Environmental River Enhancement Programme

Annual Report 2017

IFI/2018/1-4430

Iascach Intíre Éireann
Inland Fisheries Ireland

EREP 2017 Annual Report

Inland Fisheries Ireland & the Office of Public Works

Environmental River Enhancement Programme

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Inland Fisheries Ireland

OPW
The Office of Public Works
Oifig na nOibreacha Poiblí

Acknowledgments

The assistance and support of OPW staff, of all grades, from each of the three Drainage Maintenance Regions is gratefully appreciated. The support provided by regional IFI officers, in respect of site inspections and follow up visits and assistance with electrofishing surveys is also acknowledged. Overland access was kindly provided by landowners in a range of channels and across a range of OPW drainage schemes.

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Introduction

The Environmental River Enhancement Programme (EREP) underwent further modification in 2017. Discussions between OPW and IFI identified further constraints on IFI's continuing capacity to provide specific services to the project in respect of field site visits for maintenance, auditing and oversight of Capital Works exercises.

The revised programme for 2017 focussed on a series of agreed investigations that would provide OPW with information on issues within drained catchments pertinent to the Water Framework Directive (WFD) and implementation of Programmes of Measures (POMS) in regard to WFD. It was also agreed that relevant information available within IFI on fish and habitat, pertinent to OPW and its drained catchments, would be made available to OPW. This was particularly the case with data on the distribution of larval lamprey, on adult lamprey spawning and on locations of potential barriers to fish passage. Information on larval lamprey distribution is relevant to informing OPW foremen in scheduling works on specific channels. Information on potential barriers to fish passage also allows for these issues to be identified in the course of works scheduling, with the potential for passage issues to be addressed by way of capital works as and when the maintenance work reached the specific barrier.

The 2017 programme included-

- Detailed survey of the lower Inny catchment
    - Fish Population Index (FPI) surveys at a series of sites
    - Rapid Hydromorphology surveys (RHAT) covering all of the fish sites
    - Small Stream Risk Survey (SSRS) to assess water quality at all of the fish sites
    - A survey of potential barriers to fish passage (in excess of 700 potential sites)
- Long-term monitoring study repeat surveys
    - R. Clodiagh (1996-2001)
    - R. Dungolman (1993-2001)
- Survey of gravel traps in OPW catchments
- Desk study of potential locations where re-connection of meanders may be feasible

1.1 The Inny Survey Programme

The WFD was the original driver for the EREP studies, commencing in 2008, with a focus on addressing channels impacted by arterial drainage. The physical effects of the drainage were mediated through the channel hydromorphology – the hydrology, channel form (including instream and riparian condition) and channel continuity (longitudinal and lateral). The physical impacts, in turn, influenced and controlled the biology of the instream animal life (affecting fish and invertebrates) as well as the vegetation in the channel and the bank slopes.

The WFD looks at water quality in a holistic manner and, in essence, is describing 'ecological quality' by examining a range of biological indicators or Quality Elements and generating Ecological Quality Ratios (EQRs) for each indicator type – fish, aquatic plants, benthic invertebrates etc.. The scoring (between 0 and 1) for each Quality Indicator then classifies the waterbody being examined into one of the categories – HIGH, GOOD, MODERATE, POOR or BAD. This is the underlying aim with the timed electric fishing survey programme – the FPI – that IFI has developed and has been rolling out annually as part of the EREP deliverables. Use of the FPI allows a biological quality ratio to be generated for each fishing site i.e. a fish EQR for each site surveyed in OPW catchments.

In tandem with the biological quality indicators, the WFD takes the physical habitat into account and the Rapid Hydromorphology scoring (the RHAT score) provides a quality rating for the suite of hydromorphology elements. By collecting both fish and hydromorphology data using WFD-compliant methods at all study sites, the IFI study within EREP is enabled to compare the data sets from each location and examine how the fish community may be impacted by the overall hydromorphology. The RHAT score is a composite of eight different elements. Each of the eight is scored individually during the RHAT assessment of a typical 500m length of channel. This allows the fish EQR to be compared with the overall RHAT score as well as with any of the individual eight scores that make up the composite RHAT score. This is important as one or more of the individual scores may be having the largest influence on the overall RHAT score. IFI has commonly noted that many OPW-maintained channels can have a range of features e.g. tree and riparian vegetation, a range of instream depth values and of instream bed types. Many would score well in the RHAT assessment but the overall score might be brought downward due to other adverse features. Examining the individual components of the RHAT score is therefore important to identify the positive elements as well as those that could be improved.

Continuity, within the hydromorphology element of WFD, relates both to the lateral and longitudinal continuity of a river channel. The lateral continuity element relates to a channel's ability to overspill onto its flood plain at bankfull or higher discharge. OPW drainage schemes are designed to overtop on a Q3 basis i.e. for flow/flood events with a 3-year return likelihood. Thus the lateral continuity element in RHAT is not likely to score highly. However, the longitudinal continuity is something that can be addressed within EREP. Longitudinal continuity allows for the natural regime of the river to proceed downstream and permits unimpeded up-and downstream migration of biota as well as downstream sediment transport. The presence of discontinuities such as perched bridge floors, drop structures, weirs and dams in channels interferes with natural longitudinal continuity and can interfere with upstream migration of fish species e.g. elver life-stages of European eel, adult lamprey and Atlantic salmon migrating to spawning locations as well as downstream migrations of adult silver eel and salmon smolts. The aim with the Inny barriers survey was to examine all potential sites of barriers, based on a desk-assessment method, and to collect baseline information at locations of structures considered to be an obstacle to fish passage. The outcomes would provide a GIS-based layer of barriers within the lower Inny system that could be examined by the resident engineer and foreman of OPW in planning any maintenance programmes for this area. Visual examination of barriers prior to maintenance could signal what would be necessary to be done, materials to be imported on-site etc. to offset the adverse effect of the barrier. This would constitute legitimate use of Capital Works. In many cases, the remedial works would address any adverse structural effects e.g. scour of the bridge floor, at a particular site. In other words, the project would provide baseline information for WFD compliance as well as informing OPW on the status of some of its infrastructure.

1.2 Long-term Monitoring

A problem commonly identified with restoration projects is the limited time period available post-project, to assess the impacts and outcomes of the project:

- Did the project achieve its aims?
- How long did it take for the project to reach a level of 'success'?
- Was the 'success' sustained in the long-term?

Some long-term data sets available to IFI, through its work with OPW, date back to the early 1980s. The Environmental Drainage Maintenance (EDM) study predated the EREP and was commenced in 1990. Two of the studies from the EDM were selected for a 'status update' under EREP in 2017 – the Clodiagh study (Brosna CDS) and the Dungolman study (Inny CDS). The Clodiagh (C8/1, Brosna CDS) study examined the impact of the loss of substantial tree cover in an area given radical maintenance with a dragline in 1996. Monitoring had collected data prior to impact in 1996 and for several years after (1997 – 2001) relating to the fish community, tree cover and channel width, depth, cross-section and channel bed material.

Four sites were surveyed in that period and these were revisited in 2017, with repeat surveying of fish community, tree cover and the channel width and depth regimes. The Clodiagh material was of further value in a study undertaken to look at impacts of tree cover, water supply (surface-fed and groundwater) and channel character on water temperature (see Section 2.4)

The Dungolman study took place in the upper reaches of the River Tang (C8, Inny CDS) and examined maintenance strategies in regard to lateral siltation and management of berms. Two periods of monitoring were undertaken here – three sites in 1993 – 1997 and the original three plus two more in 2000 – 2002. Monitoring included the fish community as well as relevant physical habitat data. In this case wetted width and depth were recorded as well as cross-sections in the study sites and mapping of plant cover in the instream and the berm areas.

During the 2017 study all of the five sites were surveyed for the same elements as previously.

1.3 Survey of gravel traps

As stated, the longitudinal continuity of WFD relates both to movement of biota, in an up- and downstream manner, as well as to downstream movement or transport of sediment. This is a natural river process. OPW installed a limited number of gravel- or sand traps as part of the engineering design in some of its arterial drainage schemes. The aim of this work package is to geo-locate these traps and examine their impact on fish passage and on sediment transport and deposition in downstream areas of the river. Under WFD these structures are impacting adversely on river condition as they are impeding natural downstream sediment transport and may be impacting on migration of fish and other biota. This programme is intended to assess the feasibility of their removal or mitigation in order to improve longitudinal connectivity – for upstream fish movement and for downstream sediment transport, including the movement of gravels.

As a first step in 2017, IFI planned to geo-locate the relevant structures and undertake fish passage assessments on a series of them. This was done in the case of the traps on the Clodiagh at Clonaslee, the Kilcormac Silver (Cadamstown upper), both in the Brosna CDS, and on the Blackboys Bridge trap on the Mulkear CDS using the SNIFFER III coarse resolution fish passability assessment.

