 6)	SE 98454 86198 Critical habitat for the upper Derwent (Figure 3.10a).	Providing habitat for a diversity of species; although highly protected, there are areas that have been modified for agricultural purposes which has destroyed and degraded the habitat.	Heavily embanked.
River Rye Basin and its tributaries			
River Seven	SE 74735 8904 Upper River Rye catchment (Figure 3.10b).	Due to agricultural intensification riparian habitats have been removed to optimise production. Riparian areas have been neglected and subsequently become scarce.	Livestock has access to the majority of the riparian areas within this reach.
Middle to Lower Derwent (Malton to Barmby Barrage), including the Pocklington Canal			
Pocklington Canal	SE 75502 44421 Sporadic abundance of riparian vegetation (Figure 3.10c).	Man-made structure under restoration. Upper reaches dominated by macrophytes, overgrown in some instances.	Unmanaged riparian zones throughout its reaches.
Bubwith (near fisheries site 20) to the mouth	SE 71127 36148 After Malton the abundance of riparian vegetation decreases dramatically (Figure 3.10d).	River has become over wide, vast expanses with no riparian cover. Riparian land is dominated by agricultural practices.	Lower Derwent Valley protected areas (SAC, SPA and Ramser).

	
a) Just south of Forge Valley woods	b) River Seven
	
c) Upper reaches of the Pocklington Canal	d) Bubwith (near fisheries site 20)

Figure 3.10 Impacts of riparian habitat degradation and destruction in the River Derwent catchment

3.6 Summary

Chalk Rivers, including the Yorkshire Derwent, are a priority habitat under the UK Biodiversity Action Plan (BAP). It recognises the habitat for its unique ecosystem which is vulnerable to various pressures. The chemical and biological status for these rivers should be Grade A. This legislation has now been superseded by the Biodiversity Strategic Plan 2011 – 2020, which was adopted in 2010 after the Rio +20 – The Convention on Biological Diversity, the guidelines from this are already in practice (Defra, 2011; UNCSD, 2011).

Habitats have been modified by anthropogenic development such as water supply, flood defence, land drainage and navigation. These changes have had adverse effects on the Derwent; the channels have become deeper and more uniform in shape along with construction of embankments which, in turn, impounds the river for a substantial amount of its course. Condition Assessments initiated in 2003 and 2009 by Natural England recognised that all four rivers within the SSSI area of the Derwent have unfavourable conditions with respect to the WFD (EA, 2010). These unfavourable conditions include: run-off and diffuse pollution from agriculture, unsuitable in-channel construction, siltation and flood defence structures (EA, 2010).

The River Derwent as a whole is affected by morphological anthropogenic issues, which in turn, are heavily influencing the hydrology, ecological capacity and socio-economic benefits. In the upper Derwent, river morphology impacts such as riparian poaching, damage the system. There are large areas that are vulnerable to point source and diffuse pollution throughout the catchment. Whether it is from agriculture or aquaculture, there are a vast amount of suspended solids present - Rye Dale District is heavily predisposed by this. The lower Derwent has been extremely modified to a point that restoration methods brought about are likely to be too expensive with a high potential of being unsuccessful.

The ecosystem health can have radical consequences from INNS; these species can create problems by threatening native populations of fish and other wildlife. Two species present in the River Derwent catchment are signal crayfish (*Pacifastacus leniusculus* (Dana.)) and American mink (*Neovison vison* (Schreber.)), they are particularly problematic due to their well-established populations and colonisation potential. Measures to control and eradicate these threats have been explored. Additionally, there are several species of flora increasingly imposing on native riparian species, particularly Himalayan balsam (*Impatiens glandulifera* Royle.) and floating pennywort (*Hydrocotyle ranunculoides* L. f.).

There are many challenges and conflicts of uses that have to be deduced by stakeholders and system managers to pursue improvements to the River Derwent. Furthermore, the best way of enhancing the ecological and chemical status of the River Derwent catchment needs to be established through a catchment-wide management plan that should entail a coalescing of attitudes towards connectivity, flow dynamics, sedimentation and preservation of existing habitats; this is called the Catchment-based Approach.

4 River Derwent catchment fisheries

4.1 Introduction

The Humber's tributaries and other eastern rivers, such as the Derwent, are known to contain a higher abundance and diversity of fish fauna than any other rivers in the British Isles (Wheeler, 1977). There are many different game and coarse fishing species found throughout the reaches of the River Derwent. Fishing is strictly controlled and under the ownership of several angling clubs located in the catchment which preserve different sections of the watercourse. The EA also has predominant control of any riverine species as well as the licenses needed to be able to fish in inland waters. These highly abundant stocks are crucial for Yorkshire and this catchment, and the fish assemblages rely on the rivers for purposes of migration, among other things.

Fly-fishing for brown trout and grayling (*Thymallus thymallus* (L.)) commences towards the upper and middle reaches between East and West Ayton, whereas, downstream from Malton, the lower reaches generally attract coarse anglers (EA, 2006a) for rheophilic cyprinids including chub (*Leuciscus cephalus* (L.)) and dace (*Leuciscus leuciscus* (L.)). Towards the mouth of the Derwent, the deeper, slower and lower reaches provide habitat for limnophilic cyprinids species, such as roach (*Rutilus rutilus* (L.)) and pike (*Esox lucius* L.). European eel (*Anguilla anguilla* (L.)) is widely dispersed within the catchment.

The objective of this chapter is to analyse data with respect to fish assemblages in the River Derwent catchment. The acquired data from the Environment Agency was analysed to understand the No. fish/100m^2 regarding overall species abundance, distribution of major fish, fish community composition and the longitudinal variation in population abundance. Diversity and evenness were analysed. These analysing methods help to understand the health and current status of the Derwent fishery. Along with the aforementioned issues threatening the River Derwent catchment, the deduced results will help to understand how much impact these stated issues are having on the fish assemblages. From the information obtained through this analysis, appropriate rehabilitation and future management methods will be highlighted in a management plan for the River Derwent. Further analysis was undertaken on angler catch data, specifically the percentage of anglers that caught fish and catch per unit effort or overall catch rate (g/man-hr) and this analysis provides another element to the overall data set, potentially adding clarification of fisheries survey data.

Further investigation and cross referencing from 2.3 and 2.4 were carried out on environmental characteristics and physico-chemical elements (water quality, hydrology and temperature) to understand potential relationships and influences that they may have on existing fish populations.

4.2 Methodology

4.2.1 Site Location, sampling strategy and data collection

Data were obtained from two sources.

1) The Environment Agency carried out monitoring surveys at 22 sites between Langdale End Bridge (Site 1) and Barmby Barrage (Site 22) (1995, 1997, 2000 – 2012) (Table 4.1; Figure 4.1). Surveys were carried out in daylight hours using electric fishing and micromesh seine net.

2) Angler catch data were collected from angling clubs hosting matches on the River Derwent and River Rye. It must be noted that there could be potential misidentifications of specimens which could influence the outputs. Six different survey reaches were analysed with a varying number of matches in each year in each reach (1994 – 2012) (Figure 4.1; Table 4.2).

Table 4.1 Sample Sites located along the River Derwent from the upper reaches (1) to the lower reaches. U/S = Upstream. D/S = Downstream.

Location of sample site	National grid ref.	AV length (m)	AV width (m)	Survey method	Year/s of data available
Langdale End Bridge	SE 94226	50	6	Single run	2006, 2012
U/S Wrench Green Bridge	SE 96800 89200	45	9	Single run electro	2002, 2006
D/S Wrench Green Bridge	SE 96800 89200	50.5	9	Single run electro	2002, 2012
D/S Weir Head	SE 97300 88300	48	8	Single run electro	2001 - 2011
Old Man's Mouth	SE 98200 87800	39	6	Single run electro	2002
D/S Forge Valley Gauging Weir	SE 99800 85700	62	6	Single run electro	2001 – 2003, 2005 - 2012
D/S West Ayton	SE 99200 84300	50	6	Single run electro	2000 - 2003
Darrells Low Farm	SE 99353 82299	50	4	Single run electro	2006, 2012
Yedingham Fry Survey	SE 86300 79100	20	1.8	Seine netting	2009, 2010, 2012
Yedingham	SE 86300 79100	700	6	Single run electro	2001 – 2007, 2009, 2010, 12
Malton	SE 79200 71500	743	18	Single run electro	2001-2007, 2009, 2010, 2012
Low Hutton	SE 76500 67700	1000	26	Single run electro	1995, 1997, 2000 - 2005
Kirkham Abbey	SE 73400 65700	260	30	Single run electro	2001 – 07, 2009, 2010, 2012
Howsham	SE 73000 62800	531.5	20	Single run electro	2001 – 07, 2010, 2012
Buttercrambe	SE 73200 58700	483	15.66	Single run electro	2001 – 07, 09, 10, 12
Stamford Bridge	SE 71400 55700	662.5	18	Single run electro	1995, 1997, 2000 – 07, 09, 10, 12
Kexby	SE 70486 51178	200	30	Single run electro	2006
Sutton-upon-Derwent	SE 70500 47400	350	20	Single run electro	1997, 2000 – 07, 2009, 10,12
Wheldrake Ings	SE 69300 44900	600	18	Single run electro	2001 - 08
Bubwith Fry Survey	SE 70795 36275	20	1.8	Seine netting	2009, 2010, 2012
Breighton	SE 70500 35000	500	15	Single run electro	1995, 1997, 2000 - 03
Barmby on the Marsh	SE 68100 28600	450	20	Single run electro	1997, 2000 – 03

Table 4.2 Reach codes and locations from the angler catch data

Reach code	Location of reach	National grid reference
D1	Yedingham to Scagglethrope	SE891796 -> SE83378
D2	Malton to Kirkham	SE789714 -> SE737655
D3	Howsham to Kexby	SE733631 -> SE706509
D4	Elvington to Barmby	SE707472 -> SE680286
R1	Butterwick to Newsham Bridge	SE730775 -> SE808760
R2	Howe Bridge to Pickering (Costa Beck)	SE835803 -> SE797763

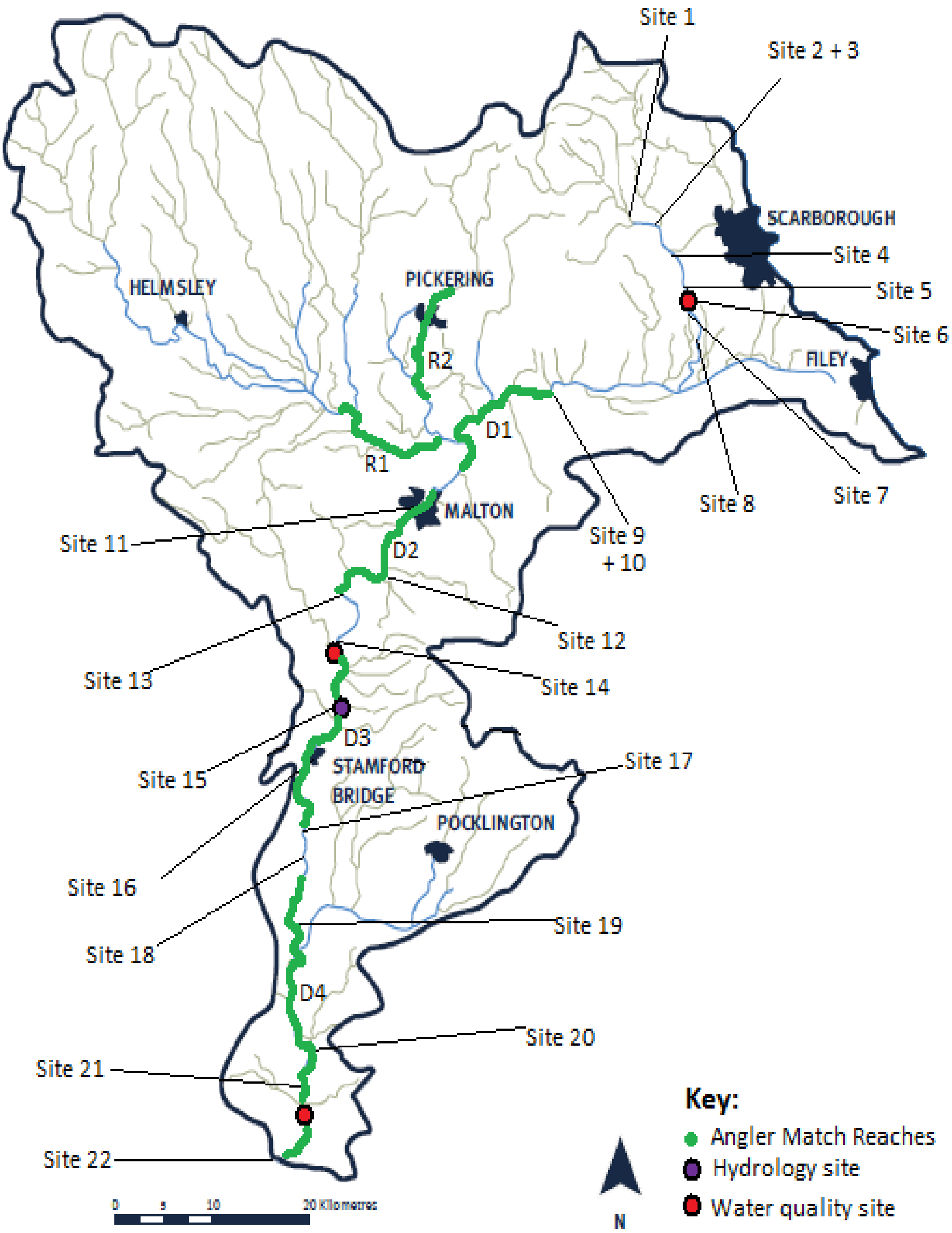


Figure 4.1 Location of 22 sample sites and six angler match reaches surveyed on the River Derwent, Yorkshire; with indication of hydrological and water quality sampling points. (Adapted EA, 2006b). (See Table 4.1 for site numbers and Table 4.2 for angler catch reach codes)

4.2.2 Data analysis

The Environment Agency survey data were analysed to account for:

Overall species abundance (No. fish/100m^2)

Categorical value analyses on specific species

Distribution of major fish with regards to relative abundance

Fish community composition

Longitudinal variation in population abundance

Diversity (*H'*) and evenness (*J*) between sites

Fish community abundance

Fry survey analysis

Angler catch data were examined for:

Percentage of anglers that caught fish

Catch per unit effort (CPUE) or overall catch rate (g/man-hr)

Fishery data collected during routine Environment Agency electric fishing surveys between 1995 and 2012 were examined to determine frequency of occurrence and relative abundance of species at different sample sites (Table 4.1; Figure 4.1; Table 4.2). It should be noted different sites were surveyed in different years so there is no consistency in the data. Frequency of occurrence of a specific species is defined as the number of sites at which the species was caught, whereas, relative abundance of a species is defined as the percentage (%) of total catches (numbers) in all surveys by that given species (Hynes, 1950; Nunn *et al.,* 2010). Frequency of occurrence (%*Fi*) and relative abundance (%*Ai*) are expressed as: $\%Fi = NI/N \times 100$ and $\% Ai = \Sigma Si / \Sigma St \times 100$, where *NI* is the number of sites containing species, *N* is the total number of sites that contain fish of any species, *Si* is the sample (number) composed by species, and *St* is the total content of all surveys in the entire sampling period (Nunn *et al.,* 2010).

Species abundance was calculated for each stretch of water (various survey lengths were used) (Figure 4.1). The number of fish was divided by the area m^2 (length x width) of the survey and multiplied by 100, standardising all figures, which subsequently provided the abundance of fish/100m^2.

Categorical values were given to species in high abundance for ease of counting and saving time in the field. The values have been given specific alphabetical scale values to indicate averages from each site where this method was used. Categorical values were given to species that were in high abundance or more iconic species. The species that had categorical values were taken out of the overall analysis. This method provides a rough estimate of how many of that specific species would potentially be in the sample. The term 'coarse species' was given to unidentifiable specimens, most likely due to the size of the fish. It should be taken into consideration that the overall accuracy of the majority of the data set will not truly represent the species abundance of all the sample sites, although trends can be deduced from this analysis. Categorical values were not given to fry surveys; independent examination was carried out.

The comparative method, Bray-Curtis similarity matrix (Bray & Curtis, 1957) was calculated and presented as a dendrogram using hierarchical agglomerative clustering (group average) to investigate similarities in: species density between sites for electric fishing or species abundance between reaches for angler catch. Non-metric multi-dimensional scaling ordination plot (MDS) (a similarity profile test) (SIMPROF) was used to determine whether clusters of sites or reaches were significantly similar to each another (Clarke & Warwick, 2001; Nunn *et al*., 2010). Bray-Curtis similarity index (C*z*) represents the overall similarity between each sample site or reach which takes the density or abundance of all species into account. It is expressed as $Cz = 2W / (a + b)$, where *W* is the sum of the lower percent abundance value of species per 100 m^2 to the catches at two sites (together with tied values), and *a* and *b* are the sums of the percent abundance of species in the catches at site *a* and *b,* respectively. Bray-Curtis similarity is between 0 – 1, where 1 means the two sites have identical composition (identical samples) and 0 means the two sites do not have any of the same species (Nunn *et al*., 2010).

The Shannon-Wiener (*H'*) ($\log_e$) diversity index was used, collectively with Pielou's measure of evenness (*J*), to investigate spatial variations in the diversity and evenness of fish species composition between sample sites and years (1999, 1997, 2000 – 2012). They are expressed as $H' = \Sigma P_i \ln P_i$ and $J = H' / H'_{max}$, where *Pi* is the proportion of the observations found in category *i* and $H'_{max} = \ln(k)$, the utmost possible diversity for a set of data of *k* categories (Washington, 1984; Nunn *et al.,* 2010).

Catches of coarse fish were monitored through the distribution of catch return cards to angling clubs that held organised competitions during the fishing seasons of 1974 to 2012. These returned cards were arranged according to river reach and season. Analyses were undertaken on angler catch data from six reaches (Table 4.2) to determine two measures of angling success, (i) the percentage of anglers fishing that caught fish and (ii) the catch per unit effort (CPUE) or the overall catch rate, expressed as g/man-hr, achieved during the competition or by an individual angler (Cowx & Broughton, 1986). The percentage abundance was determined by weighing species on a point scale dependant on their recorded dominance in the catches. Therefore, when a species was logged in the catch as occurring the most, it was given 4 points, with the next common 2 points and as other caught species, 1 point. The percentage abundance was derived by expressing the total points awarded for each species in each reach as a percentage of the total points gained by all species (Cowx & Broughton, 1986; North, 1980).

4.3 Results

4.3.1 Overall species abundance

A total of 12,385 specimens of 17 fish species were captured throughout the surveyed years. Categorical values are not included in this, overall 24 fish species were surveyed some of which were given a categorical value. The study was typically dominated by rheophilic and eurytopic fish species. Roach were the most abundant species accounting for 27% of the total catch, followed by gudgeon (*Gobio gobio* (L.)) (19%), dace (13%), pike (10%) brown/sea trout (trout) (7%) and chub (5%). Other species captured in small numbers were grayling, perch (*Perca fluviatilis* (L.)), bleak (*Alburnus alburnus* (L.)), barbel, bream (*Abramis brama* (L.)), flounder (*Platichthys flesus* (L.)), ruffe, salmon, rudd (*Scardinius erythrophthalmus* (L.)) and tench (*Tinca tinca* (L.)). Trout were the most widespread species occurring in 72% of sample sites, with roach occurring in 63% and dace appearing in 59%. Furthermore, chub, grayling, gudgeon and pike occur in 54% of sample sites throughout the surveyed years. With regards to categorical values (Table 4.3) bullhead were the most widespread species occurring in all sample sites (100%), followed by eel, minnow (*Phoxinus phoxinus* (L.)) (77%) and stone loach (*Barbatula barbatula* (L.)) (72%).

Table 4.3 A Categorical Value was given to specific species with intermediate values for fluctuating population for ease of counting and saving time in the field. Site numbers are as in Table 4.1. (/ = No data were recorded).

	Sample Site																		
Species	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	18	19	21	22
3-Spined stickleback	/	/	/	/	/	A	/	/	A	A	A	A	A	/	/	A	A	A	A
Bullhead	B	C	C	A	D	D	D	A	B	D	B	D	A	B	C	A	A	A	B
Coarse Species'	/	/	/	/	/	/	/	/	C	E	B	C	C	B	D	E	D	G	H
Common goby	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	A
European eel inc. Elvers	/	A	A	/	A	A	A	A	A	A	B	B	A	B	C	C	B	D	D
Flounder	/	/	/	/	/	/	/	/	/	/	/	/	/	/	C	B	A	A	E
Lamprey sp. inc. ammocoetes	/	A	A	A	A	A	/	/	/	A	A	A	/	A	B	A	/	/	A
Minnow	C	A	A	/	B	A	B	C	B	D	D	F	D	D	F	E	E	B	/
Stone loach	A	A	A	/	A	A	B	/	/	B	A	B	B	A	C	C	A	A	A

Categorical Values	Scale
1 - 9 =	A
1 - 99 =	B
10 - 99 =	C
10 - 999 =	D
100 - 999 =	E
100 - 9999 =	F
1000 - 9999 =	G
1000 - 10000 =	H
10000 + =	I

4.3.2 Distribution of major fish species with regard to relative abundance

Three distinct fish zones were evident in the River Derwent:

(i) Brown trout had a large proportional distribution, being dispersed from the North York Moors to the foot hills (Site 1 to 8); this would be classified as the 'trout zone'. Closely associated to this is the 'grayling zone', numbers are a lot smaller in the upper catchment (Figure 4.2).

(ii) The 'grayling zone' is more emphasised by dace and chub between Vale of Pickering to after the convergence with the River Rye but before reaching the Derwent Ings (Site 9 to 16) (Figure 4.2)..

(iii) The 'barbel zone' is characterised by roach and pike around the Derwent Ings and the Pocklington Canal down to the confluence at Barmby Barrage (Site 17 to 22) (Figure 4.2).

There is an absence of a 'bream zone', minute numbers were caught but not a significant number to reiterate a zonation. The probable cause for this is likely to be the barrage at the mouth of the Derwent and no large scale floodplain areas enabling the development of slow flowing fish community types.

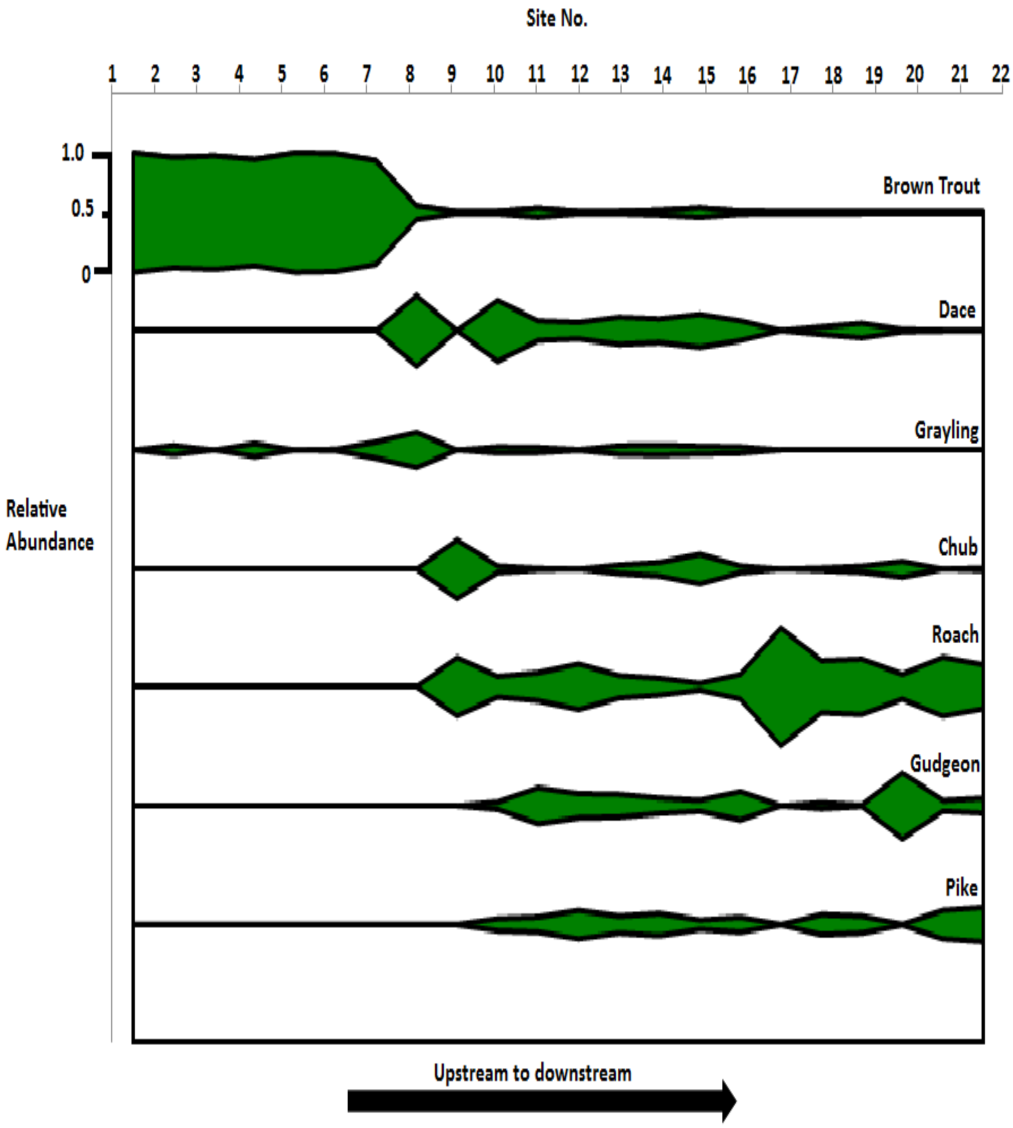


Figure 4.2 Distribution of major fish species within the River Derwent (Table 4.1 for site numbers)

4.3.3 Fish community composition

There were two main groupings between the clusters, one representing the upstream sites and the other between the downstream sites (Figure 4.3). The downstream grouping separated the sites into those dominated by trout and dace (~65% similarity, sites 8 and 10), gudgeon and dace (~70% similarity, sites 11, 12, 13, 14, 15 and 16) and gudgeon, perch and bleak (~50% similarity; sites 18, 19, 21 and 22)(Figure 4.3). The upstream grouping was dominated by trout and grayling (~85% similarity; sites 1, 2,3,4,6 and 7). Brown trout were the dominant species at sites 1, 2, 3, 4, 6 and 7 with a similarity of 60% within the group, while all other sites were 40% similar; with gudgeon and dace being the most abundant species. Four statistically significant groupings were identified (SIMPROF). Sites 1, 2, 3, 4, 6 and 7 have ~10% similarity to that of the other sites. Sites 8 and 10 have a ~45% similarity to sites 11, 12, 13, 14, 15 and 16, whereas, these previously stated sites have a ~40% similarity to sites 18, 19, 21 and 22 (Figure 4.4). Sites 5 and 17 are missing due to limited data sets, whereas, sites 9 and 20 are missing due to differing survey techniques (Table 4.1).

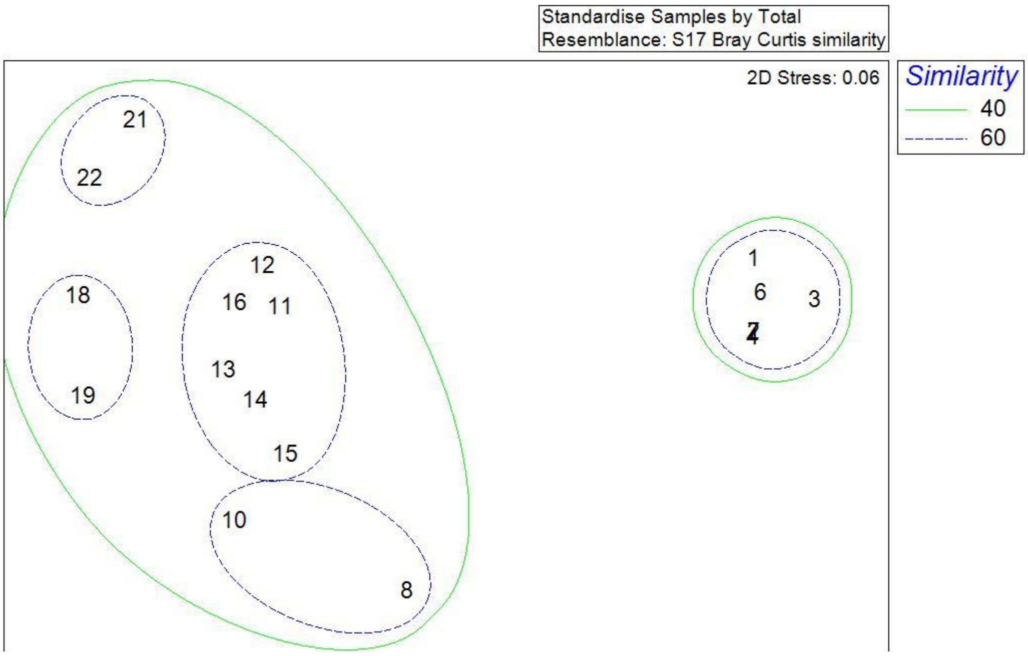


Figure 4.3 Non-metric multi-dimensional scaling ordination plot of the mean fish species density per 100 m^2 between 18 sites on the River Derwent (sites 5 and 17 are missing due to limited data sets, whereas, sites 9 and 20 are missing due to differing survey techniques). (Bray-Curtis similarity). (Site numbers as in Table 4.1.)

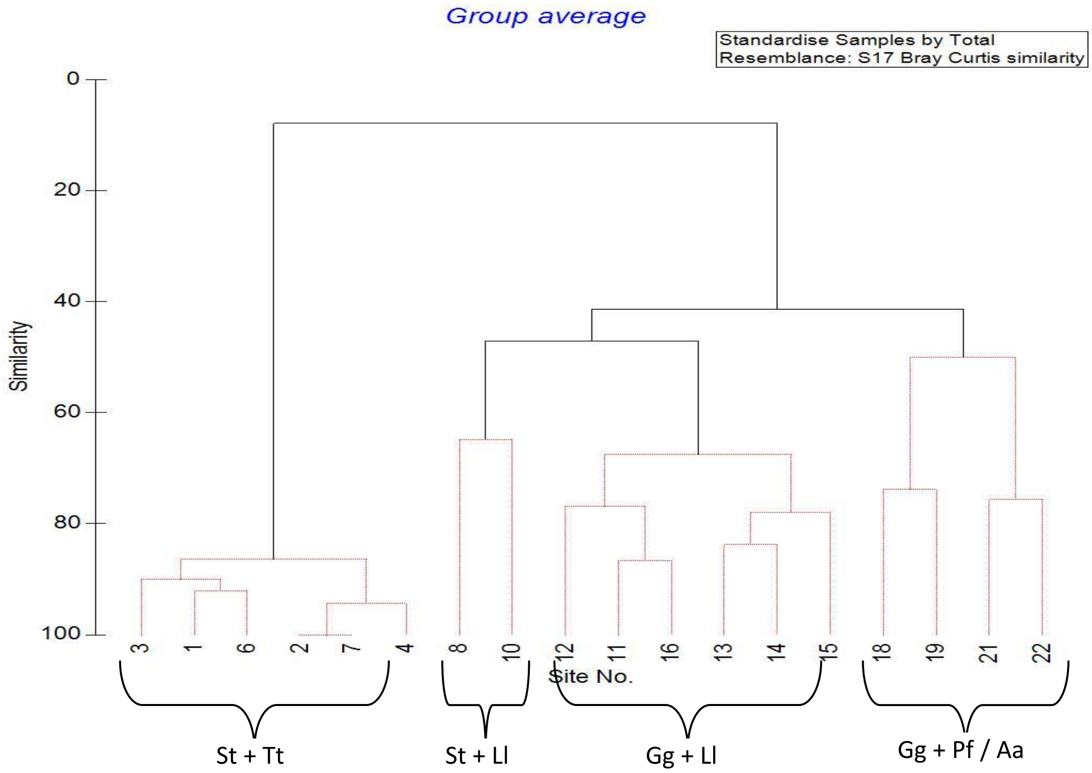


Figure 4.4 Similarity (%) in the mean fish species density in species per 100m^2 between 18 sites on the River Derwent (sites 5 and 17 are missing due to limited data sets, whereas, sites 9 and 20 are missing due to differing survey techniques). (Bray-Curtis similarity, hierarchical agglomerative clustering). Site numbers as in Table 4.1. Species name abbreviations: *St* = brown trout, *Tt* = grayling, *Pf* = perch, *Ll* = dace, *Gg* = gudgeon and *Aa* = bleak. The lighter lines link significantly similar sites (SIMPROF).

4.3.4 Longitudinal variation in population abundance

Based on the zonation pattern found (Figure 4.2), sample sites were categorised into their 'known' river zones: upper trout, middle grayling and lower barbel zones. This helps further explore zonation patterns. Site 5: Old Man's Mouth, Site 8: Darrel Low Farm and Site 17: Kexby were not analysed due to restricted data. Site 9: Yedingham and Site 20: Bubwith fry surveys were analysed separately because of the different sampling methodology and consequent community composition.

Upper catchment (sites 1 – 7)

Mean densities of fishes in the upper catchment ‘trout zone’ ranged from 5.76 to 8.93 fish/100 m^2 with a steady increase in mean densities towards downstream sites. The highest mean densities were recorded from the downstream end of the upper catchment. Site 7: Downstream West Ayton (8.93 fish/100 m^2) (2000 to 2003) followed by Site 6: Downstream Forge Valley GW (8.85 fish/100 m^2) (2001, 2002, 2003, 2005 to 2012) with slightly lower mean densities from Site 2: Upstream Wrench Green (7.51 fish/100 m^2) (2002 and 2006) (Figure 4.5). Old Man’s Mouth was not included due to it only being surveyed in 2002.

Middle catchment (sites 10 – 15)

Mean densities of fishes in the middle catchment ranged from 0.23 to 1.74 fish/100 m^2, but with considerable differences between sites. There is a decreasing trend towards more recent years (Figure 4.6). The highest mean density was recorded from Site 10: Yedingham (1.74 fish/100 m^2) (2001 to 2010 and 2012) followed by Site 13: Kirkham Abbey (1.57 fish/100 m^2) (2001 to 2010 and 2012). The lowest density was at Site 12: Low Hutton (0.23 fish/100 m^2) (1995, 1997, and 2000 to 2005). Site 8: Darrell’s Low Farm was not included due to limited data.

Lower catchment (sites 16, 18, 19, 21, 22)

The highest mean densities were found in the middle sites of the lower catchment (Site 16: Stamford Bridge and Site 18: Sutton-upon-Derwent). The mean densities in the lower catchment are of a sporadic nature. Mean densities of fishes in the lower catchment ranged from 0.53 fish/100 m^2 at Site 19: Wheldrake Ings to 1.97 fish/100 m^2 at Sutton-upon-Derwent (Figure 4.7). Consistently higher densities were found at Stamford Bridge (1.61 fish/100 m^2) and Site 21: Breighton (1.13 fish/100 m^2). Kexby was disregarded due to the capture of only one fish.

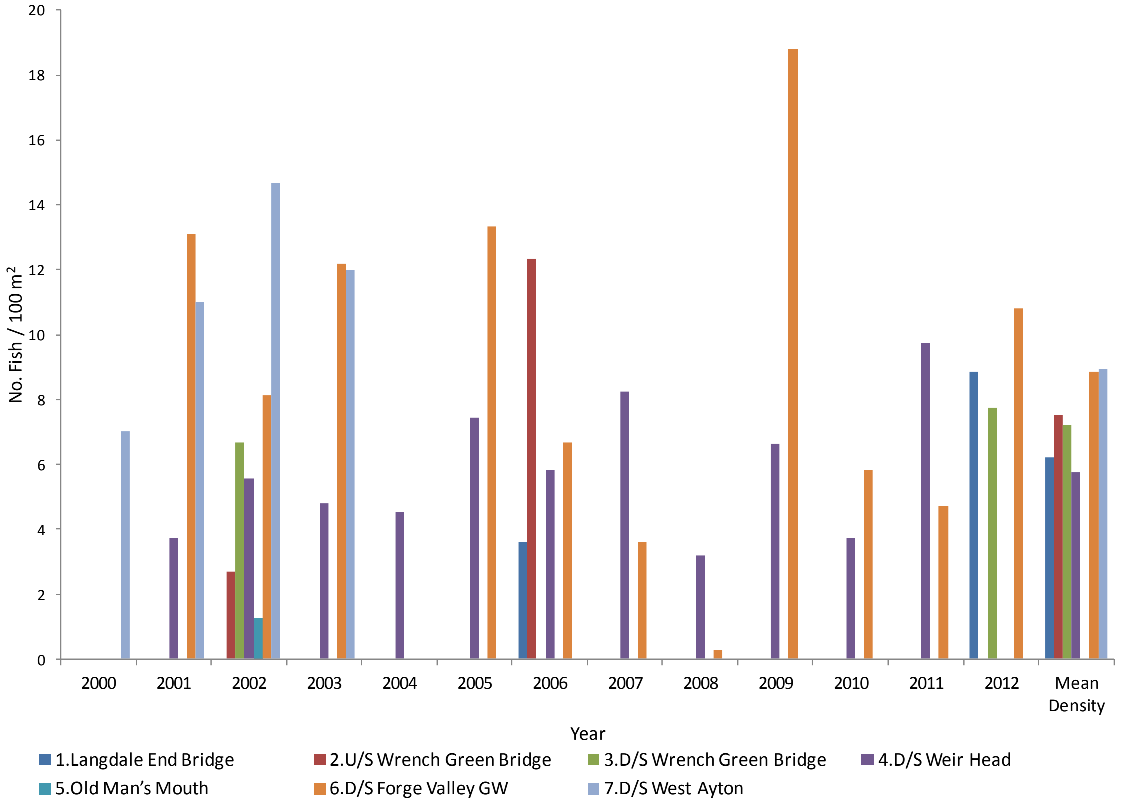


Figure 4.5 Population densities with average composition (No. Fish/100m^2) in the upper Derwent catchment

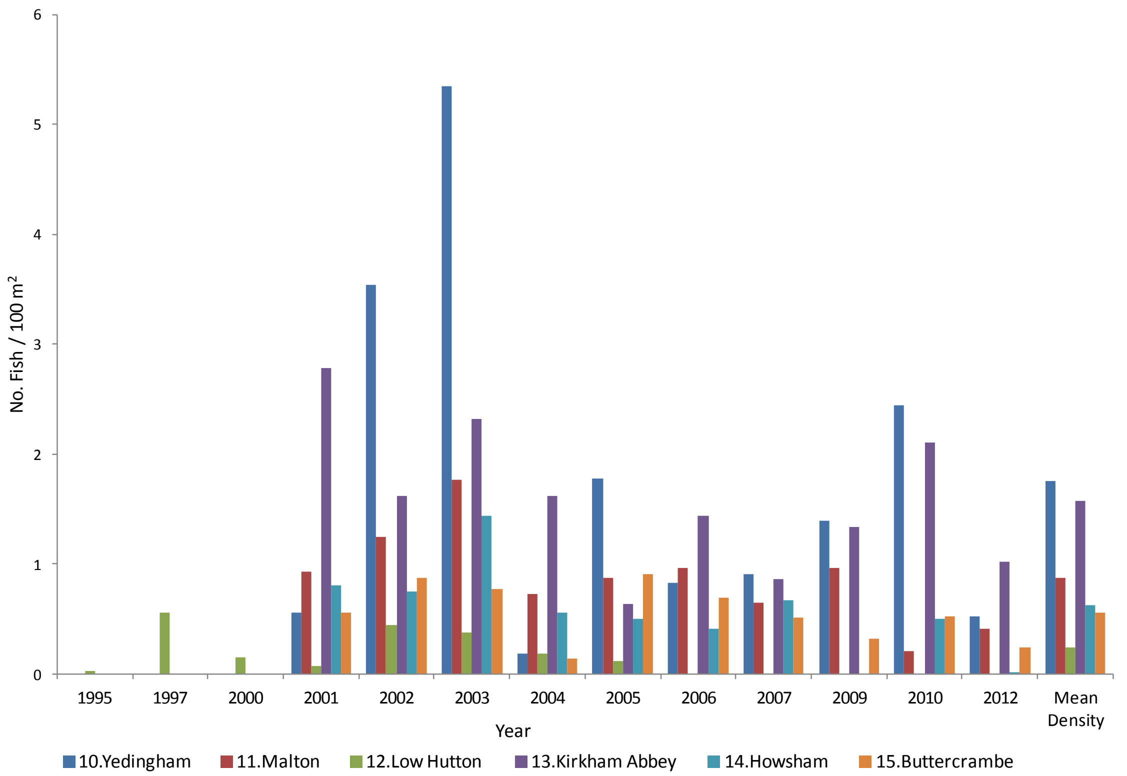


Figure 4.6 Population densities with average composition (No. Fish/100m^2) in the middle Derwent catchment

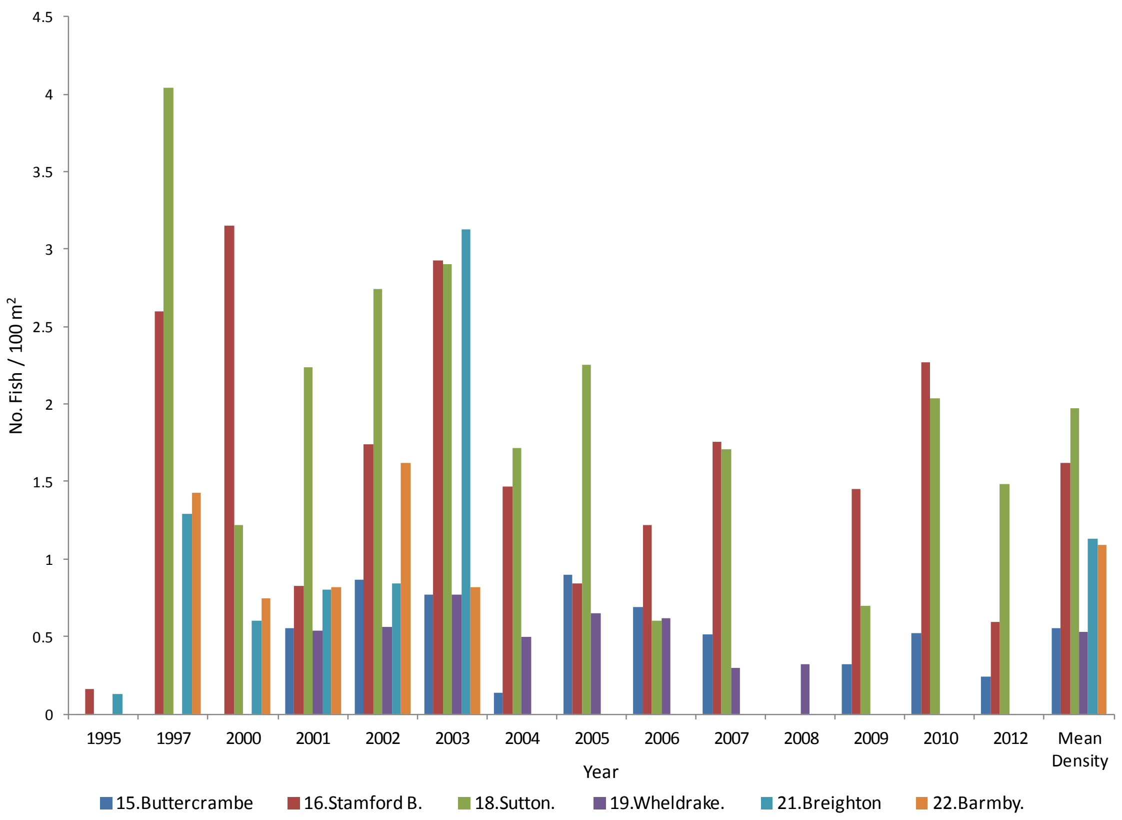


Figure 4.7 Population densities with average composition (No. Fish/100m^2) in the lower Derwent catchment

4.3.5 Diversity and evenness

Site 16: Stamford Bridge had the highest diversity (*H'* = 2.17) throughout all surveyed years followed by Site 19: Sutton-upon-Derwent (*H'* = 1.61). The lowest diversities were at Site 5: Old Man's Mouth, Site 8: Darrell's Low Farm and Site 17: Kexby (*H'* = 1). Evenness was highest at Stamford Bridge (*J* = 0.80) and lowest at Old Man's Mouth, Darrell's Low Farm, and Kexby (*J* = 0.37). There seems to be a slight trend between diversity and evenness amongst sample sites (sites 1 to 8 H' = ~1, sites 10 to 15, 17, 19, 21 and 22 H' = ~ 1.2, and anomalies from sites 16 and 18 (Figure 4.8)). Site 9: Yedingham and Site 20: Bubwith fry surveys were analysed separately because of the different sampling methodology and consequent community composition.

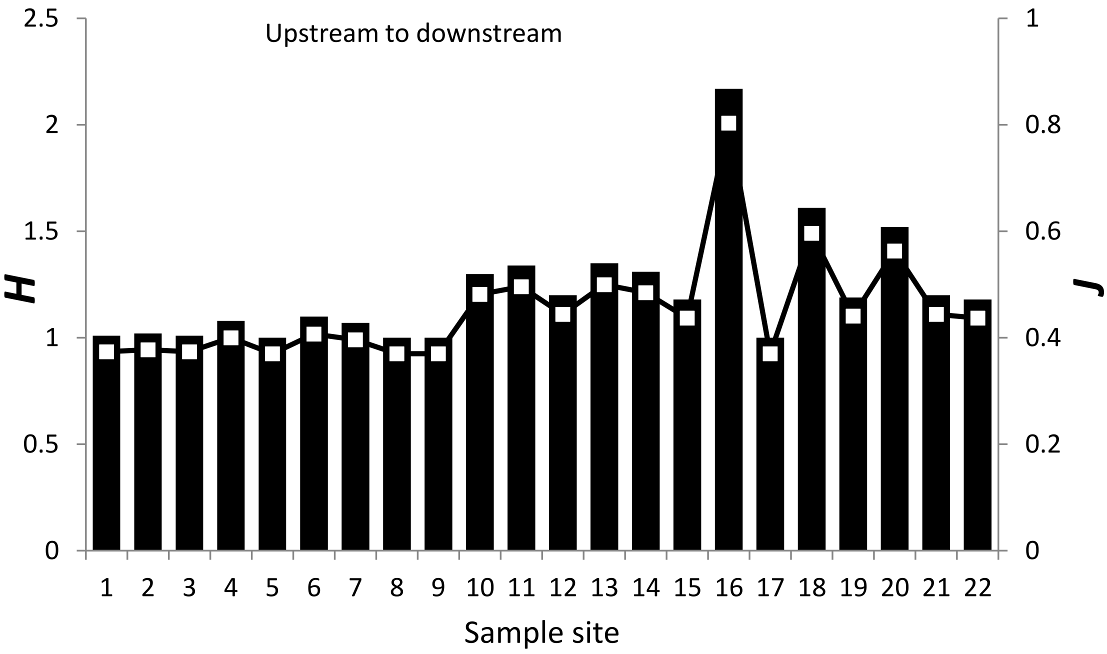


Figure 4.8 Diversity (H' = ■) and evenness (J = □) of fish catches at 22 sites on the River Derwent, for varying years 1995, 1997, 2000 to 2012. Sites 9 and 20 are missing due to differing survey techniques. Site numbers are as in Table 4.1

4.3.6 Fish community abundance

The fish communities in the upper reaches (Site 1: Langdale End Bridge, Site 2: Upstream Wrench Green Bridge, Site 3: Downstream Wrench Green Bridge, Site 4: Downstream Weir Head, Site 5: Old Man's Mouth, Site 6: Downstream Forge Valley Gauging Weir, Site 7: Downstream West Ayton) were dominated by brown trout but densities varied between years and sites (Figure 4.9; Figure 4.10). Abundances of brown trout varied but were >5 trout/100m^2 in some location (e.g. Langdale End Bridge in 2012, Upstream Wrench Green Bridge in 2006, Downstream Wrench Green Bridge in 2002, Downstream Weir Head in 2005, 2007, 2009 and 2011, Downstream Forge Valley Gauging Weir in 2001, 2005, 2009, 2010 and 2012 (Figure 4.9; Figure 4.10)). This suggests the importance of this reach for trout production. Rainbow trout were occasionally caught (Site 3: Downstream Wrench Green Bridge, Site 4: Downstream Weir Head), bullhead (categorical value 10 – 999) and minnow (categorical value 1 – 99) were found to be present in relatively higher abundance than stone loach, eel and lamprey (categorical value 1 – 9) through this upper section (Table 4.3). Few fish were caught at Site 5: Old Man's Mouth and small numbers of grayling were found in the lower sites (Site 6: Downstream Forge Valley Gauging Weir, Site 7: Downstream West Ayton) suggestion the transition to the grayling zone.