Subsequent work will require an assessment of channel bed sediment in areas downstream of these traps in order to assess impact on sediment composition. In addition, remaining structures will require identifying and visiting in 2018.

1.4 Study of old meanders and potential to reconnect these for biodiversity gain

This module avails of on-line digital imagery, both map resources and aerial imagery, to examine current channel form in OPW schemes and identify channels where significant re-routing was undertaken, either post-1945 Arterial Drainage Act or in the 19th Century. An inventory was compiled of locations where there was clear visual evidence of remnant channel form, not integrated into the present-day field pattern. This inventory was used to select a small number of pilot sites to be examined further. Site visits included a visual assessment and photo record of the current situation and an initial levelling survey to examine Ordnance Datum levels of the current field layer, in the old river pattern and the existing river bed. Initial outcomes are presented in this report.

1.5 Synergies with other IFI studies

Many of IFI's fish studies are inevitably linked. The Habitats Directive team in IFI undertakes a series of studies on the status of Annex II fish species (lamprey in particular) in catchments throughout the country as part of its requirements to report under Article 17 of the Habitats Directive. In 2017 the IFI Habitats team undertook catchment-wide surveys on larval lamprey status in the Barrow and Mulkear catchments. The latter is managed, in part by OPW in the context of the Cappamore and Newport Flood Relief Schemes. Thus the data generated in this study is of relevance and value to OPW and, in line with agreements with OPW's Environment Section, this data can be made available digitally to OPW for adding to its GIS layer of environmental items.

In addition to its catchment-wide surveys, the IFI Habitats team undertakes annual or biennial surveys of larval lamprey in a series of INDEX channels, several of which lie in OPW catchments. During 2017, the INDEX sites on the Feale main stem were examined as were those on the Monaghan Blackwater (C/1/1/5) and the Moy main stem (C1).

A further strand of relevance to OPW is the survey programme of barriers to fish migration and the programme of mitigation to address barriers issues. This has been undertaken as part of IFI's Habitats Directive Fish programme, whereby IFI undertakes surveillance and monitoring in respect of Annex II fish species of the Directive. The barriers programme assesses fish passability at barriers in the major rivers designated as Special Areas of Conservation (SACs) for Atlantic salmon and for adult lamprey (sea lamprey and river lamprey). It contributes to assessment of the potential for the migrating adult fish to penetrate into any of the SAC catchments to reproduce and colonise. The process informs as to the status of the Conservation Objectives for species in catchments and the degree to which the Conservation Objectives (COs) are being achieved. The outcomes are relevant to OPW in many cases, with the Moy, Corrib and Boyne all designated as SACs for fish species while also being Catchment Drainage Schemes with on-going maintenance. In addition to the gravel traps, referred to above, fish passability was assessed using SNIFFER at three locations in the Feale catchment during 2017.

In addition to the SAC Rivers, SNIFFER surveys have been conducted on structures in other channels in an 'on-request' basis from IFI RBD personnel. A large weir downstream of Ballinrobe, on the main River Robe channel (CM 4), was surveyed during 2017 and this information is available to OPW.

1.6 Information dissemination

IFI staff involved on the EREP study participated in a number of events during 2017 where the EREP study itself or aspects of it were highlighted. Events included:

- Meeting convened by Offaly Co Council for its foremen involved in river maintenance. IFI presented on the OPW environmental guidance protocol and this was well-received. IFI emphasised that the guidance, while developed with and for OPW, was completely relevant to Local Authorities around the country. The meeting was also addressed by EPA personnel involved in WFD implementation. IFI emphasised that, in its opinion, the Environmental Guidance protocol constituted a Measure that could be rapidly implemented in context of WFD Programmes of Measures

- Meeting with LAWCO Regional Coordinators and Community Water Officers where OPW and IFI both presented on the overall EREP study and on the Environmental Guidance protocol. As with the earlier meeting IFI emphasised that, in its opinion, the Environmental Guidance protocol constituted a measure that could be rapidly implemented in context of WFD Programmes of Measures.

- Workshop visit and seminar on management issues in lowland rivers organised by EPA and IFI in July, consisting of a one-day series of site visits with a morning seminar of presentations on the topic. Dr. Angela Gurnell of Queen Mary College, London, is widely- and highly regarded as a specialist on lowland rivers and how their hydromorphology and ecology interact. The site visits included locations on the Clodiagh and Tullamore Rivers (Brosna CDS) and on the Philipstown River (Barrow Drainage Scheme) followed by a site visit to the upper reaches of the Stonyford (Boyne CDS) where IFI has an on-going study looking at ecology- hydromorphology interactions, facilitated as part of an EREP Capital Works experiment (Section 2.2. below). The seminar was attended by hydromorphology academics from UCD, TCD and NUI Maynooth as well as consultant geographers, by OPW engineers, EPA staff and public authority colleagues. Introductory presentations were given by OPW and IFI staff, focussing around the arterial drainage maintenance and EREP project. IFI presented its published and on-going findings from the Stonyford study. Dr. Gurnell then gave a keynote talk on her work in lowland channels, emphasising that these channels do interact and pointing to the key role of vegetation in facilitating many of these interactions. She was highly impressed with the work being undertaken in the OPW-IFI Stonyford study, both the academic value of the work and also the proactive capacity of the EREP study to facilitate this type of work and its wider relevance to management of low-gradient channels.

- Technical presentation at the Fish Passage 2017 conference in Oregon where IFI gave an oral presentation on its studies using the SNIFFER III barrier assessment methodology and its comparison with the French ICE protocol. The dataset that IFI was able to draw on for its comparative work included a number of structures surveyed as part of the EREP study. The presentation is currently being drafted into a peer-review journal submission with a total of 52 structures available for analysis, including barriers surveyed in the Boyne, Cappa-Kilcrow, Feale, Brosna, Mulkear and Corrib-Mask schemes as part of the EREP.

- Presentation at the Irish Geomorphological Group's Fifth Annual Scientific Workshop 2017 at Geological Survey Ireland's head office. IFI gave an oral presentation on the ability of river plants to act as natural conduits for river habitat rehabilitation. The presentation was titled; Pioneer macrophyte species engineer fine-scale physical heterogeneity in a shallow lowland river. The dataset used in this presentation was collected and processed as part of an EREP study (Section 2.2. below).

- Internal IFI Research and Development Seminar in December 2017, presenting the EREP team's work on identifying barriers to fish passage in the in the Inny Catchment. This presentation discussed the impact of Infrastructure (bridges, culverts, weirs and dams) in fragmenting fish habitat and potentially acting as major barriers to migratory species. The challenges of finding and recording barriers were discussed and integrating this data into the WFD programme of measures. It identified that IFI is working with relevant organisations to identify potential sources of data on obstructions in rivers.

2 Scientific Investigations and Monitoring

2.1 Fish Population Index (FPI)

2.1.1 Survey Introduction

The South Inny Basin was surveyed during the months of August - September 2017. In total 34 sites were sampled in order to determine the density, distribution and population structure of the fish species in the South Inny Basin (Figure 2.1) and the hydromorphological and water quality pressures which could be affecting them.

This FPI survey represents a part repeat of a survey undertaken by the Central Fisheries Board in 1997. In 1997 a fish stock assessment survey for the EU-funded Tourism Angling Measure Program (TAM) was completed for the Inny Catchment, with the survey taking just over three months. The approach taken to repeat this intensive survey was to divide the Inny Catchment into two smaller catchments; one being the South Inny Basin. Before starting the survey, 34 sites from the southern Inny basin were selected from the 1997 survey. Choosing the same sites or sites within a close proximity to those fished in 1997 means a comparison can be undertaken between surveys.