The middle reaches of the river (Site 8: Darrell's Low Farm, Site 10: Yedingham, Site 11: Malton; Site 12: Low Hutton, Site 13: Kirkham Abbey, Site 14: Howsham , Site 15: Buttercrambe) are characterised by a mixed coarse fish community dominated by dace, roach, gudgeon and pike (Figure 4.11; Figure 4.12; Figure 4.13; Figure 4.14; Figure 4.15; Figure 4.16). Abundance of individual fish species fluctuated between years and no one species was dominant throughout, although dace were more prevalent in upper sites (note predominance at Site 15 Buttercrambe) and roach and gudgeon dominated in the lower sites reflecting the transition downstream. Buttercrambe, and to a lesser extent Howsham, were somewhat atypical with a predominance of dace and chub, suggesting the river is faster flowing in this section supporting these rheophilic species. The abundance of fish appears to have declined in more recent years but this may be an artefact sampling effort.

The lower reaches (Site 16: Stamford Bridge, Site 17: Kexby; Site 18: Sutton upon Derwent; Site 19: Wheldrake Ings, Site 21: Breighton, Site 22: Barmby on the Marsh) are dominated by a mixed coarse fish community but the prevalence shifted towards lowland floodplain, eurytopic species such and roach and gudgeon and increased occurrence of pike and perch (Figure 4.17;Figure 4.18; Figure 4.19; Figure 4.20; Figure 4.21). As elsewhere, the abundance of fish varies between sites and years, but the numbers caught are relatively small possibly reflecting difficulties in sampling the lower river by electric fishing. There is also an incursion of flounder (Site 19: Wheldrake Ings, Site 21: Breighton) and common goby (Site 22: Barmby on the Marsh) into the river in the lower sites suggesting the proximity to the saline waters of the Ouse. Only one roach was caught at Kexby but no reason for the poor catch was found. 'Coarse species', eel, minnow, 3-spined stickleback, bullhead and stone loach were caught in varying densities throughout this section (Table 4.3).

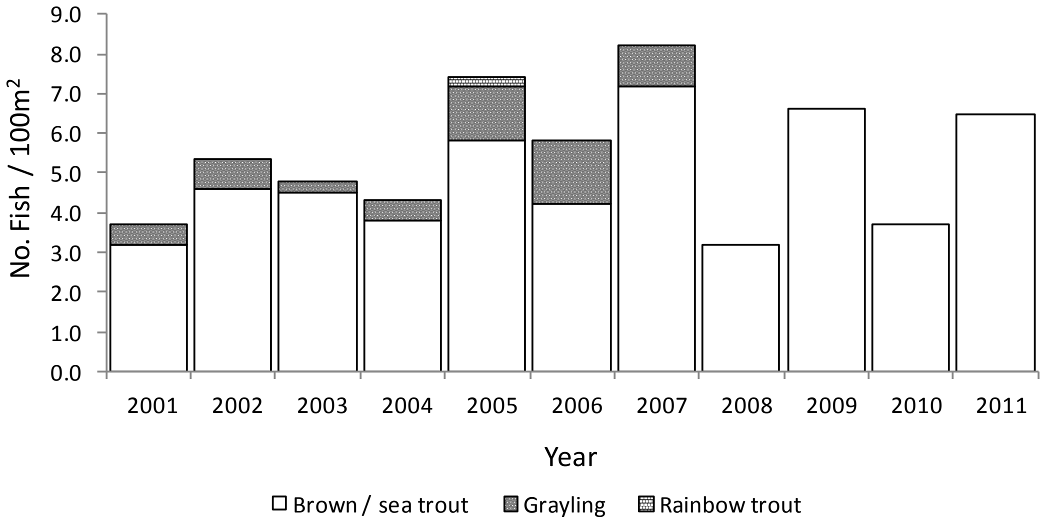


Figure 4.9 Species abundance (No. Fish/100m^2) at Site 4: Downstream Weir Head

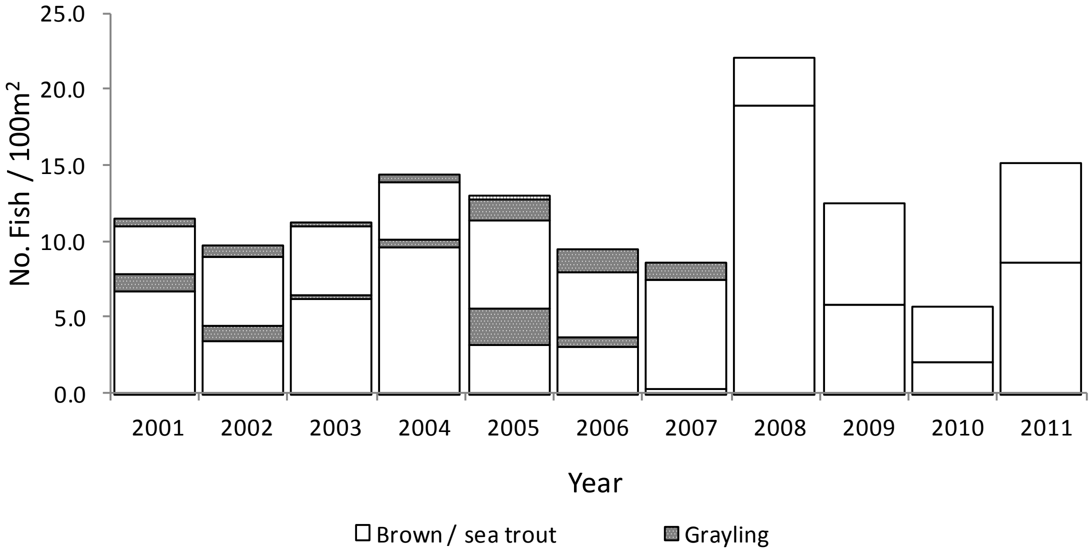


Figure 4.10 Species abundance (No. Fish/100m^2) at Site 6: Downstream Forge Valley Gauging Weir

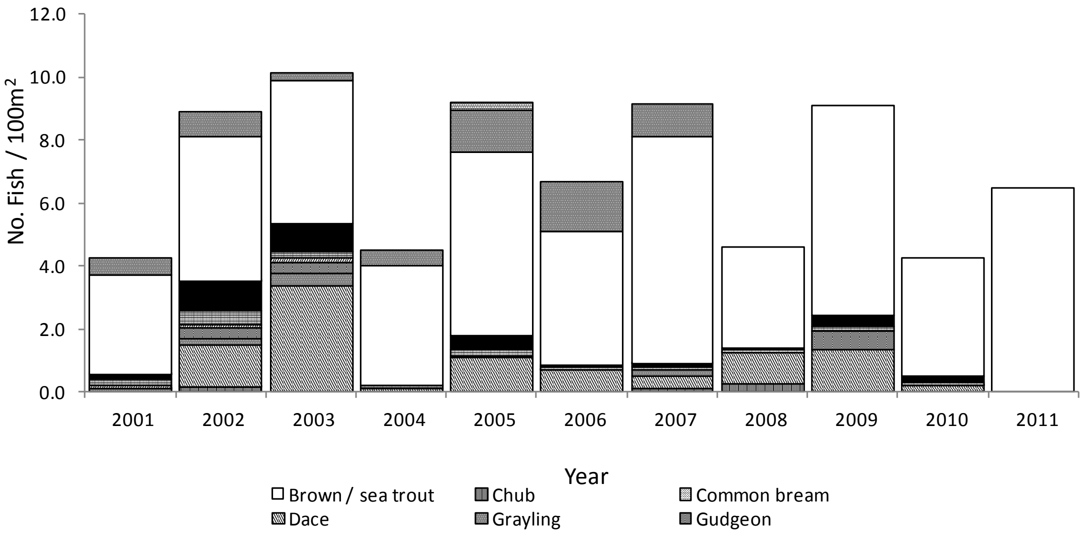


Figure 4.11 Species abundance (No. Fish/100m^2) at Site 10: Yedingham

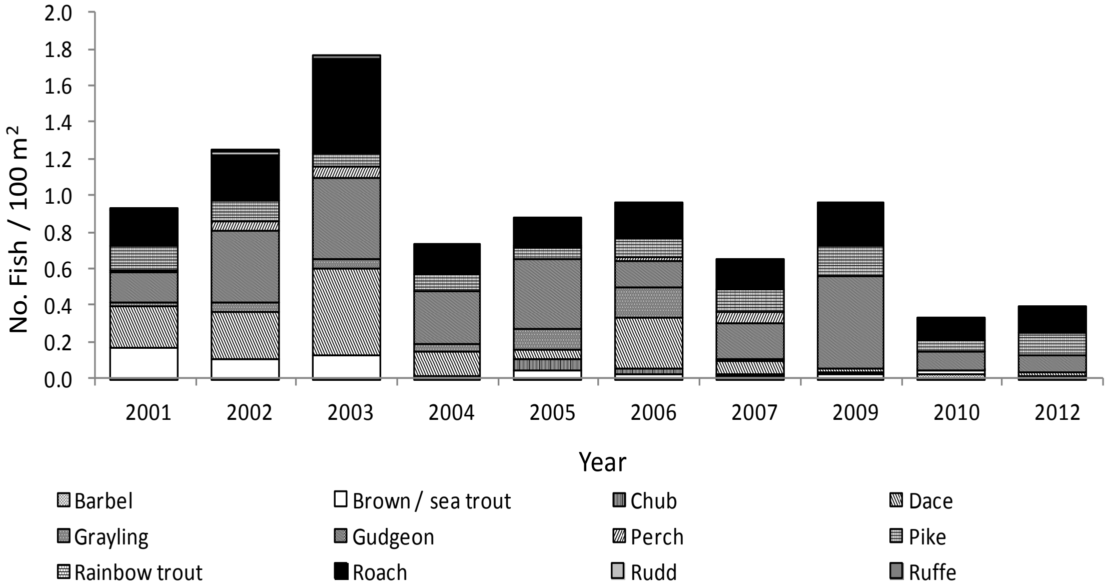


Figure 4.12 Species abundance (No. Fish/100m^2) at Site 11: Malton

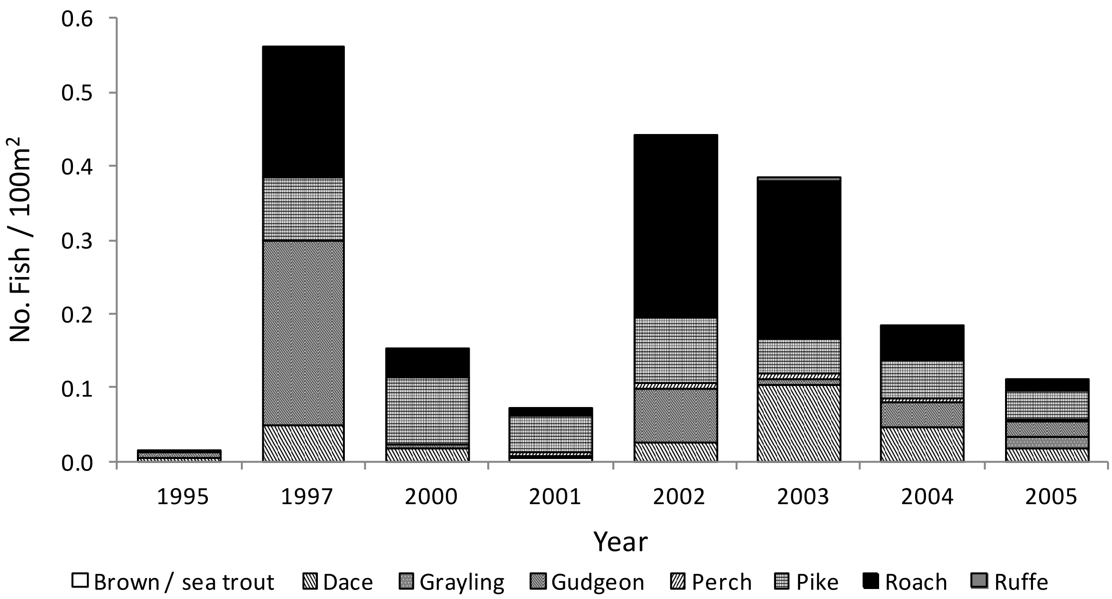


Figure 4.13. Species abundance (No. Fish/100m^2) at Site 12: Low Hutton

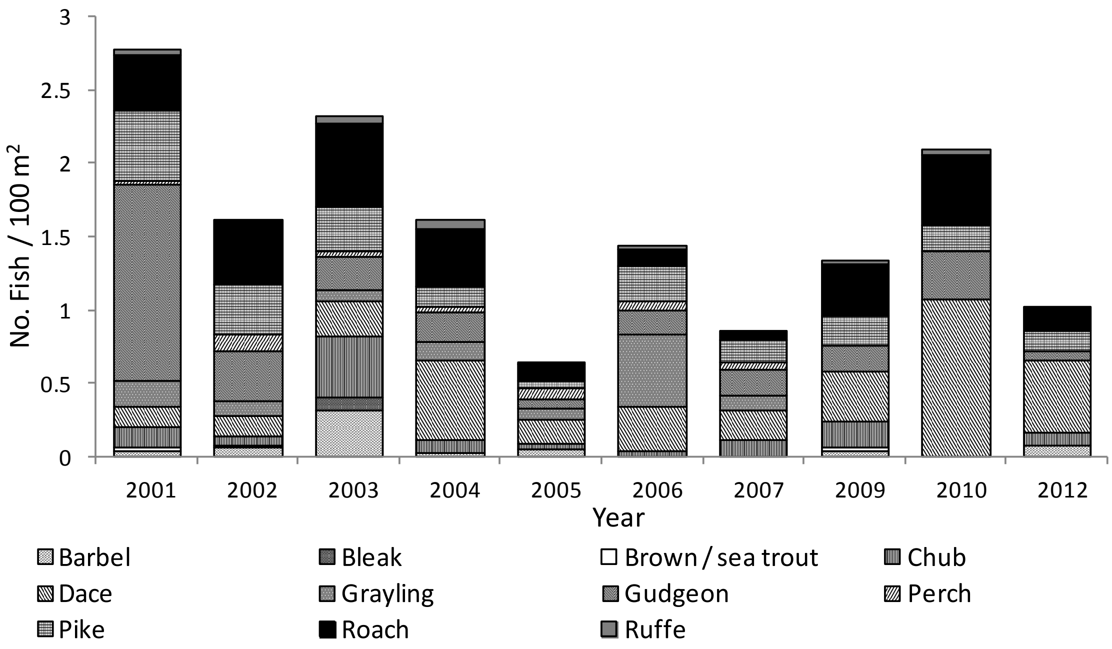


Figure 4.14 Species abundance (No. Fish/100m^2) at Site 13: Kirkham Abbey

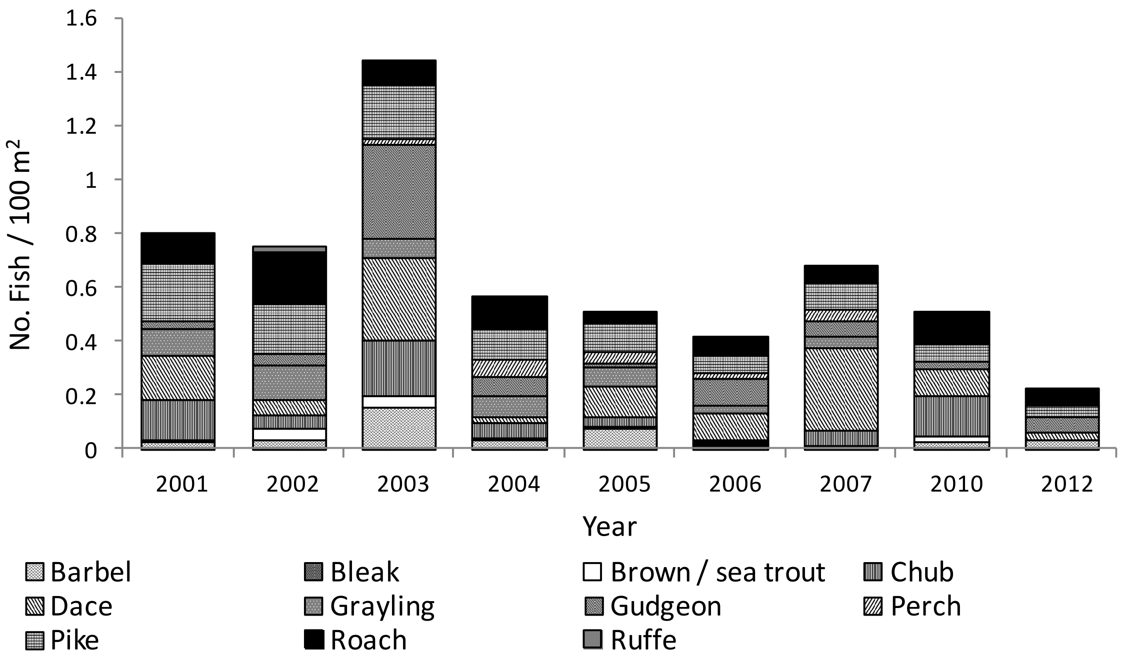


Figure 4.15 Species abundance (No. Fish/100m^2) at Site 14: Howsham

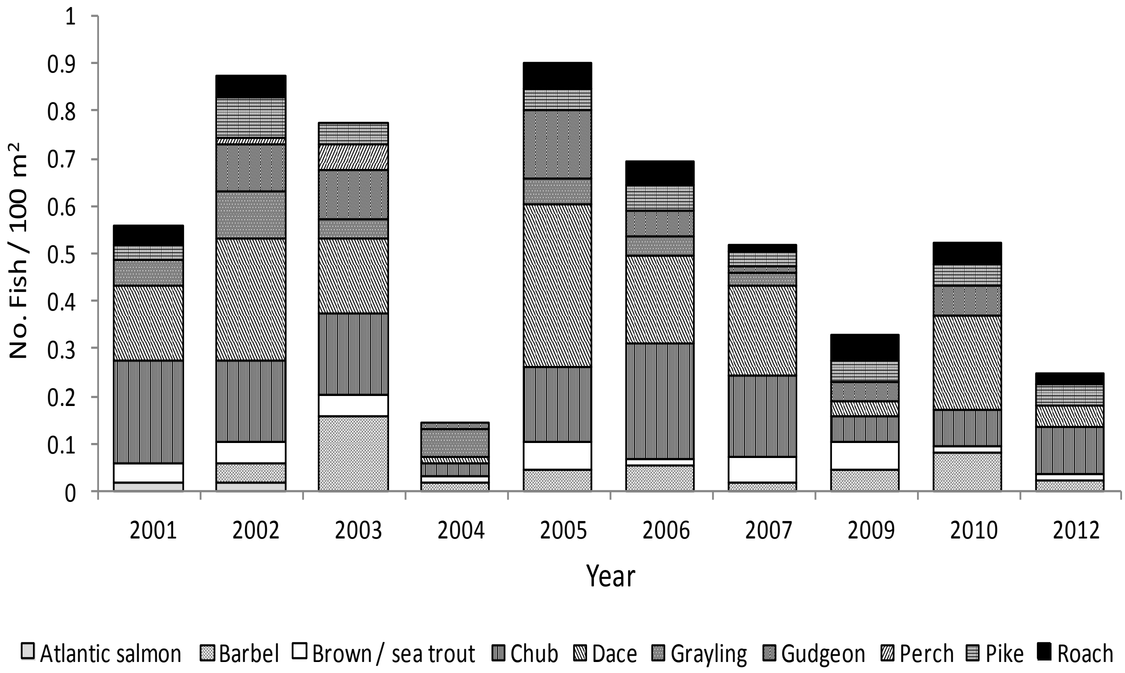


Figure 4.16 Species abundance (No. Fish/100m^2) at Site 15: Buttercrambe

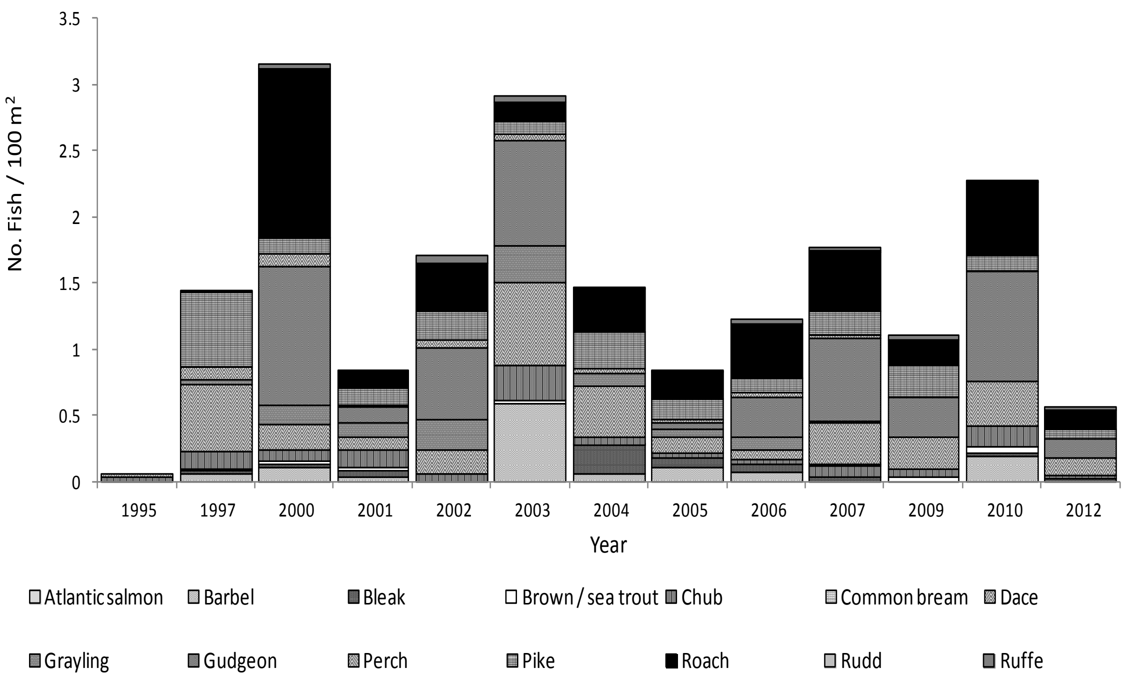


Figure 4.17 Species abundance (No. Fish/100m^2) at Site 16: Stamford Bridge

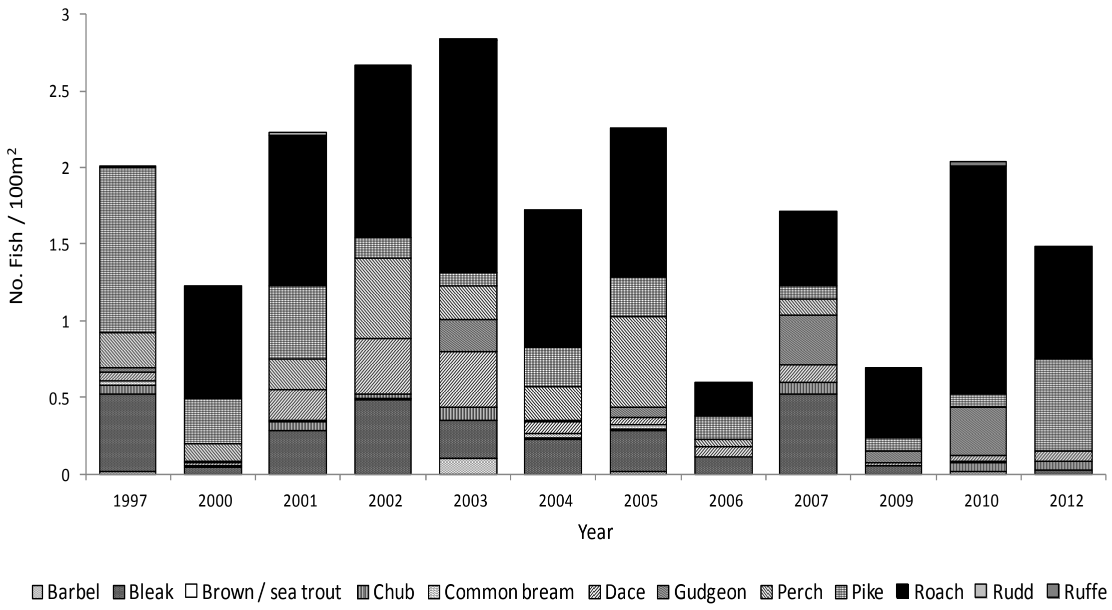


Figure 4.18 Species abundance (No. Fish/100m^2) at Site 18: Sutton upon Derwent

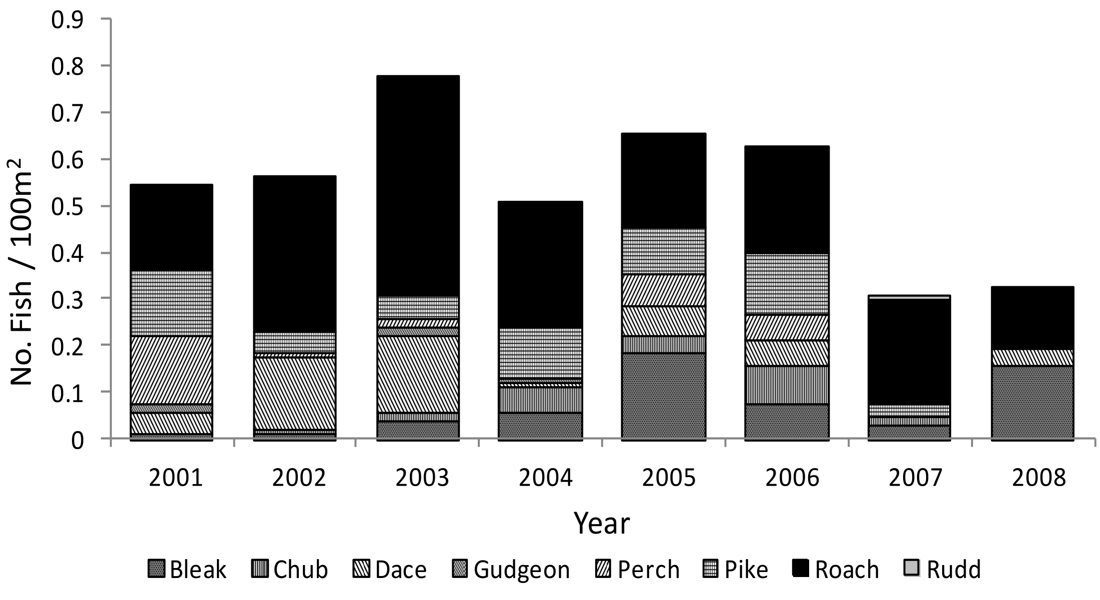


Figure 4.19 Species abundance (No. Fish/100m^2) at Site 19: Wheldrake Ings

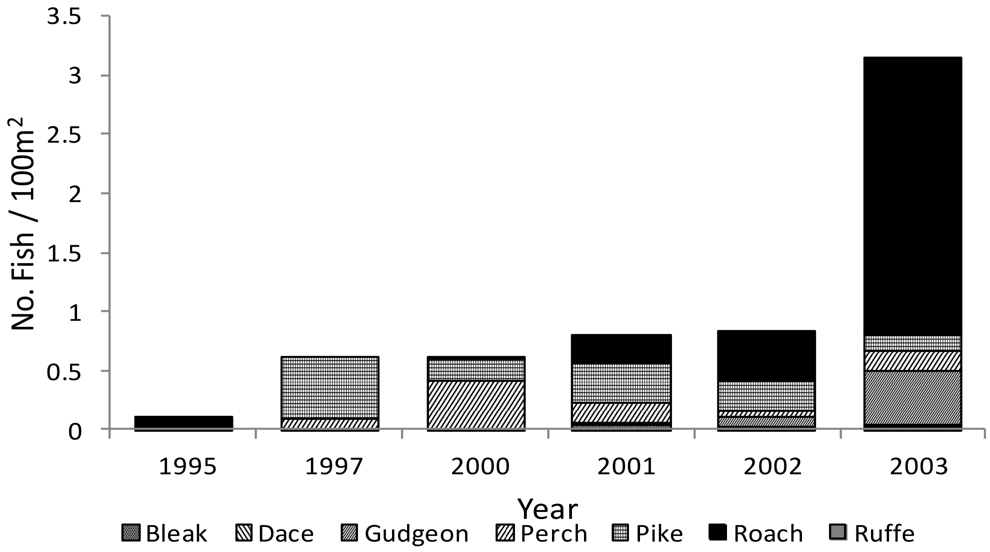


Figure 4.20 Species abundance (No. Fish/100m^2) at Site 21: Breighton

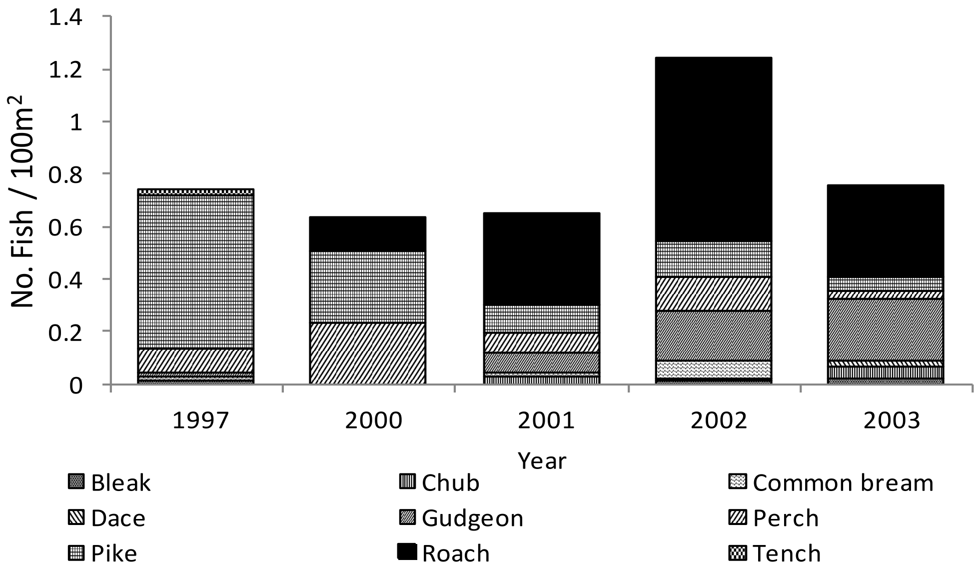


Figure 4.21 Species abundance (No. Fish/100m^2) at Site 22: Barmby on the Marsh

4.3.7 Fry surveys

Independent analysis was undertaken on Site 9: Yedingham (fry) and Site 20: Bubwith (fry) due to the different sampling method; microseine netting. Fry community compositions were deduced revealing that Bubwith recorded >100 0+ common bream in 2012 (Figure 4.22). In comparison, other sampling methods were not successful at catching common bream or they were recorded as 'coarse species' in the categorical value analysis. To understand longitudinal variations in population abundance between fry sites, mean densities were recorded with Bubwith having a considerably higher mean density (2910 fish/100 m^2) than Yedingham (18.35 fish/100 m^2); both sites were sampled in 2009 and 2010. There is a difference of 2891.65 fish/100 m^2 between sites suggesting recruitment is more successful towards the downstream end of the river. Catch from Yedingham fry survey were split between roach (50%) and chub (50%) throughout the years surveyed (2009, 2010, 2012). Chub were only caught in 2010 (16.67 fish/100m^2) while roach appear in every sampled year with the greatest abundance in 2010 (8.33 fish/100m^2). Gudgeon dominated fry samples at Bubwith accounting for 56% of the fishes captured. The largest abundance of gudgeon was in 2010 (1544.44 fish/100m^2). Small numbers of other coarse fish were recorded (bleak, bream, dace, pike and ruffe), this reiterates the transition towards the lowland floodplain and that there is successful recruitment for a range of species (Figure 4.22).

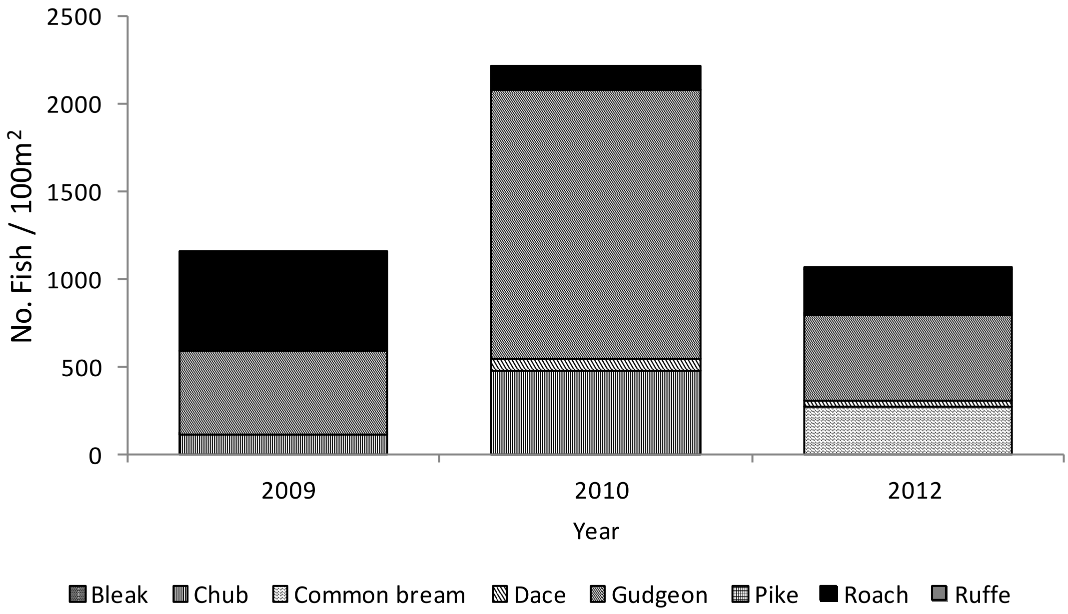


Figure 4.22 Species abundance (No. fish/100m^2) at Site 20: Bubwith (micro seine netting)

4.3.8 Angler Catches

Overall species abundance

A total of 17 fish species were captured throughout the survey period (1994 – 2012). Gudgeon were the most abundant species accounting for 23.8% of the total catch, followed by roach (23.4), perch (16.4%), dace (10%), chub (6.5%) and minnow (5.4%).

Other species captured in small numbers were trout, grayling, barbel, bleak, pike, bream, ruffe, eel, bullhead and carp (*Cyprinus carpio* (L.)).

Similarities in angler catch abundance

Two main groupings were prevalent in the catch data, one representing the River Rye reaches and the other a grouping between the middle to lower reaches of the Derwent (Figure 4.23). The MDS analysis separated the River Rye reaches because they were dominated by grayling and trout (~40 similarities). Reaches D3 and D4 are clustered together with a few outliers mainly dominated by gudgeon, roach and perch (~60 similarity). There is an anomaly from D4-2003 clustering with the River Rye; this is due to the sudden abundance of grayling. D4-2012 was an outlier because of the high abundance of ruffe and limited other species; it is possible that this could be a misidentification.

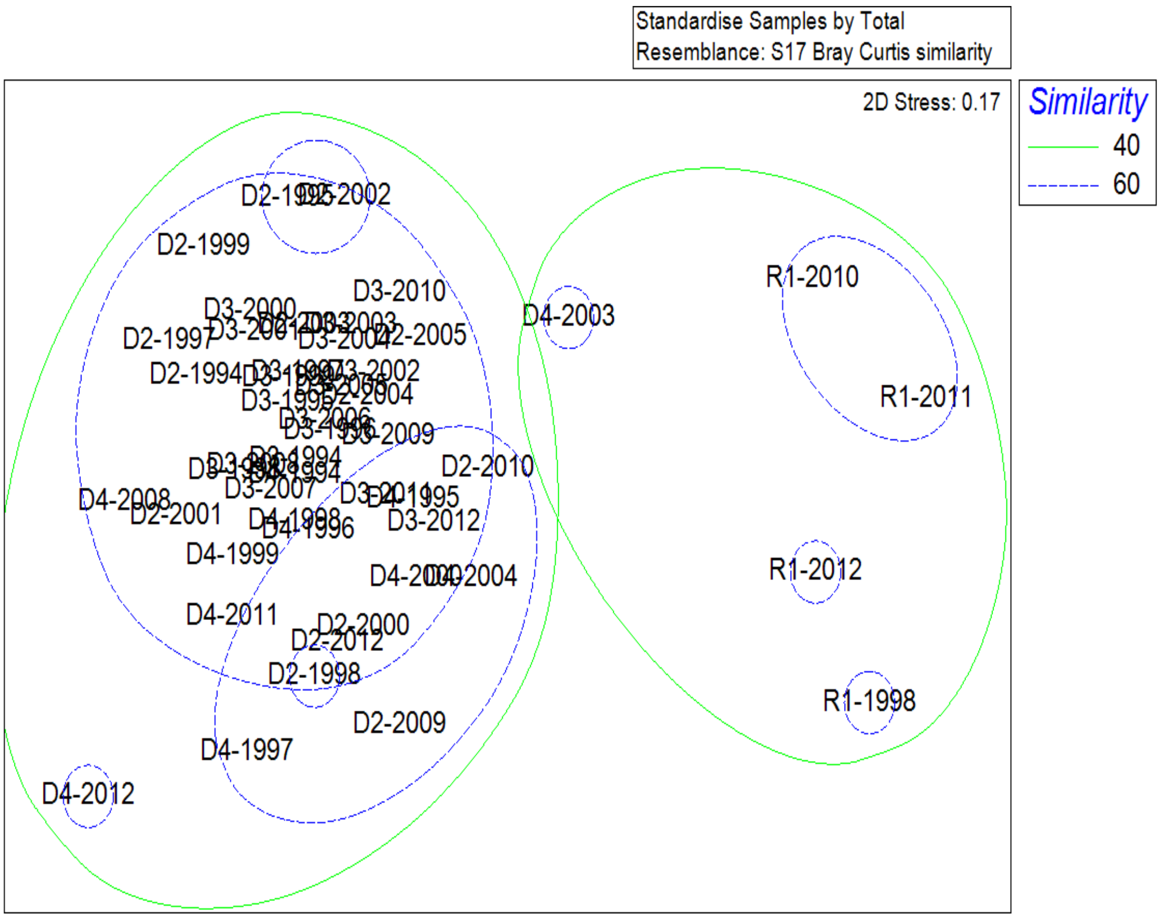


Figure 4.23 Non-metric multi-dimensional scaling ordination plot of the species abundance between five reaches on the River Derwent and River Rye (D1- 1995 and 1997, D4 2002 were removed to provide a true representation without any far spread anomalies). (Bray-Curtis similarity). Site numbers as in Table 4.2.

Species composition

R1 (Butterwick to Newsham Bridge) indicates it is located in the upper reaches due to it being characterised by a prevalence of trout, minnow and dace. This suggests that the river is faster flowing in this reach thus supporting these rheophilic species. Grayling and chub were also recorded potentially signifying the transition to the middle grayling zone.

The fish communities in D1 (Yedingham to Scagglethorpe) are characterised by perch and dace. This varied between the two surveyed years (1995 and 1997). A mixed coarse fish community was found at D2 (Malton to Kirkham) dominated by roach, gudgeon and dace. Abundance of individual fish species fluctuated between years and no one species was dominant throughout, although gudgeon were more prevalent in the earlier years with roach taking over in more recent years. The dominance of roach and gudgeon reflects that of the middle catchment (Figure 4.24).

The lower catchment is signified by D3 and D4. D3 (Howsham to Kexby) is characterised by mixed coarse fisheries but the dominance is shifted towards lowland floodplain, eurytopic species such as roach, gudgeon with an increased prevalence of perch (Figure 4.25). D4 (Elvington to Barmby Barrage) was also dominated by roach, gudgeon and perch but, as elsewhere, the abundance of fish varies between years. There is also an incursion of flounder (2000, 2003 and 2004) into the river at this lower reach mimicking that of the electric fishing data. This suggests the proximity to the saline waters of the Ouse (Figure 4.26). Eel numbers declined in more recent years in reaches D3 and D4, although, this could be due to more selective fishing methods (Figure 4.25; Figure 4.26). Again these reaches mimic that of the electric fishing survey data.

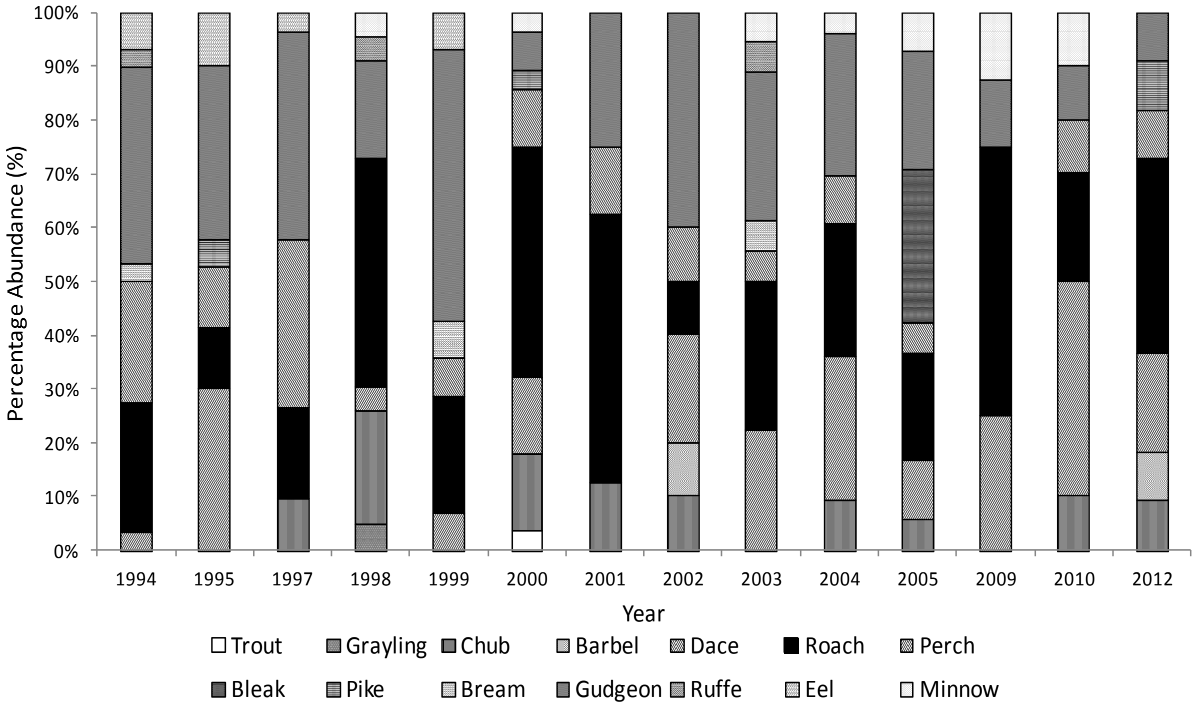


Figure 4.24 Species percentage abundance for Reach D2

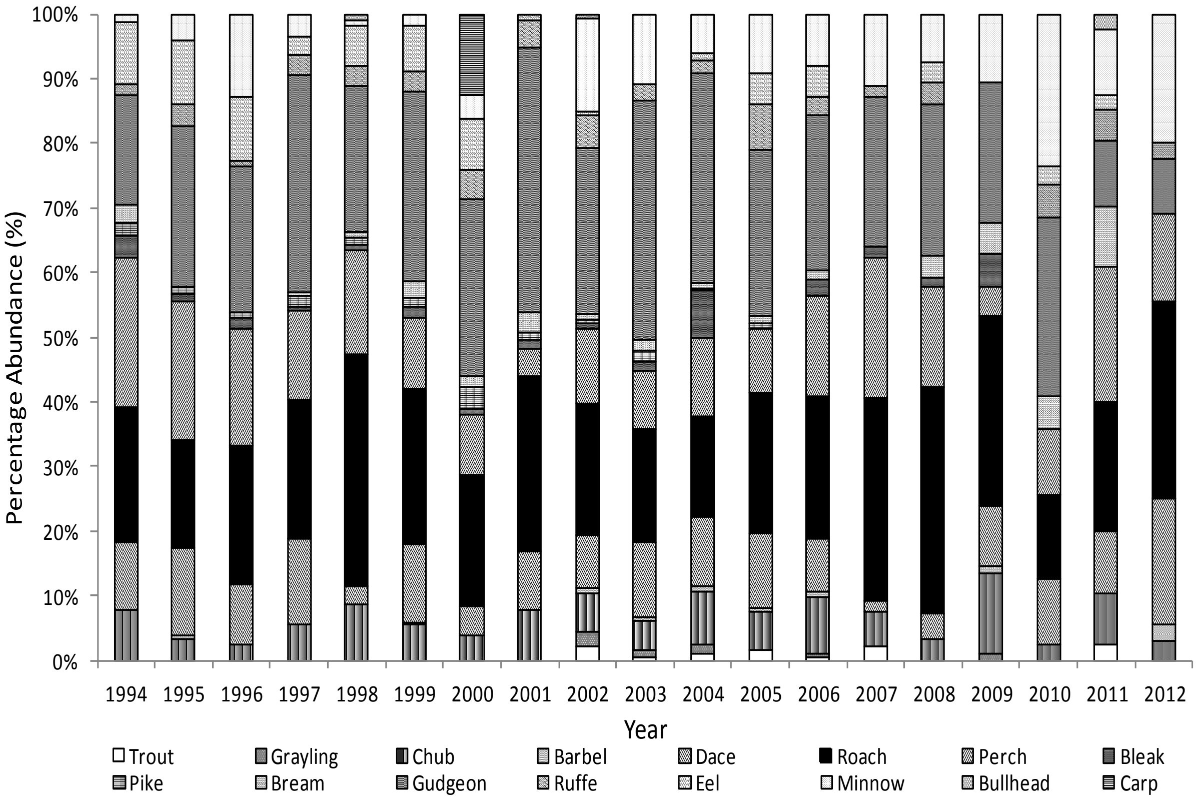


Figure 4.25 Species percentage abundance for Reach D3

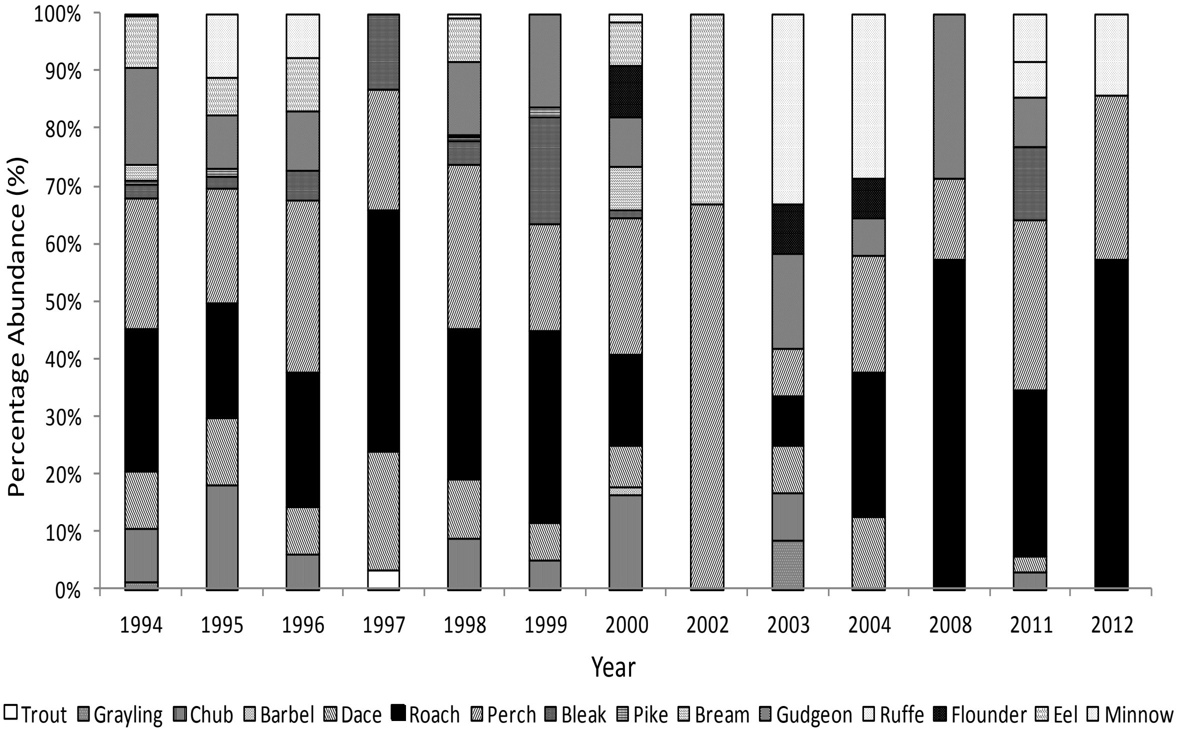


Figure 4.26 Species percentage abundance for Reach D4

Angler catch per unit effort (CPUE) (g/man-hr)

There is a great increase with catch rates over time which is correlated by the percentage success; there is a drop off towards the more recent years. The overall mean catch rate from all of the River Derwent reaches was 71.3 g/man-hr whereas, for the reaches on the River Rye, it was 42 g/man-hr. D2 has a higher CPUE suggesting that species size in this reach are increasing. All of the River Derwent reaches have a general shallow increase in g/man-hr, whereas, the River Rye tends to have a more sporadic nature. Mean percent success of catch mimics that of the CPUE with the drop off in more recent years. With regard to percent success, D2 had the highest chance of success of catch with 82.6%, followed by D3 (75.7%) with D4 being relatively close (75.9%) and D1 (58.2%) (Figure 4.27). Reach R1 on the River Rye has the highest percent of success in this river (60.8%).