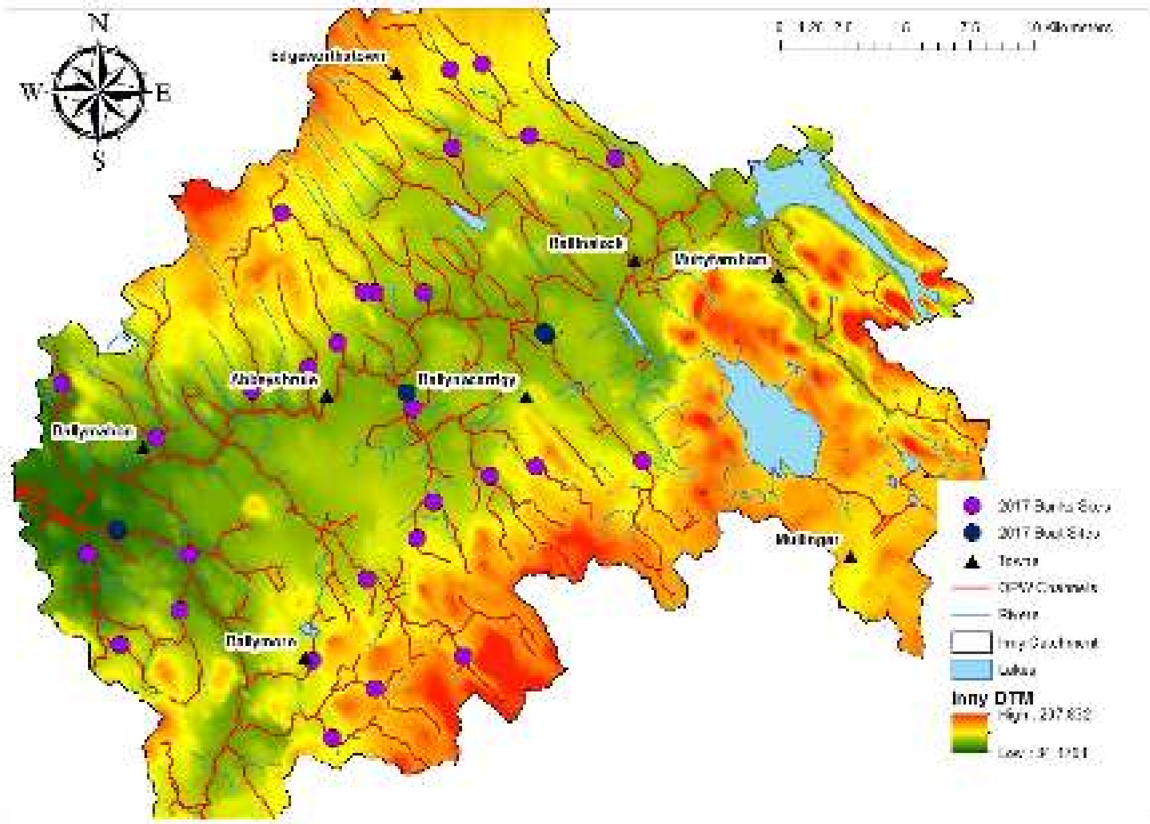

Figure 2.1. Digital terrain map (DTM) of the Southern Inny Basin and locations of bank (Purple Circles) and boat (Blue Circles) based electrofishing sites fished during the FPI Survey 2017, overlapping with sites fished in 1997.

The River Inny and its tributaries were subject to OPW arterial drainage works during the 1960s. The River Inny provides a natural boundary between Westmeath and its bordering counties Longford and Cavan. The South Inny Basin covers an area of 751km^2 and is a region of flat and slow draining land. In the southeast and northwest of the basin there are some low hills (207m) which surround the catchment (Figure 2.1). The catchment is underlain by impure limestone, although some karst has been identified in the lakes on the Meath-Westmeath border. The main lakes located within the South Inny Basin are; Lough Owel, Iron and Derravaragh (Figure 2.1) (EPA, 2016).

Downstream of Lough Derravaragh, the Inny flows southwest and is joined by the Riffey (C33) and Black River (C29), both of which flow in a southeast direction parallel to each other from Edgeworthstown. The Inny then passes through Lough Iron and, as the river continues southwest, it is joined by the Mill (C27) and Irishtown Rivers (C18) which drains the area around Ballynacarrigy. The Inny then makes its way towards Ballymahon, where it is joined by numerous small streams from the north and by the Rath River (C12), which rises near the Hill of Ushnagh from the south. Downstream of Ballymahon, the Inny is joined by the Tang River (C*) which drains the southern tip of the catchment and then flows into Lough Ree via a channel known locally as the Owenacharra River. (EPA, 2016)

In completing the 2017 FPI survey, 29 bank and five boat based electrofishing sites were fished. In conjunction with electrofishing, invertebrate (Small Stream Risk Assessment Score, SSRS), macrophyte (RVEG) and hydromorphology (River Hydromorphology Assessment Technique, RHAT) surveys were carried out at each site.

In total, 1162 fish were captured, measured and returned during the 2017 South Inny Basin FPI Survey. Brown Trout (n=614) was the most abundant species, followed by Minnow (n=228), Stickleback (n=221), Pike (n=43), Stone Loach (n=24), Perch (n=11), Lamprey sp. (n=9), Salmon (n=6), Crayfish (n=4) and Roach (n=2). (Figure 2.2)

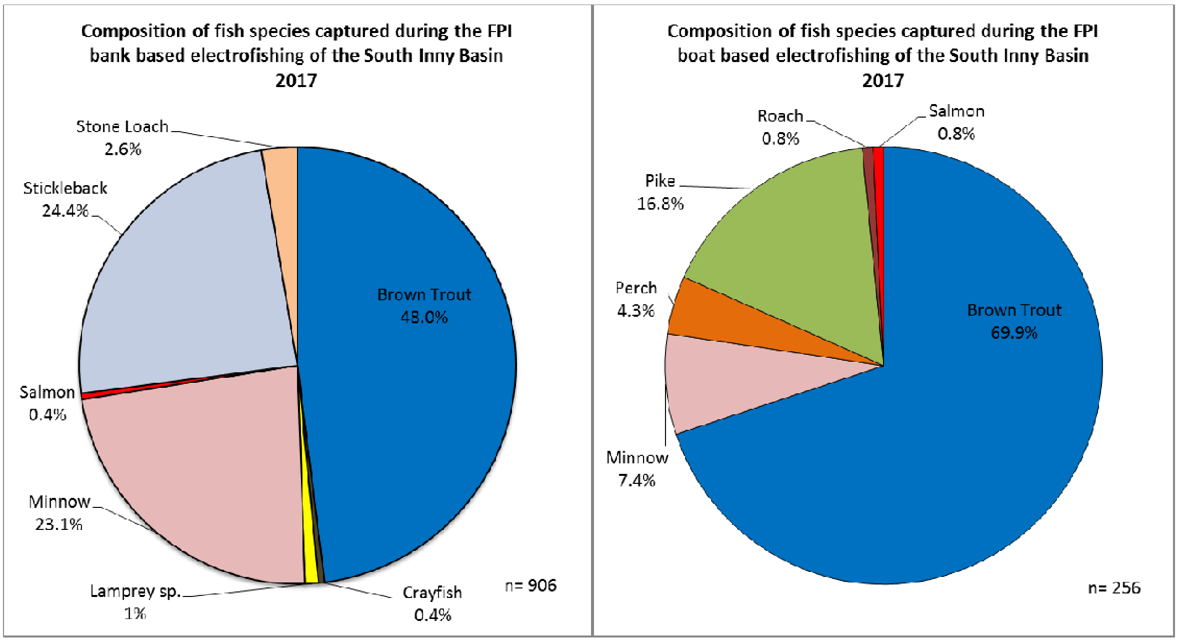

Figure 2.2. Composition of fish species captured in the South Inny Basin FPI survey using boat and bank electrofishing equipment.

2.1.2 Water Quality- Q-Values (1996, 2014)

There has been an improvement in water quality as indicated by EPA invertebrate Q-values within the South Inny Basin from 1996 to 2014 (Figure 2.3). In 1996, 10% of the sample sites were graded as "Bad Status" under the WFD's classification. Over the 18 year period the sites graded as "Bad" in 1996 have been upgraded to "Poor Status". 41% of the EPA (Q-Value) water monitoring sites in the South Inny Basin in 2014 were meeting WFD requirements or "Good Status". In the 2017 report published by the EPA on the Inny catchment (EPA Code: HA 26F), only 24% of the 41 sites monitored met the WFD requirements for "Good Status" along with 11 (27%) sites unassigned any status (EPA, 2017).

There were no "bad" Q-value sites in this sub-catchment in 2014. The "moderate" sites recorded in this catchment are scoring Q3-4 which is still within the biological limits for salmonid enhancement. However, if this "moderate" water quality decreases from Q3-4 to Q3 water quality it will threaten the salmonid population. In 2014, seven sites were reported as "Poor Status" (Q3, Q2-3) for water quality under WFD requirements (EPA, 2010-2015). Poor water status recorded downstream of Ballymore, Edgeworthstown (Black River) and Multyfarnham reflect the presence of inadequate urban wastewater treatment plants, listed for upgrading from 2021 (Figure 2.4) (EPA, 2017).