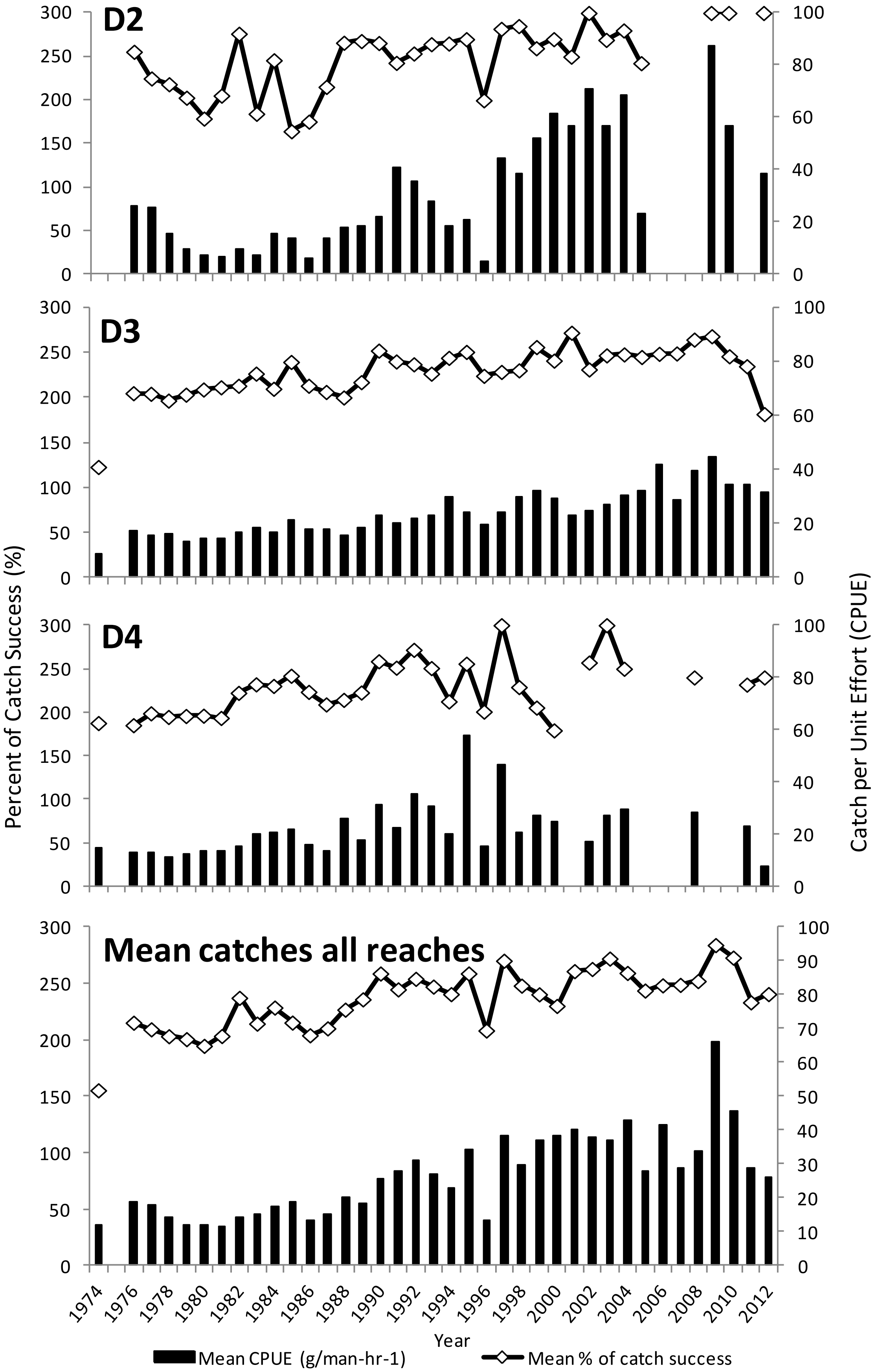


Figure 4.27 Mean catch per unit effort (CPUE) (g/man-hr) = ■)) with comparison to mean percent of catch success (%) = □)) between 3 reaches on the River Derwent. Last graph is mean of all the mean between all 3 reaches (D2, 3 and 4). Zero values = no data. See Table 4.2 for reach code.

4.4 Discussion

There are many factors that influence the structure of any given community. Riverine fishes are heavily exposed to anthropogenic activities which can have potentially drastic impacts on the life history strategies and recruitment processes (Nunn *et al.,* 2009; Copp, 1989; Jurajda, 1995; Figure 4.28). Many fish species are restricted to specific environmental conditions, whereas, some are morphologically and biologically adapted to tolerate a wide diversity of conditions (eurytopic species) which, in turn, enables a diverse range of species to exist in an array of ecosystems. Fish assemblages that occur in natural lowland rivers are generally characterised by higher diversity than that of an upland montane river. Furthermore, river systems that have been engineered and regulated are customarily associated with a lower diversity of species; this is commonly due to the uniformity of the channel (trapezoidal), along with minimal fluctuations in flow dynamics and benthic topography (Nunn *et al.,* 2009; Copp, 1989).

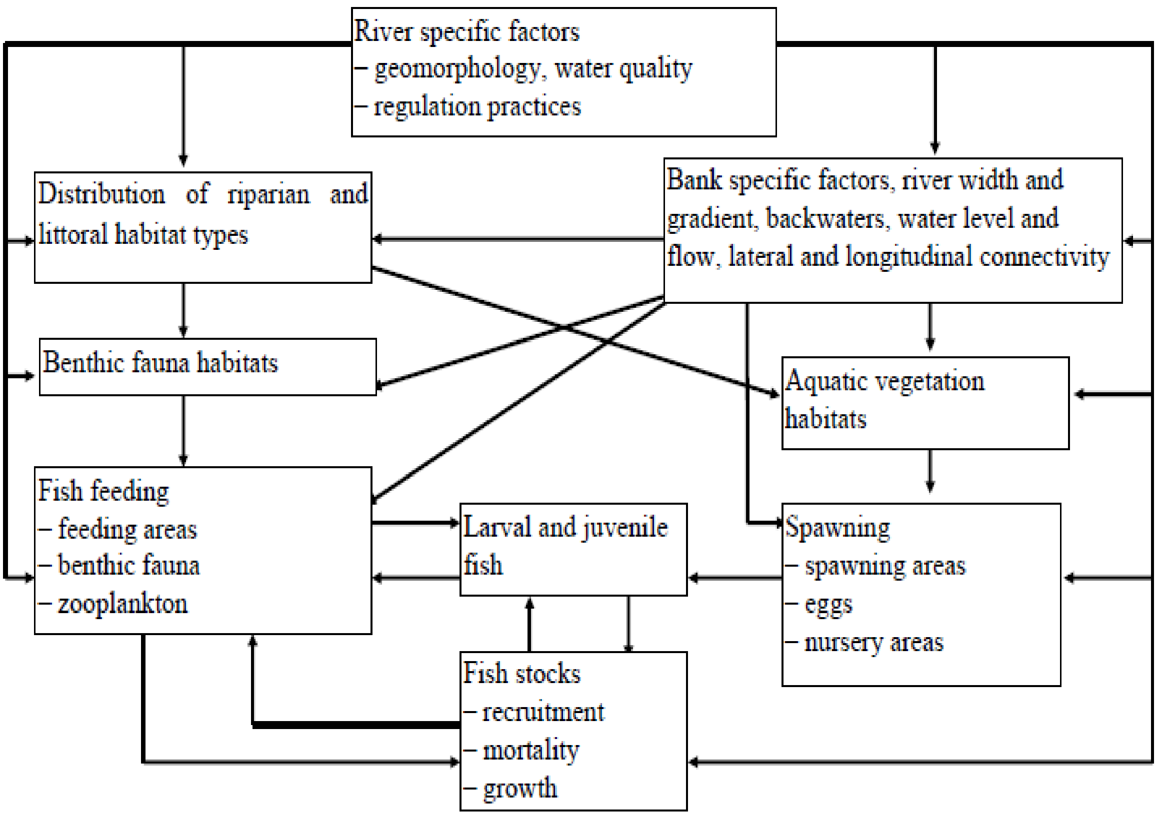


Figure 4.28 Habitat requirements (simplified) of riverine populations (Cowx, unpublished; source: Nunn *et al.,* 2010)

Species diversity (*H'*), evenness (*J*) (Figure 4.8), abundance (Figure 4.9 - Figure 4.21) and density (Figure 4.5; Figure 4.6; Figure 4.7) in the River Derwent determined from electric fishing surveys were typically highest where habitat heterogeneity is greatest. This is due to these areas supplying the essential variety of resources for fish species and all their life stages (Nunn *et al.,* 2009). The River Derwent is typically characterised by rheophilic and eurytopic species; roach was the most abundant species, accounting for 27% of the total fish caught, followed by gudgeon (19%), dace (13%), pike (10%) brown/sea trout (7%) and chub (5%). Roach was the most prevalent species, occurring in 72% of catches throughout the Derwent from 1995, 1997, 2000 to 2012, followed by pike (69%); dace (67%); gudgeon (58%); brown trout (53%); chub (53%); perch (42%); and grayling (44%). Smaller occurrences came from barbel, bleak and ruffe; salmon, bream, rainbow trout, rudd and tench were all rare.

Distinct zones were identified in the river with an upper 'trout zone' between Site 1: Langdale End Bridge to Site 7: Downstream West Ayton, an intermediate 'grayling zone' Site 8: Darrell's Low Farm to Site 15: Buttercrambe, and a lower 'barbel zone' below Site 16: Stamford Bridge to the confluence with the Ouse at Site 22: Barmby Barrage. This is consistent with the zonation theory of Huet (1959). Within European river systems, whether or not there is a high species diversity, species richness tends to increase from upstream to downstream (Santoul *et al.,* 2005). Anthropogenic intrusion has meant that certain species have become more dispersed or limited to specific reaches. Brown trout was, as expected, predominant in the fast-flowing headwaters, its distribution seems to be restricted to the areas that are somewhat 'unaltered', dense populations of trout completely diminish after West Ayton as well as after the River Rye joins the River Derwent. This is probably due to the changes in channel morphology and increases in agricultural pressures within the middle to lower section of the Derwent catchment. Furthermore, the MDS plots for both the electric fishing (Figure 4.3) and angling data (Figure 4.23) both support this zonation with the upper reaches of the River Derwent and River Rye being clustered together. Dace was omnipresent within the middle reaches but its contribution to the community composition in the lower reaches was minimal. This is probably because they favour faster flowing waters (Cowx, 1988). Further downstream is dominated by more eurytopic species and those that prefer less turbulent waters, although there is no bream zone, mainly because of the channelisation and disconnection of the floodplain from the river channel by embankments that are found through the lower river.

There are several other reasons for this distribution of the river zonation patterns; migratory barriers having great affect along with habitat degradation (riparian zone and river bed). Large migratory barriers such as the weirs located at: Kirkham, Buttercrambe, and Stamford Bridge are restricting longitudinal migration for fish species, amongst other organisms. This is evident at Buttercrambe and, to a lesser extent, at Howsham, where, due to the increase in turbulence and velocity from these weirs, the fish assemblages have shifted with an uncharacteristic prevalence of dace and chub. The Barmby Barrage is heavily influencing the lower tidal reaches of the Derwent. It must be noted that a reduction in the abundance of flounder in angler catches were reported after the construction of the barrage (Axford, 1991); this is clearly represented in the current data where minimal flounder were recorded.

Large shifts in the fish population abundance are apparent with a temporal increase in the upper catchment - this is likely to be due to the recent efforts by various stakeholder organisations, such as EYRT, and the numerous fishing clubs in the upper reaches. Much restoration work on becks and the upstream environment (breeding reaches) has been undertaken to ensure that target species such as brown trout are in abundance. As for the middle and lower reaches, there is a decrease in abundance with time. Aforementioned, the middle and lower reaches of the Derwent have been heavily altered from their original state. These decreases are due to channelisation and disconnection from floodplains; the flood plain environment is a crucial habitat for the reproductive cycle of these eurytopic and limnophilic species. Without access to this ecosystem, recruitment for certain species will be difficult as they will have to compete with more prolific species such as roach.

There seems to be a general decreasing temporal shift in the abundance at individual sites along the River Derwent. This is most apparent in the middle to lower reaches. Low Hutton, Howsham and Buttercrambe have the largest decrease in recent years. This section is heavily modified with areas that have been channelised - there is the presence of weirs and large areas that have fallen into disrepair with unmanaged riparian areas. During the walk over survey this section was noted to have high turbidity.

As elsewhere, the abundance of fish varies between sites and years but the numbers caught in the lower catchment are relatively small, possibly reflecting difficulties in sampling the lower river by electric fishing. Alternative sampling methods should be used in the lower reaches to help understand areas of fish assemblages that may have not been fully assessed.

Salmon occurred at Buttercrambe and Stamford Bridge in 2001 and 2002, but was not recorded in the angler data for D3 (Figure 4.25). This is not surprising as salmon parr are not recorded in coarse fish matches and adult salmon catch data are not recorded. Gudgeon became more prominent within D3 angler data, commensurate with the increase in prevalence in the electric fishing data. Subsequently, in the last few years the relative abundance of gudgeon has risen, this could be significantly linked to stocking programmes. The higher abundance of chub and dace within the electric fishing data were, however, not reflected in the angler catch data and probably reflect the fishing methods used and targeting of the anglers towards roach and gudgeon.

Nunn, Harvey, Noble & Cowx (2007) identified the importance of eel in the Derwent which also form a fraction of angler catches of the Yorkshire Derwent. They also found high densities of lamprey ammocoetes (Harvey et al., 2006; Nunn et al., 2007; Figure 4.29). Brook lamprey (*Lampetra planeri* (Bloch.)) are widespread throughout the upper reaches of the River Derwent (Whitton & Lucas, 1997; Figure 4.30), whereas, the river lamprey and sea lamprey have been integrated into, and have become a designated feature in the River Derwent Special Area of Conservation (Nunn *et al.,* 2008). This shows the importance of this river for these conservation species and the need for firm actions to conserve their status. This could also be said for the declining populations of eel across Europe. A regulation regarding this protected species was enacted in 2010 by the European Commission to recover the declining populations (EA, 2011/12) (Nunn *et al.,* 2007; 2008).

Elver stocking in the Derwent has been designated as low priority, this is due to the quality of the established populations of eel and lamprey which is backed up by the fisheries analysis. Although found in small numbers, elver and lamprey are found in the majority of the sample sites, emphasising the national importance of the Derwent and its catchment to these species. It must be noted that the water treatment works on the Derwent, Elvington and Loftsome Bridge are causing impingement for lamprey ammocoetes; eel are occasionally found (Dawes et al., 2004).

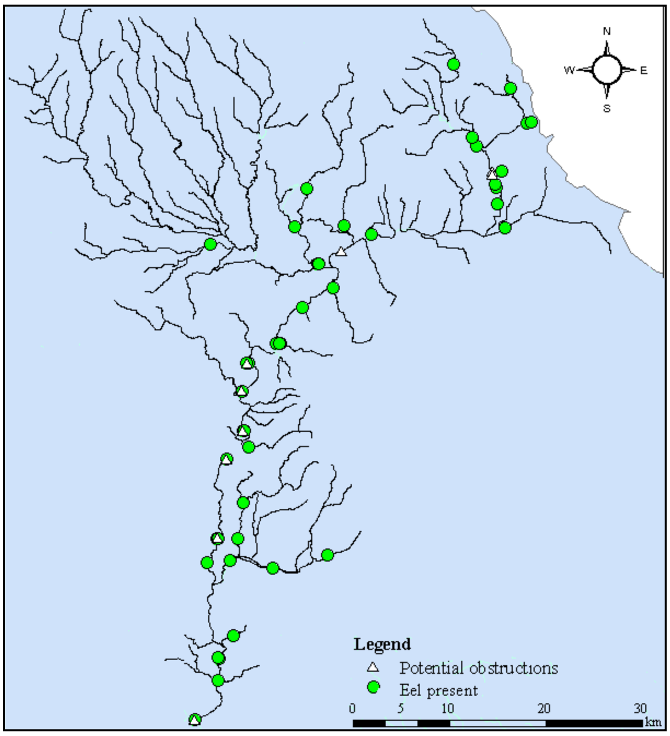


Figure 4.29 European eel presence in the River Derwent, Yorkshire (adapted: Nunn et al., 2007)

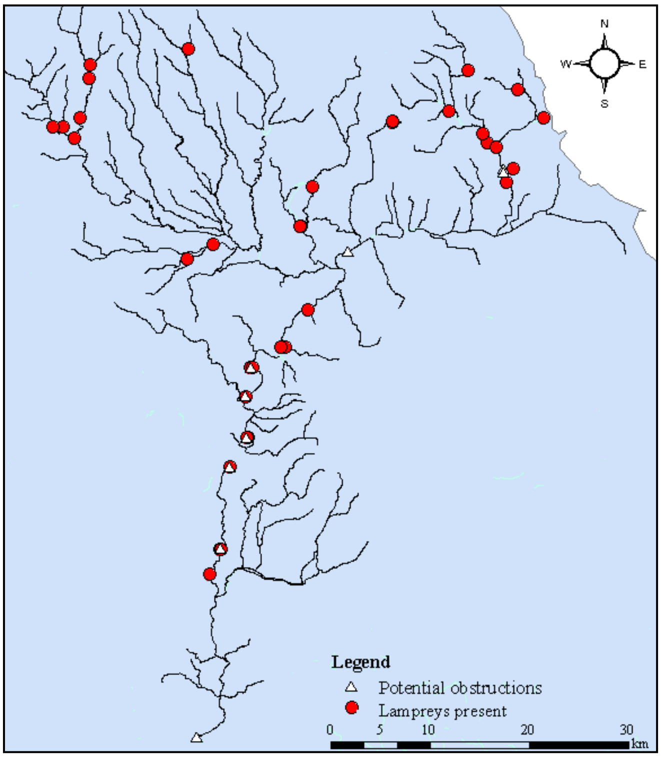


Figure 4.30 Lamprey presence in the River Derwent, Yorkshire (adapted: Nunn *et al.,* 2007).

The mean angler catch rates steadily increase until 2010 and then slightly decrease in more recent years. Mean CPUE in the late 1970s early 1980s was considerably lower than in between 2000 to 2010 (Figure 4.27). Several possible factors contribute to this change, one of which was the decimation of perch populations in the 1970s and 1980s, as a result of ulcer disease that wiped out large populations throughout the UK. These populations have subsequently recovered and contribute to the catches, especially in the lower reaches. The enactment of Water Act (1973) also led to considerable improvements in water quality, which almost certainly contributed to improvements in fish stocks post-1973, especially the recovery of sensitive species such as dace and chub; at the expense of eurytopic species such as roach and gudgeon. These improvements are reflected in angler catch data and electric fishing data. However, not all species have recovered and barbel have been stocked in the Derwent to increase their abundance in the river. The mean angler catch increased steadily over the last few decades suggesting that the fish assemblages and water quality in the River Derwent is stabilising or improving. Although there is a decrease in the last few years, this is likely to be from the frequency of matches or the lack of data that has been collected.

Naturally formed healthy assemblages of salmon (*Salmo salar* (L.)) would have historically been found throughout Yorkshire’s waterways, including the Derwent. Nowadays, salmon are found in very low numbers but are showing signs of recovery, including in the Derwent. Although salmon were not present in many sites where the habitat is suitable and populations are expected, (Figure 4.31), there is evidence of spawning up to Nunnington weir. The main reasons are restricted access to upstream spawning grounds including the large weirs at Kirkham, Buttercrambe and Stamford Bridge plus the obstruction created by Barmby Barrage denying upstream migration. Efforts are being put into place to rectify this problem and fish passes have been installed at Kirkham to provide access to the upstream habitat. In addition, the lock gates at Barmby Barrage are now partially opened to enable upstream migration.

Slight differences in habitat may also be important, with some areas potentially more favourable to larger than smaller species. The weir at Howsham has had a hydropower unit constructed on it. The increased flow leaving the hydropower unit could create an attractant flow for the salmon as they swim towards the strongest flows. If a salmon tries to swim up the turbine, impingement or entrapment is likely; this could have a drastic impact on salmon numbers.

Anglers appear to catch mostly roach and gudgeon; roach occurred in 97% of the River Derwent reaches, whereas, gudgeon occurred in 91% (Figure 4.24; Figure 4.25;Figure 4.26). This is comparable to the electric fishing survey where roach and gudgeon are the dominant species. Roach, gudgeon and dace were abundant in reach D2 (Figure 4.24) and the electric fishing surveys; from Malton, Low Hutton and Kirkham which are located within D2. Bream were caught in small numbers by anglers at D2 but were not recorded in the electric fishing data until Stamford Bridge. This disparity is of interest because there are several barriers located on this stretch which would likely impede movement and the lower reaches have been degraded by channelisation. The distribution of bream within the Derwent catchment could be more extensive than characterised by electric fishing. This difference probably arises because the species is not effectively caught by electric fishing in deeper water typically found in the lower reaches and reflects the importance of different sampling methods to understand the species distribution and abundance.

The mean catch success of all the reaches increases with time; this suggests that it is more probable to catch in more recent years. All these results are influenced by several things predominantly the amount of years and matches taken place. Percentage angler success is generally found to be mainly independent of the flow regime of a system, although critical flows can influence a reduction in angling success dramatically. On the other hand, temperature can be heavily associated with angler success (North, 1980).

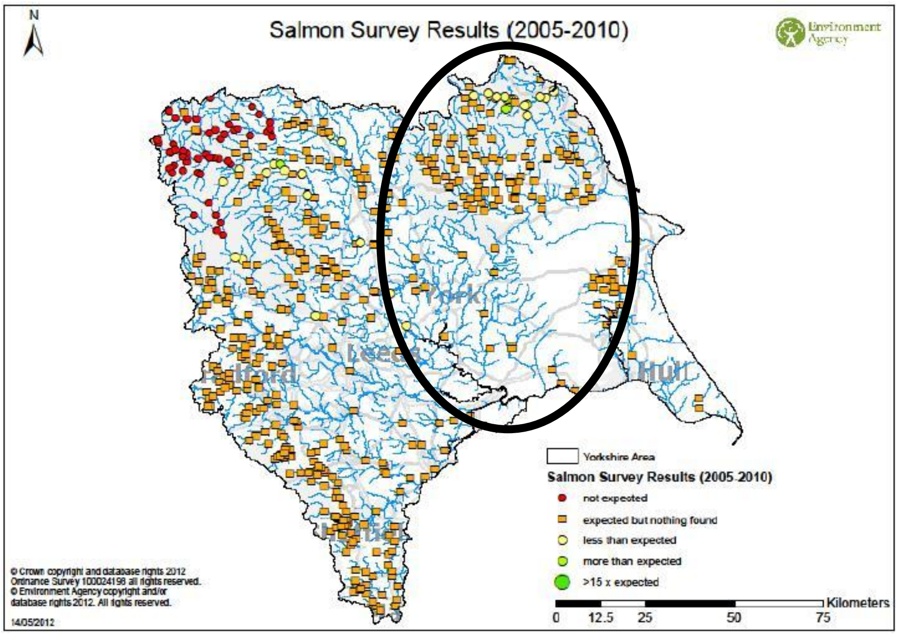


Figure 4.31 Surveys undertaken in Yorkshires river basin district indicating where salmon have been located or where potentially expected populations can be found (source: EA, 2011/12)

Pollution is an important factor to take into consideration when assessing the status of a fishery. The River Derwent has many different discharge points from water treatment works, sewage discharge and aquaculture units. The major issues in the Derwent are, however, caused by high concentrations of suspended solids, which have been credited to sewage discharges and are heavily influenced by industry (Oguchi *et al.,* 2000). This is more likely from sediment run-off from poor agricultural practices. Agricultural intensification has meant that landowners are trying to optimise their profits in turn, this means that farmers need to maximise the land they use for their crop production. In doing so, agricultural landowners are farming nearer to river systems; this is apparent in much of the Derwent. Large farming machinery churns up soil for planting crops, the uniformity to the planting means there are spaces between the crops. In times of rainfall these rows act as funnels towards the watercourse, as the run-off travels down the fields gathering large amounts of sediment which subsequently enter the water course. Agricultural riparian intrusion means there is less space for the natural removal of sediment in riparian zones which consequently means large amounts of sediment enters the water course via these areas. Increased sediment in the River Derwent can also be directly linked to riparian poaching from livestock. The abundance of species in Malton decreases with time. Malton is a busy market town and in recent years motor vehicles and traffic have increased dramatically. The increase in presence of people and the increased use of motor vehicles could be having an impact on this water course. Petroleum, oils and other storm drain run-off could be altering this habitat thus having drastic effect on the fish assemblages.

High concentrations of suspended solids can have devastating impacts on the welfare of fish; sediment can damage fish gills. On the other hand, there is a considerably higher abundance of eel and lamprey appearing at Howsham, this could be linked to suspended solids and elevated turbidity from the weir and surrounding ponds which provide ideal conditions for ammocoetes as they burrow into the sediment. Eel is present throughout the Yorkshire Derwent (Whitton & Lucas, 1997; Nunn *et al.,* 2007); specimens have appeared throughout the categorical values (Table 4.3). Likewise lamprey have been recorded in abundance throughout the Derwent (Jang & Lucas, 2005; Harvey *et al.,* 2006; Nunn *et al.,* 2007) with large densities of ammocoetes present throughout. This is supportive of the conservation designation of the Derwent for lamprey, bullhead and another Habitat Directive species which were also recorded throughout much of the catchment. Although the water quality within the River Derwent is generally good and somewhat improving, there is also a likelihood that poor water parameters derive from the tidal Ouse at Barmby Barrage. Poor water quality could be a possible barrier to lamprey migration under some circumstances, particularly during times of low flow (Nunn et al., 2008).

Environmental parameters can influence angler catch data; comparisons were made between the years of 1992 to 2012 with the mean yearly flow at Buttercrambe, which is situated in the middle of reach D2 (Figure 2.5;Figure 4.24). There seems to be no significant link between the increase in flow and the decrease or increase of success of catch. It is unfeasible to be more accurate with insufficient data of critical flow rates due to water velocity. Water velocity is the most significant influence to angling success (North, 1980).

4.5 Recommendations

As mentioned before, there are many pressures and issues that arise within the River Derwent catchment and these pressures are clearly having an impact on the fish assemblages. It is evident that fish assemblages are in a decreasing shift due to the anthropogenic activities. Areas that have been altered for agricultural purposes need to be evaluated and correct management practices need to be instated to ensure the recovery of this declining fish community.

The large in-channel structures are causing habitat fragmentation as they are acting as a barrier to fish migration, as well as causing impoundment and stopping natural riverine processes from occurring. These are altering the dynamics of the fish assemblages and correct procedures need to be undertaken to alleviate the pressures. First and foremost, it would be recommended that fish passes are made for all species present in the Derwent catchment with special attention being paid towards protected species such as salmon and lamprey. Although present in much of the catchment, due to the small recorded numbers of lamprey (categorical value 1 - 9) and their national and international importance, it is recommended that particular attention must be given to protect spawning and nursery areas. Due to a high level of turbidity the spawning areas (fine sands and gravels) are becoming muddy and turbid. Thus it is crucial to prevent exploitation of these areas, as well as improving water quality. Nursery areas (fine silts) are equally important to protect as they are vital for the primary development of ammocetoes. Due to the increased chance of impingement or entrapment at abstraction points, it is necessary that appropriate measures are put in place to lessen this, as well as increase passage at in-channel structures.

The heavily channelised section of the River Derwent at Yedingham has relatively low abundance of species; providing little or no habitat for the fish populations. Other areas, where channelisation is prevalent, need riffle and pool sections or other engineering practices to bring the River Derwent back to its original state. Necessary works need to be carried out on minimising the effects of diffuse and point source pollution as it is negatively influencing the fish assemblages. Alteration to agricultural practices to help lessen this issue need to be investigated and physical structures may need to be used to help combat this. This should be carried out with regards to the riparian habitat.

It is highly recommended that this data set is continued after necessary management methods and projects or actions have been instated to see that fish communities are recovering from the highlighted pressures. Continual monitoring programmes must rely on detecting fluctuations in the structural dynamics of a system where species distribution and abundance can be effectively managed (Cowx et al., 2009; Nunn et al., 2010).

The River Derwent has national and international importance therefore, it is recommended that this fisheries analysis is used to back up the need for immediate action for the protection of this venerable yet, highly valuable catchment. The management methods and projects indicated in Chapter 55 will help rehabilitate and restore the River Derwent and its species towards its original state thus achieving good ecological status or potential.

5 Management measures for the Yorkshire Derwent catchment

5.1 Introduction

GES or GEP needs to be achieved by 2027 on the Derwent catchment to meet WFD targets. Currently, water quality is at a satisfactory level whereas, the ecology is failing. There are different issues, pressures and impacts that are causing this underperforming status, many of which are caused by anthropogenic structures and pressures, including but is not limited to, in-situ structures, abstraction of water for the purposes of consumption and aquaculture uses. Pollutants from agriculture and practices such as aquaculture and golf course maintenance can cause major issues with regards to diffuse and point source pollution (Defra, 2008). It has been observed that agricultural practices are having negative impacts on various other areas, for instance destruction of riparian habitat through bank poaching and overgrazing, as well as fertilisers causing increased growth of algae thus smothering the waterways.

Agricultural intensification and modern advancements of equipment and techniques are the reason for the exacerbation of soil erosion among many other things; in much of the catchment. Which has subsequently lead to a reduction in the productivity and sustainability of soils. Furthermore, weakening of soils in many different aspects (riparian management and livestock) has increased sedimentation in the Derwent. The Yorkshire Derwent has many of its reaches blocked by artificial barriers (Holmes *et al.,* 1999).

This chapter provides an analytical explanation for the management preferences that have been selected. The intentions are to address the issues identified with regard to achieving WFD targets by 2027, in some circumstances medium or longer term actions may have to be put in place. An overall Catchment Based Approach (CaBA), as well as the allocation of actions to the necessary stakeholders, is the most suitable manner when considering the best approach to accomplish these goals.

5.2 Organisations and institutional framework in the Yorkshire Derwent

5.2.1 Organisational structure of the Yorkshire Derwent

There are several institutions and organisations operating in the Yorkshire Derwent catchment that could be involved with the management of the fishery and surrounding habitats (Table 5.1). The EA are responsible for the management of surface and groundwater resources, in turn, they ensure that other institutions comply with the water rights issues. Yorkshire Water is the largest water rights holder on the Derwent and abstracts water to supply domestic and industrial units within Yorkshire. District Councils are vital stakeholders that regulate the collection of revenue from businesses surrounding the Derwent. There are many Non-Government Organisations (NGO) that are involved with the Derwent; EYRT and the Yorkshire Wildlife Trust are key to the rehabilitation of the River Derwent.

5.2.2 Institutional Framework

Environmental Stewardship (ES) was put in place by the Department for Environment, Food and Rural Affairs (Defra) giving advice and funding to land owners for the conservation, preservation and even improvements for the countryside; it also gives financial encouragement to land owners to reduce various environmental impacts (Natural England, 2011; Defra, 2012a).

Defra has provided an assessment measure for the quality and productiveness of farmland which enables decisions about future planning within a system; this is embodied within the Agricultural Land Classification (ALC). Five grades constitute the ALC with grade 3 being subdivided into 3a and 3b. Land graded 1 to 3a are the most productive. Grades 3b to 5 are moderate to very poor productive lands. Approximately 40% of English farmland is graded 1 to 3b (Natural England, 2012b). The majority of the land in the lower and middle Derwent has an ALC of either grade 2 or 3; with the ALC of the upper Derwent catchment being predominantly either grade 3 or 5. The impermeable sandstone soils of the North York Moors plateau, along with the elevated altitude, sustain wide-ranging moorland consisting of heather and rough shrub-lands. Agricultural productiveness of this is grade 5, amounting to 35% of the overall agricultural land. Further down the valleys, grade 4 soils can be found, derived from more fertile soils at a somewhat deeper stratum. These are used for grazing land supporting livestock as well as dairy herds. The most notable and highest ALC of grade 3 is located south of the North York Moors where limestone rises to freely draining fertile soil (Natural England, 2012a).

Table 5.1 Institutions involved with the River Derwent, Yorkshire

Institutions	Positional standing	Region	Responsibility
Local County Council	Local government	N. Yorkshire, Humberside, Ryedale, Scarborough, Selby	Planning issues, funding initiatives.
Defra	Government organisation	Catchment-wide	National policies. Provides advice and funding to EA.
EA		Catchment-wide	Policies, enforcement, advice and data collection.
Natural England		Catchment-wide	Ecological enforcement and advice.
Yorkshire Water: Internal drainage board (IDB)	Utility company	Elvington WTW & Loftsome Bridge WTW	Abstraction (drinking water).
Canal & Rivers Trust	Non-Government Organisations	Lower Derwent & Pocklington Canal	Preserve navigational access.
Yorkshire Wildlife Trust		Catchment-wide. Specifically Lower Derwent NNR	Habitat rehabilitation and monitoring. Project development and funding.
East Yorkshire Rivers Trust (EYRT)		Catchment-wide.	Rehabilitation of waterways.
RSPB		Lower Derwent NNR	Monitor abundance of avian fauna
Angling clubs		Stretch/beat specific throughout the Derwent Catchment	Maintain fish stocks for members. Minor habitat alterations – generally for safety measures.
Pocklington Canal Amenity Society		Pocklington Canal.	Protection and restoration of locks and canal.
East Yorkshire Ramblers		Catchment-wide.	Maintaining public right of way.
Farmers & estate owners	Riparian landowners	Site specific throughout the entirety of the catchment.	Reduce the impact of activities undertaken at the sites.
Fish farms	Limited companies	Site specific throughout the upper	Abstraction, discharge. Can introduce non-native alien species.
English Heritage	Non-departmental public body	Site specific, preserved & protected monuments (Kirkham Abbey).	Preserving and Restoring England's National Heritage.

At the bottom of postglacial Lake Pickering, between the North York Moors and the Yorkshire Wolds (500 km^2), the soil types (peat, sand and glacial clay) are highly productive, thus a considerable amount of arable agriculture occurs. About 17% of the Vale of Pickering is grade 2 agricultural lands, 73% is grade 3 indicating the area is rather productive (Natural England, 2012d). The middle reaches consisted of marshlands which has now been drained and reclaimed. Glacial depositions consisting of sands and clays have formed moderately fertile soils leaving 73% of the agricultural lands at grade 3. Grade 2 ALCs are concentrated towards the central regions upholding a mixture of farming techniques. The watercourses are generally related to inadequately draining soils giving them an agricultural grading of 4 and 5. Towards the southern edge of the Vale of Pickering unproductive acidic, sandy soils are found, which support arable cultivation along with open air piggeries (Natural England, 2012d).

Although not the sole cause, agricultural diffuse pollution contributes to a considerable proportion of the contaminants and pollutants found within the River Derwent water course. Phosphates, nitrogen, agro-chemicals (pesticides, herbicides, and disinfectants), sedimentation and bacteria from faecal matter are some of the key elements affecting the water quality in the Derwent catchment. Faecal bacteria from livestock units leach into the waterways with potential negative impacts including significantly increasing the biological oxygen demand (BOD) (Defra, 2009).

Collaboration between Defra, the EA and Natural England along with the EU, has led to the introduction of Catchment Sensitive Farming (CSF). It was brought in line to raise awareness in ways to reduce pollution from agriculture into surface waters, ground waters and other aquatic environments (Natural England, 2012d). The Yorkshire Derwent comes under one of the priority catchment areas. Foremost, Defra has created a funding scheme (Capital Grants Scheme) to assist land owners in priority catchments where these famers will be able to develop and establish techniques and services, giving benefit to water quality through the reduction of diffuse pollutants (Defra, 2012d).

CSF is a nationwide initiative started in 2006 by the EA and Natural England and was commissioned by Defra. Farmers and land managers can acquire advice with regards to practical solutions to protect and maintain aquatic and terrestrial ecosystems. This land management practice keeps diffuse pollutants at a consistent level within the aquatic environment, ensuring pollutants do not impact on ecologically sensitive systems. This is achieved through appropriate management, such as the control of fertilisers, manure, pesticides and sedimentation, promotion of good soil structure and rain permeation (decreasing run-off and erosion), protecting the watercourse from livestock, reduction of stocking densities and the segregation of clean and dirty farm waters (EA, 2010).

The Common Agricultural Policy (CAP) was reformed in 2003 and in 2005 Environmental Stewardship (ES) was formed, both of which use rural development schemes to adhere to environmental requirements (RPA, 2013; Defra & Natural England, 2013). Additionally, it meets fundamental obligations under European and UK regulations, for example, Water Framework Directive and Nitrates Directive (Defra, 2013). Single Payment Schemes (SPS) among others, require the use of management practices and guidelines such as Good Agricultural and Environmental Conditions (GAECs) (Defra, 2013b). Several GAECs are relevant for the rehabilitation of the Derwent (Table 5.2) and various GAECs should be used to help diminish and lessen these impacts.

Agricultural landowners can achieve additional endorsements through financial incentives under the ES scheme at different levels; Entry Level Stewardship, Organic Entry Level Stewardship and Higher Level Stewardship (HLS). These stewardships are specifically designed to coincide with the various kinds of agricultural establishments. They are achieved by protecting and preserving the English countryside (Natural England, 2010). There is an increased chance of gaining higher grants by abiding by the guidelines set out in the GACEs. Landowners and stakeholders should work alongside one another when evaluating potential rehabilitation schemes, whether they be long or short term to increase the probability of success.

Table 5.2 Good Agricultural and Environmental Conditions with the most significance to the rehabilitation of the Yorkshire Derwent (source: Defra, 2013b).

GAECs No.	Title/ Aim	Description of Aim	Responsibility
GAEC 1 - 4	Soil Protection Review (SPR).	Uphold soil composition and organics, prevent erosion, compaction and damage of environmental features.	Agricultural landowner, EA
GAEC 5	Environmental Impact Assessments (EIA).	Regard environmental significances – uncultivated and semi natural areas including forested regions.	Agricultural landowner
GAEC 6	Site of Special Scientific Interest (SSSI).	Protect, manage, maintain SSSIs due to importance of rare species, habitats, geology and landscape.	Agricultural landowner, Natural England, EA
GAEC 7	Scheduled monuments.	Preserve monuments due to landscape importance.	Agricultural landowner
GAEC 9	Overgrazing and unsuitable supplementary feeding.	Protect important habitats which contain natural and semi – natural vegetation.	Agricultural landowner
GAEC 11	Control of weed.	Manage invasive non-native alien species specifically flora that can damage habitats, agricultural land as well as pose welfare risks to livestock and the public.	Agricultural landowner
GACE 12	Agricultural land which is not in agricultural production.	Avoid encroachment of unwanted vegetation, protecting habitats and maintaining areas not in production at a good environmental condition.	Agricultural landowner
GACE 14	Protection of hedgerows and watercourse.	Protect sensitive field boundaries and their fringing habitats. Also includes if adjacent to land (2m buffer zone).	Agricultural landowner
GACE 18	Water abstraction.	Licensing abstractions over 20 cubic metres within 24 hours for the purpose of irrigation.	Agricultural landowner

The Derwent is within the targeted region of HLS. The areas classified for HLS stretch from Rye Mouth to the convergence at the Barmby Barrage. This aims to help maintain the protected areas at a satisfactory standard. Various specific management strategies and practices for the Yorkshire Derwent have been developed to achieve this recognition (Table 5.3)

Table 5.3 Higher Level Stewardship (HLS) management strategies and practices

Management strategies and practices in the Yorkshire Derwent that are instated to achieve HLS
Preservation, re-establishment or formation of known significantly diversity and abundant areas, specifically; meadows, pastures, wetlands and low heath land.
Increase and make available wet grassland habitat which can be utilised by three or more specific nesting birds (Lapwing, Snipe, redshank, Curlew and Yellow Wagtail), also provide/ increase the amount of prey species. High breeding abundance of one of the species may have exceptions.
Alter land management regimes in order to fully reduce soil erosion and agricultural runoff, where the potentiality of diffuse pollution is rife.
Restoration of natural process to the river itself and surrounding lands with regards to field boundaries.

The EU Nitrates Directive informs about Nitrate Vulnerable Zones (NVZ). NVZ is designated to areas of land that drain and contribute to pollution levels within contaminated waters which includes surface or ground waters that contain at least 50 mg/l. If no action is taken these waters are likely to already be eutrophic or may become eutrophic. This Directive also complies to cross compliance with Environmental Stewardship scheme, including GACE 19 – No spread zones (RPA, 2013; Defra, & Natural England, 2013; Defra, 2013).

Payments are available for materials needed to carry out the relevant rehabilitation works (Table 5.4).

Table 5.4 Various expected Environmental Stewardship management options for the River Derwent with regards to payment rates (Sourced: Natural England, 2010)

Rehabilitation method/ Item	Rate per unit
Stock-proof fencing	£1.80 – £4 per m
Creation – Ditches, rhines and dykes Restoration - Ditch, dyke and rhine	£3.60 per m/£2.90 per m
Tree and shrub – whips and transplants plus planting	£1.60 each
Coppicing bank side trees	£29.00 each
Wooden field/river gate	£149.00 each
Culvert	£153.00 each
Silt trap provision	60% of costs
Wind pumps for water-level measures	80% of costs
Maintenance of watercourse fencing	£4 per 100 m
Pond creation – 1m^2	£3.00 for first 100m^2/£1.00 over 100m^2
Pond restoration – 1m^2	£2.10 for first 100m^2/£0.80 over 100m^2
6m buffer strips (rotational land or organic grassland next to a watercourse)	£500
12m buffer strips for watercourses on cultivated land	£400 ha

The Catchment Abstraction Management Strategy (CAMS) sets out the management of water abstraction; it specifically demonstrates where water is available, where, if applicable, abstraction rates should be reduced and outlining the policies on time limited licences. The Derwent CAMS consists of ten surface Water Resource Management Units, whereas the ground waters in the catchment are divided into three individual Groundwater Management Units. Although three divisions are made, only one unit is assessed under the Derwent CAMS; the Corallian limestone aquifer appears in the foothills of the Vale of Pickering within the Derwent Catchment. The majority of the Derwent is either over licensed or there is no water available for abstraction (EA, 2006b).

5.3 Sustainable agricultural and land drainage management practices

Agriculture and associated land drainage within the Derwent catchment needs to be appropriately managed to suit the needs of the stakeholders, as well as complying with WFD; amongst other drivers. These practices are directly linked to the increase in the severity of diffuse and point source pollution within the Derwent, it is highly important that correct management practices are instated to lessen the impact this issue is having in the catchment (Table 5.5).

Through the establishment of correct management practices diffuse and point source pollution can be decreased within the catchment, thus improving the water quality and biodiversity in the Derwent. These management practices will aid in the recovery of the River Derwent to meet GES or GEP.

There are various options to try and rectify high sediment and the highest priority should be given to the installation of buffer zones adjacent to the watercourse (Table 5.5). Buffer zones are areas of long foliage and dense roots that help to entrap sediment that runs off agricultural land, decreasing the overall amount of sediment entering the watercourse. If this option is undertaken effectively it could work alongside a rotational grazing or cutting strategy (Table 5.5). The areas that are being left for this strategy could be linked to a specific location that a buffer zone needs to be installed therefore giving the area additional time to establish and naturalise. Erection of stock-proof fencing on much of the Derwent is needed due to trampling and poaching occurring (Table 5.5). This option, erection of stock-proof fencing, is highly important and can work alongside the aforementioned options. Reaches that are susceptible to riparian destruction from livestock activity need to be restricted in order for the river bank and flora to recover. Options to prevent run-off through farm yards entrapping nutrient rich sediment should be taken before it enters the water course.

In some circumstances larger alterations need to be made to help alleviate the pressures from sedimentation, this can be done through the creation of a sediment trap (Table 5.5). A sediment trap is a specifically designed area within a river reach which reduces the water velocity to catch and hold excess amounts of sediment from upstream. This is likely to decrease the sediment loading downstream thus decreasing the downstream effect of sedimentation. Ideally, sediment trapping should be undertaken in existing drainage ditches adjacent to the river as this provides the largest area neighbouring the river where the sediment loading is likely to be greatest (Table 5.5).