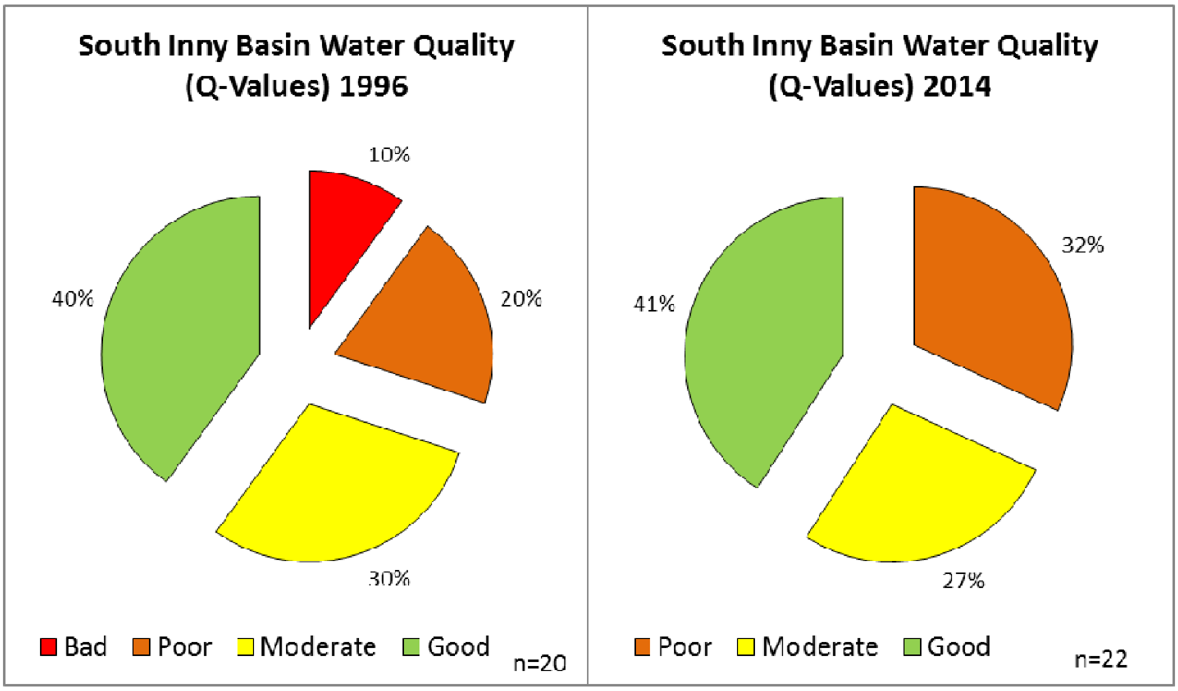

Figure 2.3. Results from EPA Q-Value (1996 and 2014) monitoring sites in the South Inny Basin.

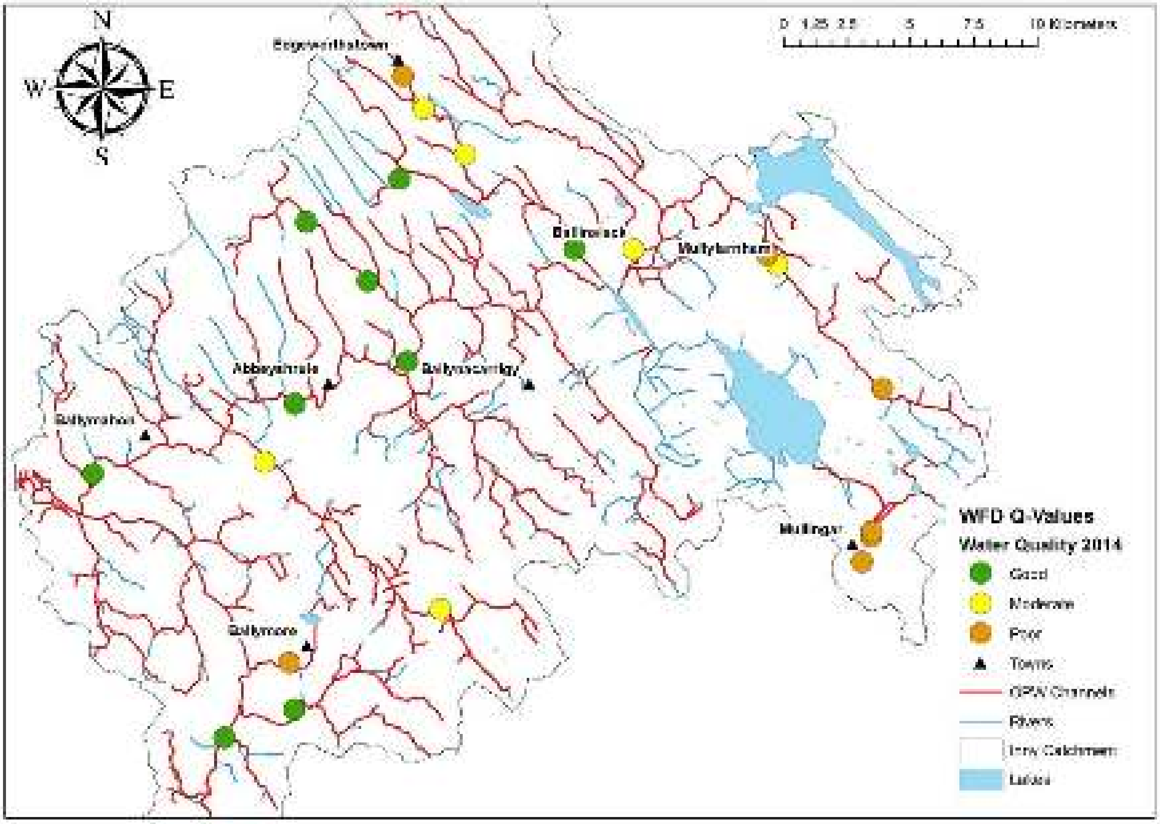

Figure 2.4. Locations of Q-Value results for 2014 in the South Inny Basin.

2.1.3 Water Quality – Small Stream Risk Assessment (SSRS)

The SSRS results from the FPI Survey indicate that 57% of the sites sampled are "at risk" of water pollution. The EPA Report (2010-2015) for catchment (HA 26F) found 51% of the monitoring sites proved "at risk" from organic pollutants, similar to results obtained during the FPI Survey.

In their report, the EPA stated that excess phosphorus resulting in eutrophication is the main issue for both the rivers and lakes throughout the South Inny Basin. The main pressures contributing to excess nutrients in the water systems are primarily agricultural; both diffuse and point sources, along with urban wastewater treatment plants. Overall, only a small number of sites (n=5) surveyed using the SSRS were identified as "probably not at risk" (24%) (Figure 2.5) indicating that run-off of organic pollutants is a major problem.

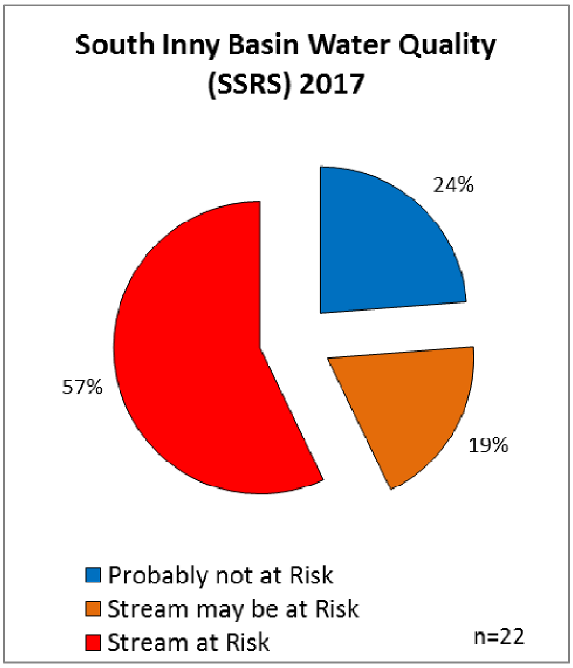

Figure 2.5. Results of the Small Stream Risk Assessment Score (SSRS) for the South Inny Basin.