Table 5.5 Management measures and projects for proposed alterations to agricultural and land drainage management practices

Options	Outcomes	Constraints	Responsibility
Investigate and manage point source and diffuse pollution			
Reduce the frequency and extent drainage ditches are cleared.	Reduce sediment supply to the river by restricting it to the drainage ditches. A 3 to 4 year rotational basis should be made, this will aid in the settlement of sediment. The sediment that is cleared should be spread on agricultural land. It is recommended that only one bank of the aquatic vegetation is removed when cleared.	Large portion of time and effort must be undertaken initially to establish a rotation scheme that works for all stakeholders, then instructions must be given to the person that will have to carry out the clearing – it may be that the EA or another agency might want to observe or make inspections afterwards.	Landowners, Internal drainage board (IDB) , EA
Encourage growth of aquatic and semi-aquatic plants.	Riparian flora can alter the flow regime as well as encourage deposition of sediment. A rotational basis should be made, in order to maintain a steady level or growth.	Upstream effect, if there are more severe problems further upstream then it is probable to decrease the success of this option. Natural colonisation can be a long process; seeding and planting may increase the rate of colonisation.	EA, Defra, Landowners, Natural England, Wildlife Trust
Install sediment traps within the river channel.	Organic in-situ structures create a small impoundment of water, sediment accumulates behind the obstacle. Sediment is then removed to coincide with the new maintenance rotation scheme. This could decrease the sediment load of the system.	With entrapment of sediment comes other nutrient rich substances, these can accumulate and cause an increase in phytoplankton blooms. Subsequently these blooms block out light and contribute to lowering the oxygen level of the water. This could have dramatic effects on macro-invertebrate abundance.	Landowners, EA, EYRT
Install buffer strips adjacent to the watercourse.	Intercept diffuse pollution (run-off), minimises adjacent soil erosion (decreases sedimentation), can trap heavy pollutants (hydro-carbons), provide additional habitat for riparian and aquatic species (Roni et al., 2005; FAO, 2008).	Due to the excessive amount of nutrients that are inputted into an aquatic system through riparian zones, generally this is a direct food source for many aquatic species. Increased and unmanaged leaf falls and large woody debris can cause constraints in the river channel potentially leading to localised flooding. Natural colonisation is a long process.	Landowners, EA, EYRT, Yorkshire Wildlife Trust

Options	Outcomes	Constraints	Responsibility
Restrict livestock access to riparian areas			
Fence off areas that have become trampled and poached. Troughs could be provided with funding.	Prevents access to banks enabling rejuvenation of flora, fauna, and water quality, although riparian habitats should not be left unmanaged. Livestock drinking water should not come directly from the main channel, troughs should be filled with the river water and used.	Unmaintained, it is highly likely that the riparian areas will become over grown and potentially swamp the channel. It is also probable that because of the lack of vegetation in this specific niche that invasive non-native species may utilise this area and become the dominant species. There are many factors that manipulate the potential success of these measures; including the geology, channel type, climate, INNS, native ungulates, effectiveness of the control on the intensity and duration of poaching and grazing and, size of the area (buffer strip included) (Roni *et al.,* 2005).	Landowners through subsidies (Environmental Stewardship) •
Establishment of a rotational grazing or cutting strategy.	Limiting the period of time and number of livestock that are allowed to drink or graze in or near the river bank (no more than a week!), seasonal and weather conditions permitting. Access points can be altered along a stretch to lessen the overall impacts. This also can be an effective way of riparian management if undertaken correctly. Set-aside or cutting can also be undertaken.	Large portion of time and effort must be undertaken initially to establish a rotation scheme that works for all stakeholders, and then allocations must be given to each reach. It may be that the EA or another governing body may want to undertake inspections to check impacts are not worsening (EA, 2010).	Defra, Landowner

5.4 Aquaculture

There are many differing anthropogenic activities that arise throughout the Derwent. The intensity of aquaculture units located on the sensitive reaches of the Derwent are having a significantly detrimental impact on the aquatic ecosystem. Parameters such as: decreasing and diverting flows, water quality in terms of sedimentation and the probability of the introduction of INNS, as well as the addition of various diseases and novel pathogens, are heavily influencing the catchment locally and more specifically, these factors are intensifying as they travel downstream.

Two thirds of the water abstracted in the Derwent catchment is down to aquaculture: 35% of the abstraction licences on the Derwent CAMS are limited under timings due to the sensitive nature of the river system, for instance, the winterbourne sections and the infrequent absorption rate of the aquifer near West Ayton. Many of the farms are categorised as flow-through systems thus not fully impounding the water, although, in some circumstances, this can worsen water quality issues (EA, 2013b). Infringement of habitats and diversity of organisms from aquaculture should be taken into regard when renewal of abstraction licences are needed.

To alleviate and halt aquaculture pressures, considerable communication and cooperation has to be put into practice between all agencies and stakeholders to achieve a common goal. Achieving any solution will be an expensive operation. The foremost dilemma when proposing solutions is the cooperation of the farm owners because any mitigation schemes will be driven by financial constraints thus limiting any measures. It is recommended that CaBA events should bring together the common interests and help distribute the financial pressures to primary stakeholders; the fish farmers. Local angling clubs and EYRT could offer support with habitat restoration works. Alongside this, further investigation should be undertaken to determine whether more financial support can be provided by the EA and Natural England.

5.4.1 Management measures and projects

Table 5.6 Management measures and projects for proposed alterations to alleviate the pressures from aquaculture

Options	Outcomes	Constraints	Responsibility
Decrease the length between abstraction and discharge (specifically Moorland Trout Farm – Pickering Beck) – lessens the stretch affected by low flows, sedimentation and channel alterations (width & direction).	Reinstate natural water parameters – flow regime; thus lessening the likelihood of macrophytes colonising the channel. Also decreases the turbidity by flushing the river with stronger flows. Water quality issues caused by any stagnant areas (increased DO) less likely.	Initial investment would be costly in terms of new equipment and construction costs. Could negatively impact the river system to start off due to changes in parameters but natural processes would be restored.	EA, Moorland Trout Fm, Costa Spring Hatchery Ltd, Willowdene Watercress & Trout Fm Ltd, Sinnington Trout Fm Ltd. (ALL FISH FARMS)
Relocate all watercress beds or discharge points next to/ above abstraction points or pump discharging waters up and through beds prior to discharge (utilisation of water cress beds as an organic filter).	Utilisation of natural filtration would reduce turbidity and entrap particulate matter. Excess nutrients would also fertilise thus increasing growth of watercress. Pumping of effluent waters could coincide with previously stated solutions.	A rather unrealistic goal due to costs and resources but if achieved will negate any other filtration methods and is likely to increase productivity of watercress.	EA, Willowdene Watercress & Trout Farm Ltd.
Construction of buffer zone between outfall and main channel (tiered vertical flow reed bed filtration system).	Would aide in the removal of excess nutrients, this could be used alongside watercress buffer zone which may reduce the need for settlement chambers.	Surface area to water ratio is very high therefore somewhat impractical and expensive – although when waters have passed through beds it would be possible to reuse directly creating a semi-closed system.	Moorland Trout Farm Ltd, Sinnington Trout Farm Ltd.
Increase settling facilities in the aquaculture units before effluent is discharged.	Reduction in suspended solids being released into river system – decreasing turbidity potentially reducing sedimentation issues downstream.	Costly exercise although re-circulation of water could be installed creating a semi closed system thus helping the problems with low flow and sedimentation.	ALL FISH FARMS

Options	Outcomes	Constraints	Responsibility
Closure of farms.	Termination of licences, bring halt to any impacts of farms.	Would require a large amount of funding as will have to pay compensation.	EA, Defra, ALL FISH FARMS
Increase naturalisation of water course (natural process that may not be present) after effluent out flow (help alleviate pressures, proving better habitat – increased riparian zones, pool and riffles etc). Specifically for Moorland Trout Farm Ltd.	Restoration of natural processes – subsequently resulting in good environmental condition thus leading to better ecological and biological status due to near natural habitat (similar practices should be undertaken as have been downstream of the farms on Costa Beck).	Funding will be the key issue, cooperation of land owners and stakeholders is key – although like Costa Beck local angling clubs can help with construction works.	EA, EYRT, ALL FISH FARMS

5.5 In-channel structures and potential modifications

The in-channel structures within the River Derwent are an obstruction to fish migration. Migratory species such as salmon and sea trout have a large significance in a water course and can boost the local economy. Due to the huge alterations to the River Derwent by in-channel structures, the aquatic species present have had to adapt to ensure survival. When considering solutions for rehabilitation, it is essential that suitable habitats are preserved for the species protected under SSSI and SAC status.

Investigations (April 2013) have been undertaken on the operational times of the Barmby Barrage by Yorkshire Water, Natural England and the Open University to deduce the relationships between the functioning of the barrage and its management on the protected lower Derwent (EA, 2013c). The likely outcome is that the barrage should be opened for extended periods of time (4 – 8 hours) with periods being shut; thus making much of the lower Derwent tidal again and encouraging migratory species back to the River Derwent. This will aide in the restoration of natural processes to the River Derwent, which in turn, will assist in meeting WFD targets. Subsequently, this could reduce issues regarding sedimentation in the short term but, if the barrage remains open, this will change the naturally muddy areas in the lower Derwent by creating a 'flushing out' effect, potentially leading to mass habitat change affecting some of the protected species within the water course. Water abstraction at Elvington WTW relies on the barrage to provide sufficient water for abstraction - these proposed alterations must not impact this facility.

5.5.1 Management measures and projects

To ensure the restoration of longitudinal and latitudinal connectivity within the River Derwent to its floodplain ecosystems, drastic measures have to be undertaken. These measures must include improvements to fish access and allow natural processes to occur (water, sediment, organic material and nutrient transportation), this will assist in natural environmental characteristics that native aquatic flora and fauna need to thrive. When considering the removal and modification of the weirs located on the River Derwent the creation of passages (fish pass/bypass channels) is vital to help restore upstream migration for aquatic species (Pess *et al.,* 2005; Roni et al., 2005; Table 5.7).

Dredging has been undertaken on the River Derwent for many years to mitigate sedimentation issues. Yorkshire Water removes around 25,000 tonnes of sediment annually from the lower Derwent at Elvington WTW. This solution is incredibly threatening to an aquatic ecosystem but is extremely important to stop the build-up of sediment as it is essential in the mitigation of flooding in populated areas. Therefore, it must be reiterated, a sensitive approach to dredging should be undertaken ensuring that the local ecosystem is not heavily impacted and that water supply is still readily available; areas that are likely to flood will need special attention such as Stamford Bridge. It was noted that, at the time of the walk-over survey recent dredging had been undertaken in the middle reaches of the Derwent. Due to the abundance of the nationally scarce white clawed crayfish, it is now recommended that trapping and relocating of present specimens is undertaken on this stretch before future dredging.

Potential management measures or projects will be affected depending on the original use of the structure. The highest priority should be given to installation of a fish pass providing connectivity to the river system as a whole, especially for protected and scarce species (Table 5.7). High priority should also be given to modification to in-channel structures for instance through the creation of a v-notch in the structure. A v-notch would lessen the effects of impoundment (but still keep suitable amounts of water for abstraction), also creating a potential area where fish could pass; this option should be undertaken in conjunction with a fish passage to optimise upstream migration. Ultimately, if the complete removal of the structure is feasible, without impacting its original use and funding was available, this should take privilege (Table 5.7). It must be noted that if this was to commence a riparian strategy would also be necessary.

Table 5.7 Management measures and projects for proposed modification to in-channel structures

Options	Outcomes	Constraints	Responsibility
Remove structure			
Structures that are not obligatory for management of waters for flooding (such as Howsham Mill weir) should be removed to restore natural processes to the river channel. This can be instated in reaches where milling activity was prevalent. This option needs to be undertaken with other in-channel restoration measures, for example, bed alterations regarding (rock chute) depending on the difference between the bed height at the bottom or the weir to the top or the creation of several rock or log weirs to increase the gradient (Roni *et al*., 2005; House, 1996).	Removal of structures will eventually restore the river and its designated sites to its natural processes; water depth, flow velocity and sediment movement return to natural processes (decreasing siltation) due to removal of impoundment; longitudinal migration of aquatic species will return without barriers.	There are several types of structures within the Derwent catchment with a variety of purposes; the function of a structure could have been for milling (outdated), hydrological gauging and impoundment for water abstraction, the national importance and heritage of a structure, and existing in-stream habitats can be considerably impacted by removal of a structure. Also various habitat types within reaches would be altered by the structure, these habitats are likely to have developed to the structure specific habitats like high sedimentation in navigation channels as well as the areas of high scarification after the turbulent flows of a weir; socio-economic value must be considered (FAO, 2008). Highly invasive in-situ works will be required to remove the structure, heavy construction equipment would be needed to remove the foundations. Temporary damming will have to be undertaken to provide suitable working areas. Prevention measures need to be established to stop contamination from equipment. This would be an expensive option (EA, 2010).Careful consideration needs to be taken regarding the surrounding areas and habitats.	EA, IDB, Land owners, Natural England, Defra.

Options	Outcomes	Constraints	Responsibility
Modify structure			
It is essential that in-channel structures do not impair the movement and passage for aquatic fauna. This option improves longitudinal migration which helps to improve the localised area and even the river as a whole. Existing structures can be modified and altered in a few ways; a reduction in the height of the weir crest which should allow fish passage up and downstream during slow flows, also there will be a decrease in the amount of water impounded; a v-notch can be cut into the weir potentially allowing fish movement; put in place an undershot system which will improve passage of fish upstream and sediment downstream; modify the structure into a step weir with areas of pools to aide fish migration; where the wrong fish passage has been installed or it is unsuccessful a different style could be put in place (NSW, 2006; EA, 2010).	Physically modifying a structure to still undertake its original task, for instance, increase water levels for public water supply as well as keeping a stable level of clean substrate for gravel spawning species. These modifications are made to make the structures easier to pass for fish, water and sediments. This option will help restore habitat connectivity in the catchment and will be cheaper and more feasible than complete removal.	Dependant on the original operation of the structure it can be incredibly difficult to undertake alterations on an in-channel structure. There are several constraints with undertaking modification to a weir: time consuming, rather expensive to commence, existing structure may not be steady enough for additional works due to age and maintenance regime, the original operation of the structures such as water level control function and the nearby habitats. Due to the original purpose of Barmby Barrage (maintaining river level for abstraction) strict practices must be appointed. Careful consideration needs to be taken regarding the surrounding areas and habitats due to some weirs being in protected areas.	EA, IDB, Land owners, Natural England, Defra.

Options	Outcomes	Constraints	Responsibility
Alter operation of structures			
Not all the structures on the River Derwent are operational therefore only a few structures can be taken into consideration (Kirkham Sluice (Flood Defence), Stamford Bridge Sluice (Flood Defence), Elvington Sluice (Water Abstraction) and Barmby Barrage (Water Abstraction).	Altering the way a structure is operated with consideration to its original purpose is the only way to ensure safe fish migration and transportation of sediment. Some of the structures are operated manually by a pre-set timetable and/or by the conditions in the river. Others are operated automatically with regards to constant conditions in the river (EA, 2010). It is possible that these procedures can be altered to be sympathetic towards natural riverine processes. If they are left open for longer periods of time the impoundment effect will be reduced, flow regime and sediment transportation will begin to recover, connectivity and free movement of organisms will be restored (Rickard *et al.,* 2003).	The original purpose must not be affected. The majority of the weirs in the River Derwent catchment are to maintain water levels and/or flood alleviation. It may be feasible to allow for the continual opening of Kirkham and Stamford Bridge Sluices under most flow conditions although it may be necessary to close when flow changes dramatically. Elvington Sluice was put in place to maintain water levels for abstraction for domestic water supply. Thus alterations to the operational protocols to reduce the impoundment may not be feasible.	EA, IDB, Land Owners, Natural England, Defra.

Options	Outcomes	Constraints	Responsibility
Provide suitable fish pass and/or suitable attractant/deterrent measures			
There are many methods of adding in-channel structures to aide fish migration (FAO/DVWK, 2002). Bypass channels - a waterway that is excavated around the river bank which borders the barrier. Modification or utilisation of an old obsolete structure for this purpose is ideal for instance, Stamford Bridge Sluice. Stepped fish pass - the height that needs to be achieve is broken down into steps. This is generally undertaken on small weirs, a small pool is created at each step for the fish to rest. This is ideal for salmonids e.g. pool and weir. For instance Brompton Beck. Sloped fish pass - baffles are put in place to decrease the velocity of the flow so that species can swim up the passage. These can sometimes be long and steep (e.g. rhomboid pass). Various objects can be put in place to deter aquatic species away from in –channel structures such as sensory deterrent systems (acoustic air bubble curtains, electric barriers, underwater strobe lights) (USACE, 2012).	Provides connectivity for aquatic organisms to the River Derwent catchment without affecting the original purpose of the obstruction. Reconnection of up and downstream habitats will potentially increase breeding success, provide better access to nursery areas, increase food availability. There will also be an increase in genetic integrity through the reconnection of isolated populations. Screening will be needed near water abstraction points (grills), pumping stations and hydropower schemes, to prevent entrapment and impingement (Popper & Carlson, 1998; Noatch & Suski, 2012).	There are several constraints to provide the necessary connectivity, attractant or deterrent to overcome an in-channel structure: topography of the existing obstruction, structural condition of the existing obstruction, up and downstream water levels (navigation), access and working conditions (space and location), ownership, conservation matters, planning matters, utilities (water abstraction) and finance (EA, 2010; EA, 2010c). The species that are present need to be taken into consideration due to connectivity, salmonids are strong swimmers thus can use most passes whereas, coarse species including lamprey are weak swimmers and will need a gentler flow, stepped weirs are better for these species. Some of the current passages are unsuitable for specific species due to turbulent flows and height of the weir. It is important that the right provisions are made (EA, 2010). Another constraint with fish passages is the inability to provide insufficient attractant flows to entice the fish towards the pass to migrate upstream. In some circumstances additional flow must be added to attract fish towards the pass.	EA, IDB, Land owners, Natural England, Defra, EYRT

5.6 Bank and riparian rehabilitation, and modifications to flood embankments

In much of the Derwent catchment bank side areas including riparian zones are under significant pressure from habitat degradation. These areas are essential for the continuation of natural processes, riparian areas provide much of the habitat needed for terrestrial prey for fish species such as winged invertebrates. Many of the flood embankments are completely restricting natural processes such as sediment disposal into floodplains. There are many ways that these obstructions can still be used with having a decreased effect on the surrounding ecosystem.

5.6.1 Management measures and projects

Correct management of river banks can have positive effects on fish assemblages through the creation of limited habitats and reconnection to vital spawning areas and this is important for the recovery of the system.

Rehabilitating the river morphology is vital, severe anthropogenic impacts have destroyed and altered it. Two methods can be used to help rehabilitate such areas; soft and hard engineering (Table 5.8). Soft engineering techniques use organic materials to alter the morphology of the bank or bed in order for the river to regain natural processes and has minimum impact on other areas. INNS management is to eradicate and control such species like Himalayan balsam; protected areas should be dealt with first. By far the biggest option is alterations to embankments, whether it be complete removal, part breach, lowering or setting back. Depending on the original purpose of the embankment may influence what, if anything, can be done. Most embankments were constructed for flood prevention but they restrict the rivers course and eliminate any flood plain processes. Highest priority should go to soft engineering techniques and should be initiated immediately as these methods are green and most practical as maintaining the river at its current state is important. INNS eradication should be medium priority with development of long term plans. Also, medium priority should be given to part breach or setting back of embankments, this option will take time to commence as flood management plans and relevant agencies will need to be thoroughly consulted, specifically landowners, EA and IBD.

Table 5.8 Management measures and projects for bank and riparian rehabilitation, and modifications to flood embankments

Options	Outcomes	Constraints	Responsibility
Rehabilitation of riverine banks and bed			
Soft engineering techniques.	Artificially altering the river bank and bed reducing the gradient which subsequently creates shallow faster riffles and slower deeper pools. There are several techniques such as log structures (deflectors and spurs), brush bundle/ root wads (these include live willow withies, spiling, faggoting) and the creation of aquatic ledges. These techniques help restore the river back to its natural processes. Newly created aquatic ledges provide a series of shallower, narrow and deeper areas (riffle and pool) that alter the flow dynamics, which improves the emergent/marginal flora and fauna diversity and density (Roni *et al.,* 2005; FAO, 2008; Pretty *et al.,* 2003).	There is much speculation about the suitability of in-situ enhancement due to some of these techniques being naturally occurring without evaluation of what factors impact the habitat complexity, as well as what processes need to be corrected that may be limiting physical and biological production (Roni *et al.,* 2005).These techniques suffer from rotting, being eaten or even potentially being washed away in high flows.	EA, EYRT, Natural England
Hard engineering techniques.	There are several techniques that could be used such as bolder structures or gravel addition (to create a riffle), gabions and gabion baskets, geotextile rolls which incorporate native plants species, and stone riprap. Although not the most aesthetically pleasing, these techniques need to be used in areas that are under substantial pressure from erosion, for example at the bottom of a weir where turbulent flow is high.	The main constraint to hard engineering techniques is that they are permanent and not natural: geotextile is not a naturally occurring material, so it is recommended that hard engineering techniques are used alongside soft engineering techniques to create the best result for the system. It must not be forgotten that these techniques are predominantly successful when coupled with restoration of natural processes. Contrarily these enhancement techniques are more than likely to treat the symptoms that arise from the issues rather than addressing the fundamental causing of the degradation of the habitat (Roni *et al.,* 2005).	EA, EYRT, Natural England

Options	Outcomes	Constraints	Responsibility
Improvement and adaptation of riparian habitats management			
Riparian flora and invasive non-native species (INNS) management (Brush removal management) (Roni *et al.,* 2005; Richardson *et al.,* 2007)	There are many techniques to address the lack of shading and over-shading including: pruning, trimming coppicing, and staking These methods alter the densities of riparian vegetation which will improve the overall riparian and marginal habitats. Willow is ideal for planting due to its vigorous nature and it provides good bank support. When planting trees and shrubs, the plants should be put in clumps dispersed along the bank, it is essential that some areas are left open. It would be ideal to add flora to areas that are suffering from bank erosion or similar issues.	Over shading could occur if areas are not managed correctly, a mechanical rotational management scheme should be established on a 10 – 15 year basis for trees and shrubs, and a yearly plan for INNS eradication. Excess nutrient loading into a system can increase the productiveness of flora, in some circumstances these may be invasive species. INNS can choke shallow streams, so intensive eradication should be undertaken to ensure none are present. Over shading decreases the primary production in a system by limiting vegetation and phytoplankton growth (Roni *et al.,* 2005).	EA, IDB, Land owners, Natural England, Defra, EYRT
Complete removal or part breach or lowering of embankments			
Complete removal or part breach or lowering of embankments	Will increase natural localised flooding, natural processes will slowly start to be restored and the river will gradually recover. This option provides potential benefits to the river catchment; connectivity to flood plains removes sediment suspended in the water column, also natural colonisation of riparian and floodplain wetland habitats will occur (increasing one of the most distinguished features of the Derwent Ings).	The topographical nature of the Lower Derwent Valley may allow for complete removal of embankments without potentially having an effect on the localised flooding. Measures should confer with the Derwent Catchment Flood Management Plan. Complete removal is unlikely due to the socio-economic impacts that would arise, the area has been modified for a long time, and sudden change may have dramatic effect on the SSSI and SAC sensitive species. It would also be expensive to undertake.	EA, IDB, Land owners, Natural England, Defra.
Set back of embankments and re-meandering	Creating a large expanse next to the river where natural processes can occur (flood plains/re-meandering). When setting back an embankment the surrounding industry should be taken into consideration, the materials that were used to construct the old embankments can be reused. Re-meandering increases the total length of the river as well as reinstating natural riverine processes. This will increase the total habitat available which in turn increases the total biomass and diversity. In some circumstances where set back or re-meandering is not possible different method can be commenced, e.g. the addition of large woody debris and riffle/pool sections rather than a meander (FAO, 2008).	This is a more feasible option than complete removal, although, many different directions can be undertaken with this option. Like any other modifications to embankments there are potential effects that it may have on the surrounding habitat as it would have adapted overtime to the change in habitat type. Sudden alterations could do more harm than good. Again this would be costly to undertake.	EA, IDB, Land owners, Natural England, Defra.

5.7 Angling

There are several angling clubs situated along much of the Derwent; York & District Amalgamation of Anglers being the biggest having access and maintaining fishing rights to over 30 stretches in the Derwent. Some angling clubs are the riparian landowners but in some situations they rent the rights from landowners. Many stretches of the Derwent have had populations of brown trout or coarse fish species stocked for either angling purposes or for increasing genetic integrity for instance, barbel stocking near Malton at the start of 2013. Stocking takes place on a regular basis at different locations, due to section 30 consent it is essential that regular monitoring of the magnitudes of stocked species, as well as fish health checks are undertaken. This ensures that the wild populations are continuing and that stocking is not negatively affecting them. When fish are stocked, it could be recommended that some are tagged; this could help to see the true connectivity of the Derwent due to the in-situ barriers at some locations.

The Derwent and several other rivers in its catchment are listed in the National Trout & Grayling Fisheries Strategy (2003), which aims to conserve and improve stocks of trout and grayling along with providing better socio-economic benefits that derive from these fisheries (EA, 2003). Due to the need to maintain natural genetic integrity, only female triploid trout are now stocked; this still adds more fish from the perspective of an angler but interferes less with the natural environment, thus not decreasing genetic integrity through inbreeding (by 2015 female triploids will be the only type of fish that can be stocked) (EA, 2011b; EA, 2003).

Having a well-established salmon and sea trout fishery in most Derwent tributaries will benefit the local economy, with a trickledown effect that local economies could receive up to £2,500 per fish (EYRT, 2012b). Yorkshires only Salmon Action Plan river, the Esk, is accomplishing its SPA status and subsequently producing over 200 salmon and 600 sea trout per annum along 28 miles of the river. As the length of the Derwent exceeds that of the Esk, when making a comparison it can be deduced that 500 salmon and 1400 sea trout would potentially be caught if specific protection measures were put in place. Further on from this, it could also be deduced that from these figures that this could supply the Ryedale/Yorkshire economy with over £12.5 million (EYRT, 2012b).