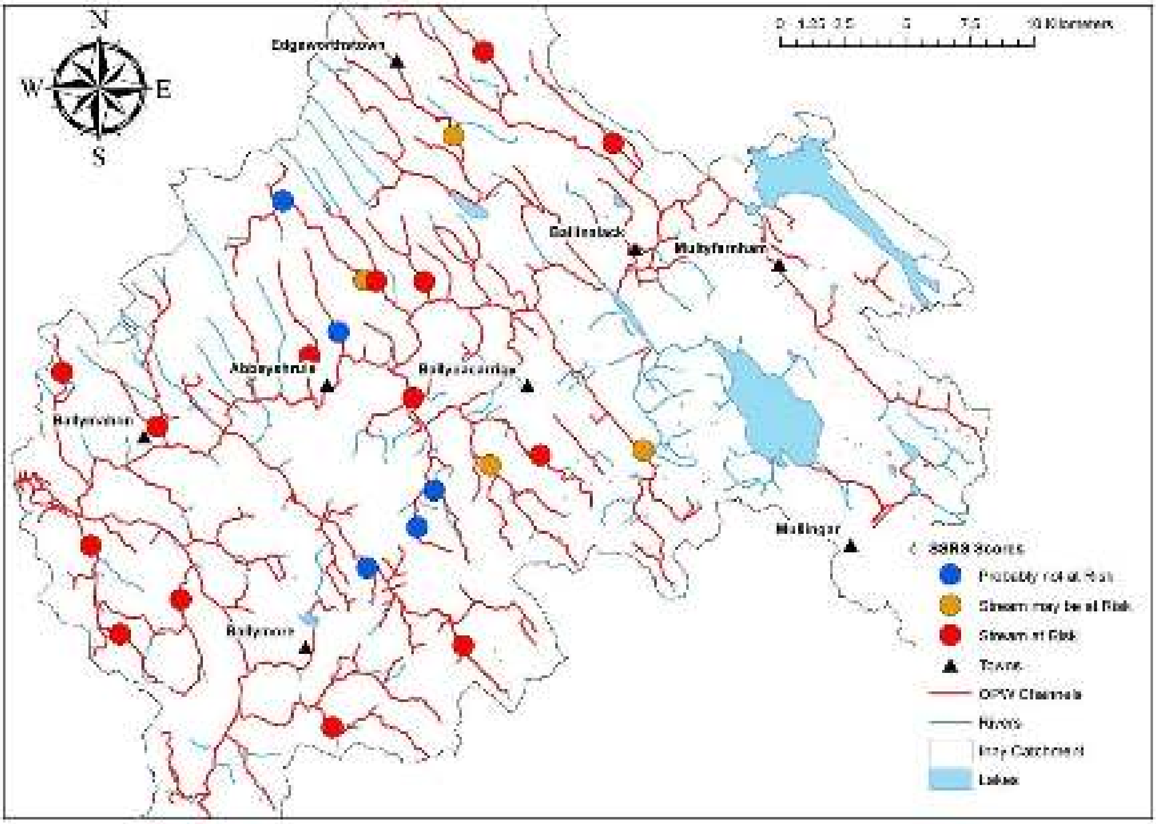

Figure 2.6. Location of Small Stream Risk Assessment Scores (SSRS) results from the South Inny Basin taken during the FPI Survey 2017.

2.1.4 Fish Communities and Brown Trout Populations (1997, 2017)

The fish community in the South Inny Basin is dominated by trout (*Salmo trutta*) (Figure 2.2). Trout were present at 88% of the sites surveyed, whereas Salmon (*Salmo solar*) were only present in the Rath (C12) and Tang (C8) River and not in large numbers (Figure 2.9). Total number of salmon captured during bank and boat fishing 2017 was n=6, compared to the trout total of n=614. Only a small percent (2.1%) of the brown trout captured during the survey were of angling importance (12 trout >28cm in length). Although the brown trout stock in the small tributaries was undersized for angling, the larger tributary boat sites (Sonna (C27), Tang (C8) and River Blackwater (C18)) supported a stock of coarse fish with good numbers of pike (*Esox lucis*), perch (*Perca fluviatilis*) and roach (*Rutilus rutilus*) (Figure 2.2). The lengths of pike captured, measured and returned ranged from 9-53cm; with six of the pike caught measuring >40cm in length.

In comparing brown trout populations from 1997 and 2017 the main observations related to abundance (Figure 2.7) and distribution (Figure 2.8). In 2017 there was a greater number of fish (n=614) captured over the 34 sites compared to 1997 (n=446). Brown trout were present in 30 of the 34 sites in 2017, while they were only present in 22 of the same sites in 1997 indicating changes in distribution over the 18 years between surveys (Figure 2.8).

In regards to size classes and the age groups of the trout captured during both surveys, each show a similar trend. During the bank based electrofishing from both years fry (0+) and juvenile (1+) brown trout were captured. Fish under 10cm are classified as brown trout fry, with juveniles ranging between 10-18cm and any fish > 18.1cm regarded as an adult fish. It is clear from the graphs (Figure 4.7.) that bank/handset fishing identify water no deeper than 0.5m, as brown trout recruitment and nursery areas.

Boat based fishing, targeting deeper sites, captured brown trout of a larger size range (7-43cm). Adult trout move to deeper areas for better feeding opportunities. In both years 1997 and 2017, brown trout captured fell into each category of their life cycle (fry, juvenile (1+) and adult stages) indicating recruitment of the trout population throughout the South Inny Basin.

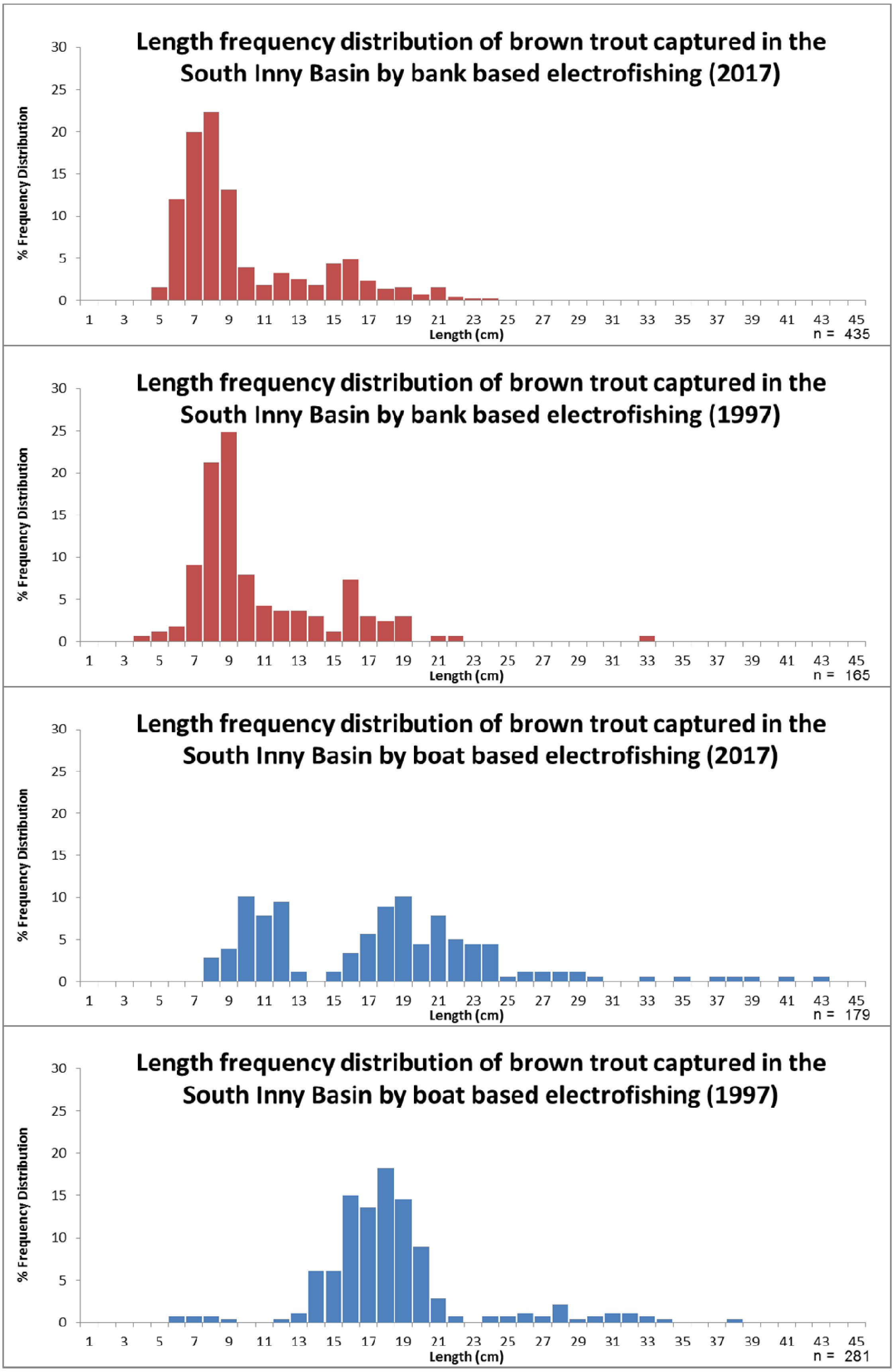

Figure 2.7. Length frequency distribution of Brown trout captured by boat (Blue Graph) and bank (Red Graph) based electrofishing from the South Inny FPI Surveys in 1997 and 2017.

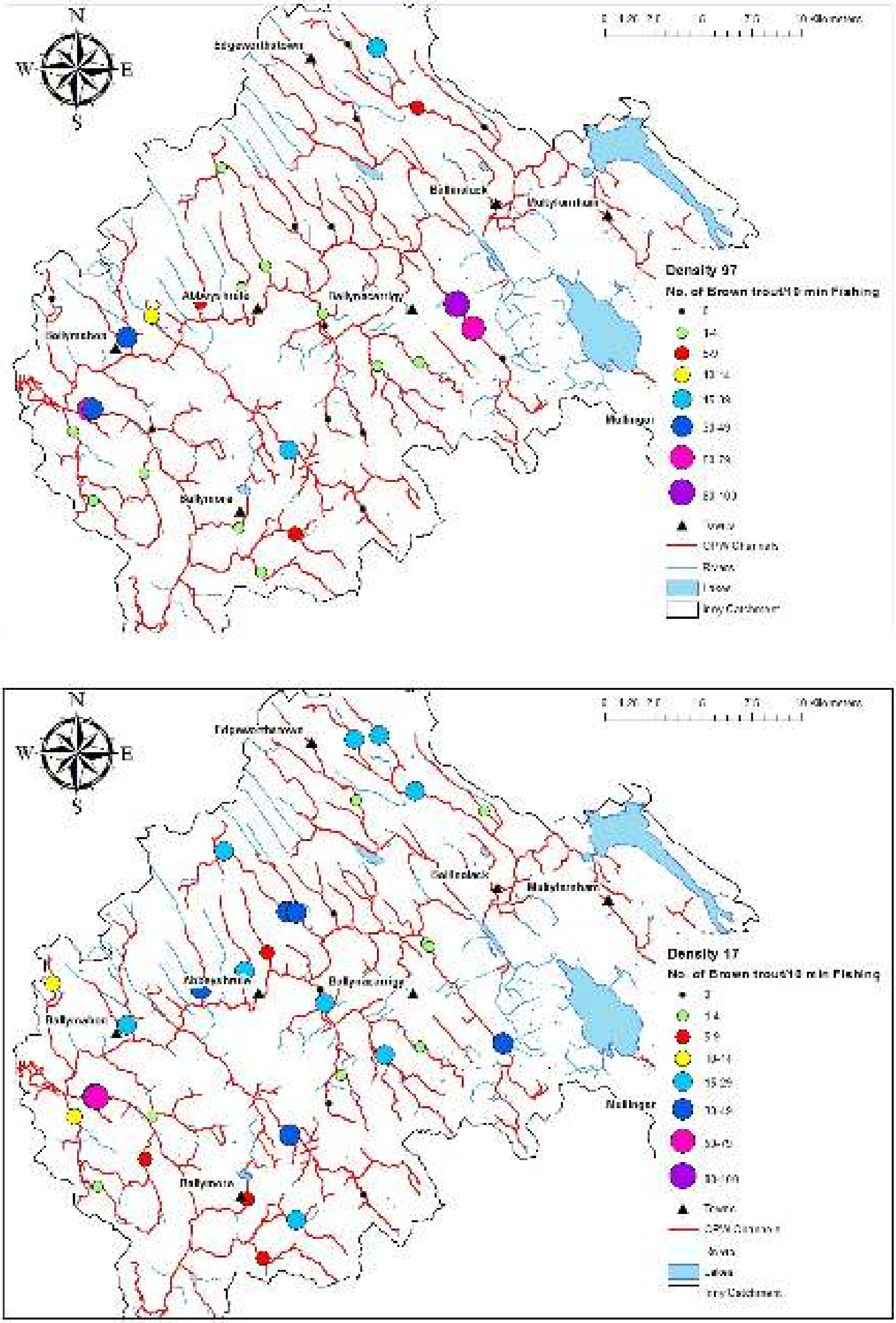

Figure 2.8. Maps displaying the number of Trout captured per 10 minute electrofishing session at each site in 1997 (Top) & 2017 (Bottom).

2.1.5 Crayfish and Lamprey Distribution (Presence/ Absence)

During the FPI Survey, presence and absence of Annex II species were recorded. These included; Crayfish, Lamprey and Salmon. It can be concluded from the results (Figure 2.9) that the distribution of Crayfish, Salmon and Lamprey in the South Inny Basin are extremely patchy. Although Crayfish and Lamprey were not the main focus when electrofishing each site, they were recorded if they were captured.

A dedicated study focused on the distribution (presence/absence) of lamprey *sp.* throughout the Inny catchment undertaken in 2009 showed that lamprey was more widely distributed. 14 of the 26 (54%) sites fished in the South Inny Basin in 2009 had lamprey present compared to five sites out of 28 (18%) in 2017. Another study completed in 2007 focused directly on crayfish distribution (presence/absence) within the Inny catchment. Results from this survey indicate poor crayfish status, similar to results from 2017. Out of 57 sites sampled for crayfish in 2007, 10 has crayfish present (18%). In 2017, 9% of the sites fished had crayfish present, both years showing a low distribution of crayfish within the South Inny Basin.

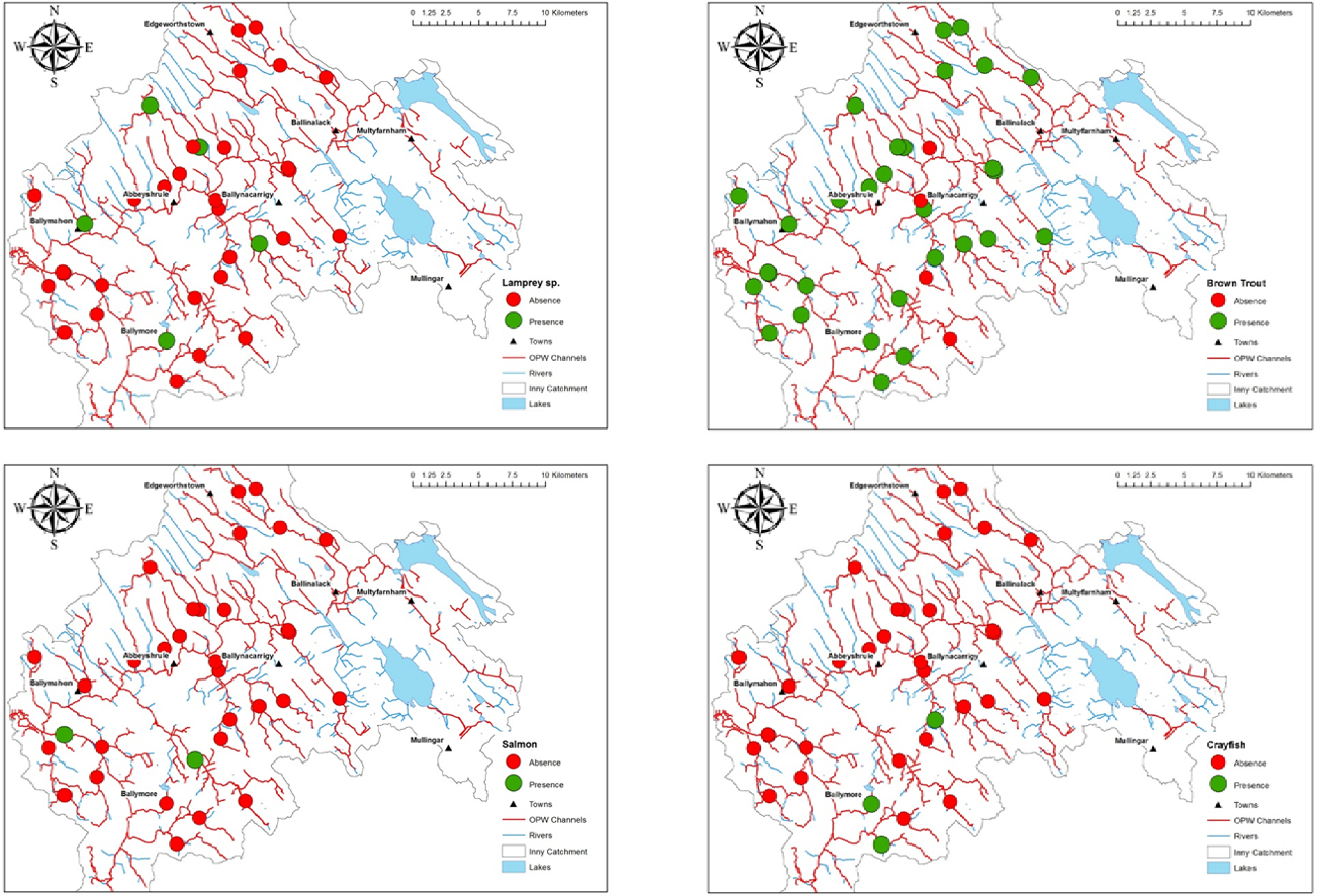

Figure 2.9. Presence/Absence of Brown Trout, Crayfish, Lamprey sp. and Salmon throughout the South Inny Basin 2017 (Red Circles; Absent, Green Circles; Present).