5.8 Conservation and preserving existing habitats for the future

There are many protected areas along the course of the Derwent and within its catchment (terrestrial and aquatic). The vast majority of them are classified as 'unfavourable' or 'unfavourable recovering', although some, in recent years due to preservation management practices and conservation efforts, are regaining 'favourable' condition status. Where the units are failing to meet the favourable conditions it is generally due to the downstream effect rather than directly linked to the riparian owner. Pollution and sediment from the upstream environment is brought downstream intensifying as it travels further towards the mouth. As previously mentioned, cooperation between stakeholders is essential; the existing affiliation between them will have to be built up and reinforced by conservation bodies such as EYRT and Yorkshire Wildlife Trust, under the CaBA initiative. In doing so, management practices will become more socio-economically feasible by defining specific roles to the correct organisation to undertake particular tasks.

The conservation sector can only thrive as a result of considerable effort from its volunteers. Recent efforts by the Yorkshire Wildlife Trust have brought a new management project for the internationally important grasslands surrounding much of the Lower Derwent NNR (Wheldrake Ings). The 157 ha expanse was granted funding from Biffa Awards and Natural England's HLS scheme. This provides an insight into the potential for favourable conditions of the Derwent, as a whole, in terms of the practicability and removes financial drawbacks. Additionally, funding was also granted for the erection of stock-proof fencing around the nature reserve (6.5 km) which will bring more regular and effective grazing management (YWT, 2013; 2013b). Moreover, this project will limit access to riparian areas and thus contribute to addressing riparian poaching, thus potentially decreasing sedimentation within the Derwent.

The continuous efforts of the EYRT should be unscaled through the CaBA and used to engage with stakeholders to meet obligations set out through the WFD.

Involving local communities in conservation activities is essential. Community integration can help to provide additional grants though various financially supporting companies' schemes. There have been many local community groups that have formed and folded over the years in the Derwent catchment, some of which were within public eye with good scope for change, although in most circumstances very little came about. Yorkshire Wildlife Trust and EYRT can work alongside riparian owners to increase community participation in the restoration of the river and surrounding are; the community will subsequently gain a sense of ownership thus increasing educational awareness. This is not likely to be an easy task to begin.

5.8.1 Conservation through education

The integration of local communities is as important as any other; the easiest way to undertake this would be through the creation of an action group or through education of adults and children. Programmes and schemes could be set out by landowners, under the HLS scheme using agricultural or riparian land for educational purposes can be financially rewarding. It is encouraged that free visits from schools and colleges are increased to explain agricultural practices as well as conservation and the production of food. Much of this is basic information that can be relayed through farming factual leaflets produced by Natural England in partnership with the landowner. All relevant other legislation and checks will have to be undertaken prior to the establishment of these trips (Defra & Natural England, 2013). It is also recommended that landowners consult with other bodies for a cross compliance which, in turn, could get the children more involved rather than just education. The Salmon & Trout Trust can help with education, especially with the River Fly Partnership (S&TA, 2013; 2013b).

Wheldrake Ings is a perfect area for educational purposes, with recent funding providing an ideal opportunity for the incorporation of education into the surrounding community. This site is mainly visited for bird watching; there are several hides and an information office, which is run by Natural England with help from Yorkshire Wildlife Trust. This information office could provide more up-to-date information on the River Derwent and highlight the impacting issues in the catchment. Rather than solely targeting the wetlands, it would be better to express how the wetlands would not be there without the natural processes from the river. During open days, displays and talks could be given about the river which, in turn, could potentially help raise awareness of the River Derwent - these could be undertaken by the EYRT. Practical sessions could also be undertaken during this time which would help evaluate the abundance and diversity of species present. The EA owns various strips of land along the course of the Derwent, specifically along the heavily channelised section in the middle reaches. Here, after restoration works have commenced, the EA can hold courses for young people.

5.8.2 Preservation of existing habitats

Although much of the Derwent is under considerable pressure from anthropogenic activity, the existing areas have gained recognition for specific habitats and species therefore, the preservation of existing habitats must not be disregarded and should be a high priority (Table 5.9).

Table 5.9 Management measures and projects for the conservation and preservation of existing habitats

Option	Outcome	Constraints	Responsibility
Preservation of existing quality habitats			
Cost effective conservation method; protection of current habitats is vital, rather than restoring later (Roni *et al.,* 2005). Habitats to preserve include gravel/pebble/ cobbles substrate reaches (specifically for spawning fish) as well as fine substrate areas (lamprey nurseries), existing aquatic and marginal macrophyte communities which support a diverse array of species, reaches of high flow and morphological diversity, wetlands and in-channel woody debris.	It is vital that these management options are carried out on a catchment-wide scale including the protected areas. Preserving these areas will ensure that the highest quality habitats within the Derwent catchment are maintained without interference or potential degradation. A management scheme should be developed to minimise impacts; these should be site specific. With regards to woody debris, removal should be stopped and a management regime should be made to ensure a high percentage of this specific habitat is upheld. If areas are preserved correctly, there is potential to achieve conservation recognition.	Due to the areas within the Derwent failing to comply with WFD, the entirety of the Derwent is being affected in some way or another. Pristine areas of the Derwent could be neglected due to organisations wanting to increase restoration and rehabilitation at different locations. Although large woody debris is essential for aquatic life, increased amounts occurring within the system can cause potential damage to large structures at high flows, such as bridges which subsequently increases the flood risk, this has occurred in the Rye District. If the increased risk outweighs the environmental benefits, sensitive management should be endorsed.	EA, Defra, Natural England, Land owners, Yorkshire Wildlife Trust

5.9 Development of a River Basin Action Management Plan

As previous highlighted, it is crucial that collaboration between stakeholders, government agencies and conservation bodies is put into practice to rehabilitate the River Derwent. This is akin to the catchment partnership promoted under the Catchment-based Approach (CaBA) promoted by Defra (Defra, 2013) to meet the requirements of the WFD and implement a catchment management plan. There are many stakeholders from different sectors with concerns for the rehabilitation of the Derwent - creating partnerships makes available a variety of skills and resources to deliver the plan. Without such co-operation, constraints will come about with conflicts between stakeholders and this will potentially exclude groups or individuals providing additional resources to develop projects. Charitable organisations should prevail in forming an alliance towards meeting the WFD targets in consultation with government agencies. This will enable a positive response and give ownership of projects within the stakeholder's expertise and given resources.

For overall successful rehabilitation of the Yorkshire Derwent catchment, it is necessary to develop a plan with a series of actions following the project cycle of identification, formulation, implementation and post-project monitoring.

Primarily, the issue that needs addressing has to be identified. Some of the potential issues have been highlighted in the 'Issues threatening the River Derwent and its tributaries'. After the project has been identified, the proposed project can be prepared through formulating a series of tasks and goals. These tasks and goals can then implemented ensuring that priority is given to projects that need further planning, feasibility and walk-over surveys. Finally, it is critical that post-project monitoring is undertaken to ensure that all stages of the project cycle have been correctly completed. Amongst this a review of the key drivers for the project can be used to find funding.

It is important that further investigations such as feasibility studies and walk-over surveys are undertaken prior to implementing a project. These may include detailed designs and planning applications that could be time consuming so it is essential that these are undertaken at the start of the project to provide sufficient time to carry out these appraisals. Actions that arise can be incorporated at a later date.

Issues that arise from agriculture and aquaculture practices are considered high priority due to their constant negative impacts, but constraints make targeting these unfeasible to start off with. The sheer scale of operations, along with the expenditure of implementing such projects, will suggest that these should be long term goals, although many smaller tasks linked with these can be undertaken, potentially lessening the effects. Subsequently, concerns should be shifted to smaller, more frequently occurring cases where interactions between stakeholders are high and act as the starting blocks for bigger longer-term targets. Specific projects similar to that on the Costa Beck, where fencing has been erected and the river channel has been modified creating a more diverse habitat, should be recommended.

Currently a large proportion of restoration works for the River Derwent are being undertaken by the EYRT, for example the Straightened Derwent Project and Costa Beck channel restoration. The considerable knowledge and experience within the Trust is down to the vastly differing stakeholders from many backgrounds that all have a common goal, 'restoring rivers to their natural state'. There are also several other organisations that have commenced restoration works on the Derwent and its headwaters. Many of these projects work in unison with each other on different stretches to achieve the main targets of the WFD.

The Catchment Restoration Fund (CRF) was set up in 2012 by Defra to support third sector groups such as charities like EYRT and action groups. CRF aims to restore natural features in and around watercourses, reduce the impact of man-made structures on wildlife in watercourses, as well as reduce the impact of diffuse pollution (Defra, 2013c). This funding scheme among others should be heavily used to implement the strategies, projects and options in the river basin management action plan.

Potential projects have been identified with the specific locations to where these identified issues are having the most impact. The proposed projects are to meet as many drivers for the actions as possible. First and foremost, trying to comply with the water framework directive (WFD) ensures that the projects help to meet good ecological status or potential. It is also important for these projects to meet other drivers such as catchment sensitive farming (CSF), environment stewardship (ES), nitrate vulnerable zones (NVZ) and catchment flood management plans (CFMP). These projects have been given importance whether it be low to high priority or whether it is a short to long term action. These projects and actions are indispensable for the successful rehabilitation and restoration of the River Derwent, Yorkshire (Table 5.10).

Table 5.10 Potential projects that could be undertaken on the Derwent by different stakeholders

Projects	Location	Drivers for actions	Priority and feasibility
Stock-proof fencing (fencing off sections or reinforcing cattle access points, although the latter is not the best option). At strategic locations throughout the catchment, more detailed walk-over surveys must be undertaken to identify the specific areas being impacted the most.	○ Rye Dale (Upper reaches of River Seven). ○ Flyingdale Moor to Weir head ○ West Ayton to River Hertford Confluence. ○ Some reaches of the lower Derwent (Buttercrambe, Howsham).	WFD: Preserve and improve everywhere possible, increasing ecological value of marginal aquatic habitats, bank and riparian zones. CSF, ES. NVZ: Stopping additional faecal matter (nitrates) entering the water course.	Short term action with high priority due to the destructive nature of livestock. Practicability of this project is high due to the various subsidies that are available to undertake stock-proof fencing.
Installation of sediment traps.	○ Heavily motorised areas (towns and roads, A1709). ○ All major tributaries and drainage ditches (River Hertford, River Rye, Sherburn Drainage Ditch). ○ Drains near golf courses and sod farming (Malton & Norton Golf Course). ○ Menethrope Beck. ○ Costa and Pickering Beck (Aquaculture units present).	WFD: Decrease sediment input and loading on the catchment. CSF, ES, R.Derwent CFMP, NVZ, CRF.	Short term action with high priority, feasibility is high funds being readily available. It must be noted that consideration must be given to the sheer amount of potential sediment within any given reach; sediment traps have a limited amount of space available to trap silts. Alternate methods should be investigated.

Projects	Location	Drivers for actions	Priority and feasibility
Investigate the feasibility and implement the clearing of sediment accumulated behind weirs, also analysis should be undertaken to determine the content within the sediment (harmful substances).	○ Majority of the weirs in the catchment will have high sediment loads (Specifically Forge Valley Gauging Weir).	WFD: Reduces sediment dispersal within the downstream in the catchment. ES, NVZ, CRF.	Medium to long term action with medium priority. It is recommended that this is undertaken before any modification or removal works. Contaminated sediment is expensive to remove and dispose of correctly.
Bank protection from erosion.	○ Areas of high boating activity (Specifically Breighton/Bubwith Reaches). ○ Howsham Mill. ○ Channelised sections (Middle reaches).	WFD: Preserving existing habitat from further degradation. CRF.	Medium to long term action with medium priority, although it is essential to protect and maintain quality habitats. Straightforward to undertake with relevant organisational assistance.
Addition of features (in-channel modifications) Large woody debris, pool & riffle, pinching, and bank re-profiling.	○ Costa and Pickering Beck. ○ Middle Reaches (River Hertford to Rye Mouth).	WFD: Improve habitats for marginal plants and invertebrates as well as predatorily species. CRF.	Short term action with high priority, this action is easily undertaken and funding is readily available.

Projects	Location	Drivers for actions	Priority and feasibility
Breach and/or set back embankments (Creation of lowland hay meadows, restoration of relic channels, and flood storage amongst wetland flood plains – which will promote floodplain sedimentation settling).	○ River Hertford to Rye Mouth. ○ Howsham Reaches. ○ Stamford Bridge to Kexby. ○ Bubwith to Breighton.	WFD: Increases floodplain connectivity. ES (HLS special projects, subsidies available). UK BAP: provides more specific habitats for protected species. SPA, SAC, CRF.	Medium to long term action with medium priority. Expensive to undertake but large cross compliance will benefit a vast amount of stakeholders and species.
Reconnection of pristine isolated headwaters (including active management to improve drainage systems)	○ Head waters of Sherburn Beck. ○ Brompton Beck. ○ Ruston Beck. ○ Lower Derwent Valley.	WFD: Decrease sediment input and loading on the catchment, increases connectivity for migratory species. CSF, ES, R.Derwent CFMP, NVZ, UK BAP, CRF.	Long term action with medium priority. Further investigation needed to establish the necessity of this action. Achievability is likely to be low due to the agricultural land owners and drainage, although subsidies are available for maintenance and improvement works.
Installation of buffer zone/strips (or increase length and width). Enhancing the existing riparian area through planting and correct management.	○ Upper River Seven. ○ Middle reaches of the River Derwent – River Hertford to Rye Mouth. ○ Areas of expected high run-off (Near towns/ busy roads – A1709, specifically near Kexby).	WFD: Decreases sediment input by entrapping particles. Sensitive vegetation management. Provide habitat for protected species (lamprey and bullhead). ES (HLS special projects, subsidies available). R. Derwent CFMP, NVZ, UK BAP.	Medium to long action, with medium to high priority. Viability it very high due to ES and CSF.

Projects	Location	Drivers for actions	Priority and feasibility
Management, removal, thinning and relocation of plants (riparian and aquatic) (trees & shrubs) (Including INNS) where over shading.	○ Pocklington Canal Headwaters. ○ Densely populated areas specifically the Lower Derwent Valley.	WFD: Sensitive vegetation management ES (HLS special projects, subsidies available), R.Derwent CFMP, UK BAP.	Continual management regime needs to be upheld. Priority is high because of the aggressive and prolific nature of INNS specifically Himalayan balsam.
Installation of screens in conjunction with deterrent equipment at abstraction points, pumping stations and hydropower units.	○ Elvington and Loftsome Bridge WTW. ○ Minor WTW (Stamford Bridge and Wheldrake). ○ Howsham Mill (Hydropower, Lock and Mill Diversion channel). ○ Stamford Bridge Mill (Bypass channel, pond).	WFD: Structures restrict access to certain areas to divert migration to different paths without causing harm to existing species (catchment connectivity) R. Derwent CFMP. UK BAP.	Long term action, priority is low but feasibility is high. Other more essential methods need to be undertaken first, like providing full catchment connectivity.
Installation of fish passes.	○ Complete redesign at Stamford Bridge. ○ Nunnington Weir (within AONB) could be undertaken as a part of a hydropower scheme. ○ Whitby Road Bridge Weir (Sea Cut). ○ Kirkham Weir (elver pass).	WFD: Structures provide connectivity to waters up and downstream of the impounding structure. UK BAP.	Short to medium term action, priority is very high. Providing connectivity these actions are likely to be undertaken easily, potentially as mitigation strategies for other projects.

Projects	Location	Drivers for actions	Priority and feasibility
Removal and modification of in-channel structures (weirs and sluices)	○ West Ayton Mill Weir (No modern day purpose) ○ Middles Reaches of the River Derwent (Flap gates and drainage ditches are disconnecting pristine headwaters (Sherburn, Brompton and Ruston Becks) ○ Kirkham Weir (potential implications towards nearby bridge and Abbey) ○ Howsham Lock (needs draining and isolating from the main channel).	WFD: Structural changes to in-channel structures will enable fish connectivity up and downstream UK BAP: providing connectivity for priority species. CRF.	Long term action, with high priority. Feasibility is low as more in depth investigations will need to be carry out to assess the potential detrimental implications towards the surrounding environment and infrastructures.
Alteration to operation of structures.	○ West Ayton Sluice, could potentially be used as a fish bypass channel for upstream migration. ○ Stamford Bridge Sluice, potential bypass channel. ○ Elvington Sluice/Lock (although essential for water abstraction).	WFD: Structural changes to in-channel structures will enable fish connectivity up and downstream. UK BAP: providing connectivity for priority species. CRF.	Short to long term action, priority is high. This action is easier to commence than others previously stated actions. Cross compliance with this action is essential as many organisations and stakeholders will have various jurisdictions on different structures, due to land drainage or flood alleviation.

6 Conclusion

The River Derwent catchment, East Yorkshire, has national and international importance and has gained several statuses. The Derwent has areas protected as SAC and SSSIs, amongst other statuses, for a few primary named features which include the existence of lamprey and eel, as well as for specific flora. The Derwent is failing to comply with WFD (meeting GES or GEP). Several major features have been highlighted throughout the catchment that are causing detrimental effects on the overall ecosystem health, these include: diffuse and point source pollution, channelisation and disconnection from the floodplains, riparian habitat degradation and destruction and in-channel structures. These derive from, and are influenced by, anthropogenic pressures. These anthropogenic and morphological pressures are affecting the magnitude and quality of waters within the catchment, thus dramatically altering and depleting the natural habitat resources. There are also other minor pressures some of which are derived from recreational activities (angling, boating and other water borne interests).

In producing a Fisheries Management Plan, various aspects need to be researched and analysed. From this, the current status of the River Derwent was assessed by evaluating all available literature and a walk-over survey was conducted to determine and emphasise the major issues that arise within the Derwent catchment. Statistical analysis was carried out on available fisheries data (electric and angling) and, finally, a brief outline of the relevant institutional framework was consolidated along with various suggestions for future management methods and projects that could be carried out within the catchment.

Fish assemblages within the River Derwent catchment are under severe threat from anthropogenic impacts. The fish stocks are in relativity poor condition: this was validated through comparison between electric fishing and angler catch survey data. A diverse range of species were recorded. The River Derwent conforms to the typical zonation described by Huet (1959); this cannot be said for the River Rye due to limited data sets. Catch per unit effort (CPUE) was analysed with regards to the angler catch data. An increase in No.fish/100m^2 in more recent years was found which could indicate that the habitat quality, prey organisms and recruitment are improving.

Broadening the angler catch data is crucial. Angling clubs, agencies and other organisations should be encouraging anglers to record more, if not all, their catches which will help increase the River Derwent catchment fisheries data set and provide more accurate data.

One of the main underlying weaknesses of this management plan is inadequate spatial and temporal fisheries data on which to validate the conclusions. It is necessary for the future of the River Derwent catchment that the Fisheries Management Plan (FMP) and the New River Basin Management Plan (RBMP) are combined. The FMP can provide indications of the status of the fisheries. It is recommended that the existing work is built upon and the aforementioned management methods and projects are implemented immediately. Monitoring of the fish assemblages should continue after the proposed interventions have been successful (post-project monitoring). It is also suggested that, where possible, the numbers of surveyed sites are increased. Survey sites could be added up and downstream of a specific feature; for instance a breach in an embankment where a new flood plain is rejuvenating would indicate the colonisation rate of this area.

Building from what this study has found is essential. The highlighted issues can be monitored and when the options and projects have been implemented for the rehabilitation of the Derwent, the surrounding area can be monitored to see how successful the projects have been. This will help to provide insight into other future methods and whether they need to be amended.

Another highly beneficial aspect to further this study would be to analyse the age classes of fish (recruitment) within the catchment (including <0, 1+, 2+ and 3+ years). This would mean that the length (cm) of fish would have to be measured rather than just the frequency. This would be ideal for iconic species such as salmon, eel and lamprey. Measuring the year classes of these protected species will aide with the overall management of the system.

When considering the rehabilitation of the lower Derwent, it is necessary not to compromise the water abstraction and impoundment for the treatment works, as well as affect the protected areas located within the Lower Derwent Valley. This is one of the main reasons Barmby Barrage was put in place at the mouth of the River Derwent and jeopardising this could lead to severe socio-economic impacts. Any other methods of rehabilitation within this area will have to be seriously considered and feasibility studies will have to be undertaken. Due to the variety of different anthropogenic pressures that arise within the Derwent catchment, there are many other benefits that originate from these. For instance, agricultural land use is not completely impeded by this management plan and that the catchments socio-economic benefits are not hindered.

Returning a river reach to entirely pristine condition is impractical given constraints and likely irreparable damage. The restoration potential of a system should be defined to reflect an achievable target (Kamp *et al*., 2007; Haase *et al*., 2013). This can be reflected through a variety of aspects including, biological as well as hydromorphological indicators (Lepori *et al*., 2005). The formulation of targets and end points are a necessity that are developed and portrayed in a series of solutions:

- Alteration to agricultural practices; erection of riparian stock-proof fencing and creation of buffer strips in order to decrease sedimentation.
- Modifications to in-channel structures; creation of a suitable fish passage way(s) and/or alterations to the operation of the structures; this will increase connectivity.
- Modification to embankments; removal and/or set back to increase essential flood plain habitat and processes.
- Alterations to riparian management; INNS eradication management and active riverine engineering, control of harmful invasive species as well as rehabilitate and restore the river to near natural conditions.

These targets can be implemented catchment-wide ensuring the CaBA is used to aid the systems recovery. It is also essential that environmental assessments are undertaken on the success of the rehabilitation and restoration practices that are carried out on the catchment. This is to ensure that the management measures put in place are successful and that they are not having further implications. It is recommended that all riverine work is disseminated through river managers and other stakeholder organisations to that specific reach.

Furthermore, the next stage in getting the River Derwent catchment to good ecological status or potential should be the creation of a River Derwent Catchment Action Group (DAG). This group would be a collaboration of various stakeholders and landowners, government bodies, local government, and with specific positions for example; press and media, volunteers (specifically schools). DAG's main goal is to help with the restoration efforts within the Derwent catchment through concerning itself with any issues that involve the protection and revitalisation for public and economic benefit. DAG could also petition for conditions of planning to be implemented, if necessary. DAG will help protect the river by integrating the local community into monitoring the rivers and its protected areas. Promotion of future projects could be through newsletters, events and talks and a website including social media. This should also include a financial fundraising side as it is vital for any of these options and projects to be undertaken. DAG will help the rejuvenation by proposing and contributing in restoration schemes where possible. It is also suggested that DAG should propose its own schemes, with the help of other charities like EYRT, so that maximum effort is being taken and that no conflict arises.

Landowners and organisations will need to obtain funding through various means for instance: government schemes, fund raising, and sponsorship. As previously mentioned, there are a few government schemes that enable agricultural landowners to potentially attain funding for the options and projects through HLS or other similar stewardships. Also, the Catchment Sensitive Farming's Capital Grant Scheme could provide funding for specific areas such as watercourse fencing and sediment ponds and traps. The landowners will have to go through Natural England's relatively competitive application process. It is suggested that organisations such as DAG and EYRT highlight these opportunities for landowners and aid their completion of applications with the hope of further success.

The Environment Agency has a considerable amount of funding to deliver the Water Framework Directive (WFD) outcomes, which is available for local action groups, like

DAG. This is a sustainable funding source which is ideal for DAG to enable set up and establishing itself before outreaching further funding. The Catchment Restoration Fund (CRF) should also be used when DAG is established as the CRF targets will help in meeting good ecological status or potential under WFD.

Other aspects of funding could arise from fundraising whether it be from organising an event to major donors. Charitable organisations like EYRT could run an event with DAG educating local people on the issues that the Derwent catchment is facing. In doing so, they will be able to raise awareness and hopefully gain financial support from local residents. Some large corporate companies pride themselves in sponsoring local charities, DAG would be a perfect beneficiary for this.

Although, it is evident that the River Derwent catchment and its fisheries are under a substantial amount of pressure from various anthropogenic threats and issues, this Fisheries Management Plan highlights the importance and provides new management methods and projects that need to come into fruition immediately so that the catchment returns to near natural functioning and is un-constrained. In doing so, it will help to achieve good ecological status or potential before 2027 in line with WFD.

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