2.1.6 South Inny Basin – Assessment of physical habitat using RHAT (River Hydromorphology Assessment Technique)

'Hydromorphology' describes the interactions of geomorphology and hydrology of a river system in space and time or more simply put, hydromorphology is the physical habitat of a river constituted by the physical form (abiotic and biotic) and flow of the river. Key elements include the flow, sediment regimes, channel and floodplain dimensions, topography and substratum, continuity and connectivity (longitudinal, lateral, vertical and temporal), sediment transport and the interaction of all these components in both space and in time. Anthropogenic features such as bank protection works, artificial barriers (weirs, dams) and modifications to processes (gravel traps) are also included.

As a "supporting element" Ireland must report directly to Europe on the hydromorphological quality of Irish Rivers. The River Hydromorphological Assessment Technique (RHAT) a tool developed specifically for WFD is the Irish reporting method for Hydromorphology. The RHAT is based on the Environment Agency (EA) River Habitat Survey (RHS) and the US Environmental Protection Agency Rapid Bio-Assessment Protocols. The RHAT is designed to characterise and assess the physical structure of river channels. In short the RHAT will detect degraded hydromorphology (river form and function).

Twenty-nine sites in the lower Inny basin were surveyed for hydromorphology using the RHAT (Figure 2.10. and 2.11). No sites passed the WFD minimum requirement of good status, with 62% categorised as moderate, 35% as poor and 3% classified with a bad status. There is potential for increasing this RHAT score in a number of the Inny tributaries and in the main stem itself.

Throughout the catchment, hydromorphological attributes of some rivers are impacted as a result of the release of sediment downstream. Physical actions which result in the discharge of fine particles into the water bodies include; poaching from livestock, forestry and channel modifications which assist drainage. Such impacts alter the morphology of rivers, and in turn modify habitat conditions.

A number of strategies could increase the RHAT scores in the lower Inny. These include mitigating the adverse effect of barriers, avoiding channel modifications, the re-instatement of natural riparian cover and encouraging fencing on river banks exposed to livestock.

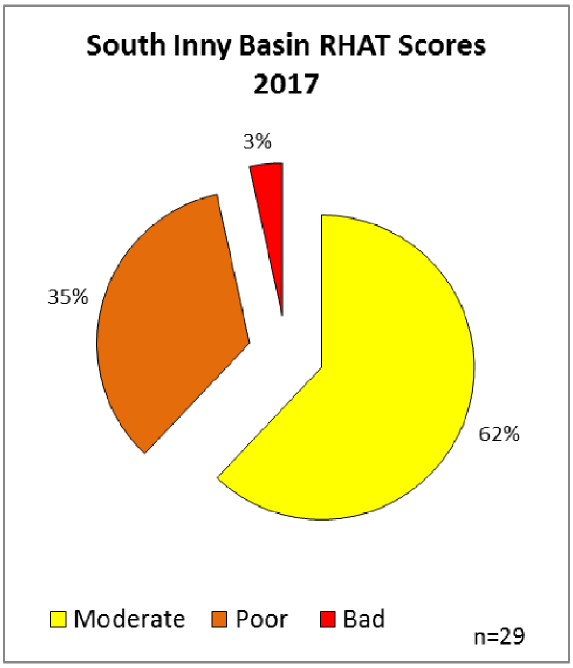

Figure 2.10. River Hydromorphology Assessment Technique (RHAT) results from the South Inny Basin FPI Survey 2017.

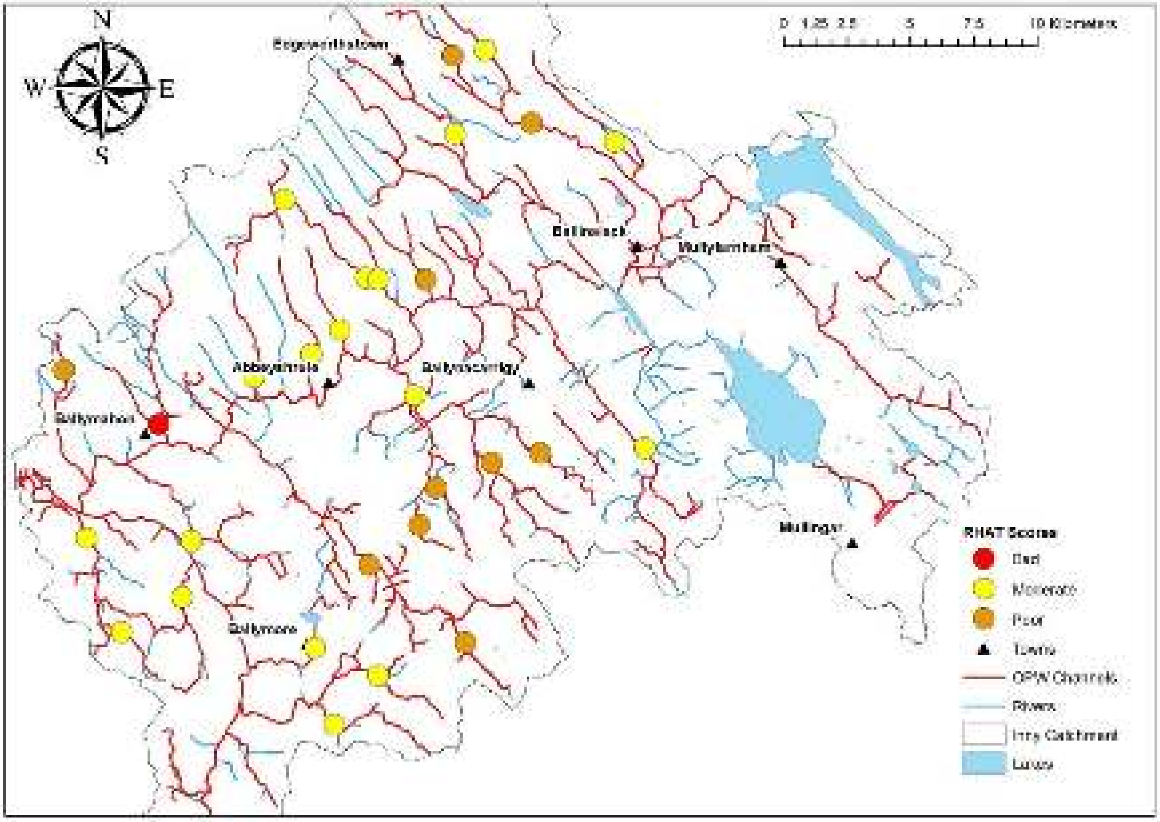

Figure 2.11. Locations of River Hydromorphology Assessment Technique (RHAT) results from the South Inny Basin taken during the FPI Survey 2017.

All of the sites assessed during this survey were located in the Inny OPW Drainage Scheme. With none of these sites passing the WFD requirements of "Good" hydromorphological status, it is obvious that drainage/maintenance works may a contributing factor for channels to be in an "unsatisfactory" hydromorphological condition.

The overall RHAT score is generated from the individual scores given to each attribute (x8) which is scored independently when on-site (Figure 2.12). Each component is scored from 0-4, with 4 being the highest possible score given per section. Bank Structure & Stability, Flood Plain Connectivity, Riparian Land Cover and Channel Form & Flow Type scored the lowest (1.09 - 1.26) in the lower Inny. These categories are directly affected by the arterial drainage process with the over-widening and deepening of the river bed resulting in the creation of a trapezoidal cross section within the channel.

Drainage works result in a number of significant hydromorphological changes, flood plain connectivity is interrupted, bank structure is un-natural and canopy cover is impacted. Post drainage, river processes will try to return the river to a more natural state (vegetation growth / sediment deposition) but this process can be reversed by channel maintenance. Unsympathetic cyclical maintenance not adhering to the "10-steps of environmentally friendly maintenance" will impact on the recovery of five of the eight RHAT components and prevent improvement in RHAT scores. Rigorous implementation of the "10-Steps" has the potential to improve RHAT component scores in Channel form and flow type (Step 4, 7, 8 and 10), Channel Vegetation (Step 2 and 4), substrate condition (Step 3, 8, 9 and 10), bank structure and stability (Step 1, 2 and 5) and bank vegetation (Step 1, 2, 5 and 6).

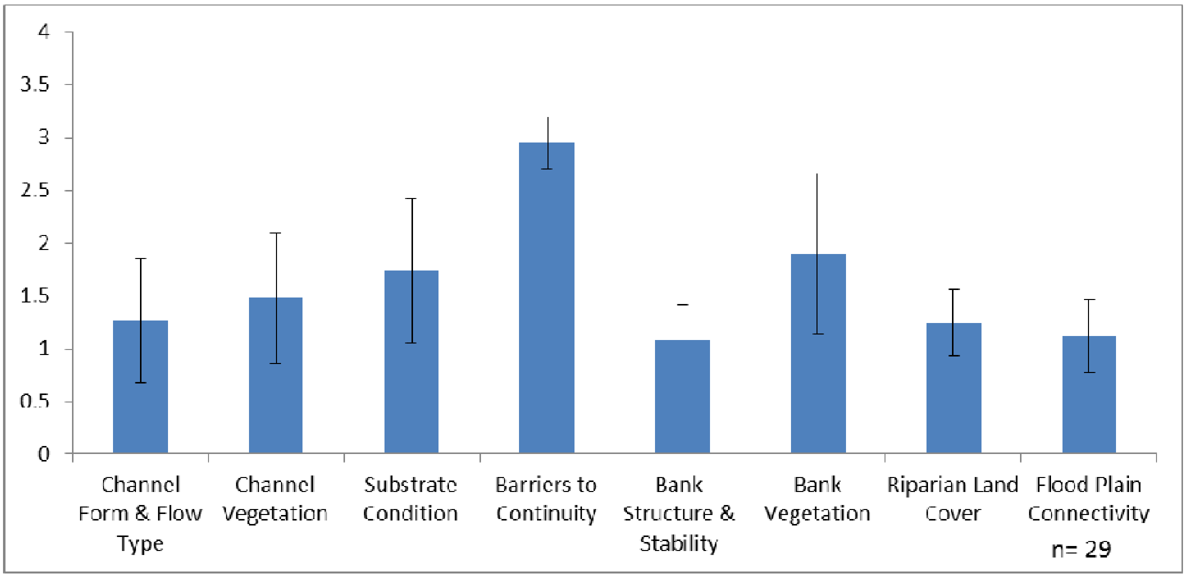

Figure 2.12. Mean and Standard deviation of the 8 RHAT components which comprised a WFD status score for all OPW channels surveyed in the South Inny Basin during the 2017 FPI Survey.

2.2 Stonyford River (C1/32/33), Boyne Catchment "Spontaneous restoration" Fencing Experiment

This experiment was proposed to evaluate the effectiveness of fencing as a management tool in the rehabilitation of riparian and aquatic vegetation and its consequent impact on the hydromorphology and fish community in a reach of degraded river

2.2.1 Project Objective

The objective is to quantify the effect of this commonly adopted (Fencing) stream rehabilitation methodology on a small channel. The rehabilitation strategy is to exclude livestock by fencing off the riparian zone, provide cattle drinks and allow the riparian and instream channel to revegetate. The key research issues under investigation are:

- ❖ The response of riparian and aquatic vegetation to fencing, and to habitat change in the longer term (3-5 years)
- ❖ The response of channel morphology to riparian and aquatic vegetation rehabilitation
- ❖ The effect of riparian rehabilitation on flow regime and bed sediment
- ❖ The response of the fish community to riparian and aquatic vegetation rehabilitation (2-3 years) and to habitat change in the longer term (3-5 years)

The basic experimental design is a BACI (before, after, control, impact) style design with the target channel (Stonyford tributary (C1/32/33)) monitored for five years. This section is reporting four years post fence instillation.

2.2.2 Introduction

The study of spontaneous river restoration has been split between biology and fluvial geomorphology. Fluvial geomorphology has focused on the role of stream energy and erosion/deposition processes in changing channel morphology while biologists have focused on the processes by which plants themselves modify their environment to create a more self-benefiting river setting. However, river evolution is driven by both the abiotic (floods, droughts) and biotic components of an ecosystem and the plant growth which creates a diverse mosaic interacts with, and potentially drives, river form (Gurnell 2014).

Macrophytes achieve their greatest biomass and corresponding influence on river channels, in shallow lowland rivers. In these locations, where macrophytes occur in abundance, they modify flow, sediment and nutrient processes and therefore act as an important component in river ecosystem functioning (Clarke 2002). Recent research has deemed some plant species as 'ecosystem engineers' and suggests that these plant species can create morphological channel adjustments that stimulate physical recovery in channelized rivers, which has important implications for river restoration schemes (Gurnell *et al.* 2012).

In summary, instream vegetation encourages sediment aggradation by trapping and stabilising sediment within its roots and canopy. This fluvial "biogeomorphic succession" supports the development of embryonic bed forms that may evolve into more substantial physical forms e.g. bars, islands and berms (Corenblit et al. 2009). In turn, this enables plant species with different environmental tolerances to establish and continue to anchor sediment, thus enabling evolution of the river's morphological form (Hupp 1992). The ability of such pioneer macrophyte species to readily establish after channelization works provides an opportunity to investigate plant colonization and succession and the physical effect of these processes on channel attributes.

The effect of channelization on fish community composition and their life stages has been studied both in Ireland and on continental Europe (Jurajda 1995,O'Grady 1991). Channelization of the Trimblestown River (a tributary of the river Boyne) led to a species shift, from brown trout to cyprinid dominance (McCarthy 1983). Recent studies in Danish lowland streams noted that the simplification of riparian habitat led to lower salmonid abundances (Teixeira-de Mello et al. 2016). In the current study, changes in fish community composition have been documented along with the recovery of instream macrophytes. It is hypothesised that the increase in instream heterogeneity will increase micro-niche availability allowing for a greater carrying capacity for salmonids.

Data was collected on plant community structure, fish community composition, channel physical morphology, bed type characteristics and flow regimes in five different sites along a single stretch of the Stonyford river, with varying levels of macrophyte cover. Subsequently, all vegetation was removed from the study reach as part of stream management works aimed at improving water conveyance and a fence was then erected to exclude livestock. The study then documented the macrophyte species that established post-removal, and their effect on descriptors of physical state within the channel. Plant species were recorded and classified at each sample site according to plant traits (O'Hare et al. 2016), fish species and abundance was sampled using depletion electrofishing over the five sampling sites.

2.2.3 Study area

Sample sites (N=5) of 30m length were distributed within a 1.5km non-shaded tributary of the Stonyford river, a tributary of the River Boyne (Figure 2.13). The Stonyford River is a characteristic Irish lowland river with low-moderate flow velocities (maximum recorded velocity at sample sites = 0.75 m s^{-1}), abundant macrophytes and a mixed bed load. Its fluvial patterns are typified by a meandering single-thread channel, bounded by cohesive alluvial plains. The average bed width was approximately 4m and average water depth was 0.4m. Water quality was reported as achieving good ecological status based on the macroinvertebrate community recorded in the study site between 2012 and 2015 (EPA 2015). The river has been arterially drained and channel morphology exhibits many characteristics typical of channelization e.g., deeply incised, trapezoidal form that isolates the river from its historical floodplain, and uniform flow dominated by extended glides. The channel has also been subject to cyclical river maintenance which has helped to maintain a very homogenous physical form.

Figure 2.13. Site 3 looking downstream in January 2018, showing extent of instream vegetation dieback during winter months, top of Study Site 3 at cattle drink see figure 2.15

2.2.4 Sampling

Data was collected in late July of 2013 and 2014 before vegetation removal and subsequent fencing. Additional data was collected in July 2016 and 2017 to assess the fish populations, vegetation and morphological response and recovery. A series of lateral transects (T) were used to estimate plant frequency/distribution and physical attributes (depth, flow and substrate type) in the five sites of 30m length within the experimental river sections. The fish community composition was sampled through electrofishing at each of the 30m sample sites. Plant presence was recorded in 31 cross sections spaced every 1m at each sample site. Physical attributes (depth, flow and substrate type) were recorded in 11 cross sections spaced every 3m. Substrate type was determined in the field by visual inspection and categorised as fines (≤ 3mm), gravel (4-64mm) or cobble (65-190mm), according to the dominant type (>60%) at each sample point.

2.2.5 Results

Macrophyte frequency

Branched broad leaved emergents (BBLE) and tall linear emergents (LE), were consistently the most frequent macrophytes recorded in each sample year. These morphotypes accounted for approximately 82% of all records. Species within the BBLE group consisted predominantly of *Nasturtium officinale* L., *Apium nodiflorum* L. and *Berula erecta* L. and were widely distributed within the wetted channel. Tall linear emergents (LE) were accounted for by *Phalaris arundinacea* L. almost exclusively, which was limited to the wetted margins. The distribution and change in plant morphotypes in site 3 is given in Figure 2.14.

Flow velocity, depth and substrate type

There were close interactions among physical variables *(flow, bed type and depth)*, and also between physical variables *(flow, bed type and depth)* and plant presence. The results suggest that up to a certain point (~70% cover) increasing plant presence has a direct positive effect on heterogeneity in stream depth and flow velocity, with subsequent indirect velocity-mediated effects on substrate, i.e., greater differences in velocity leads to a shift from fine material to gravel and cobble substrate. The 2017 results indicate that if plant cover reaches >90%, there is a negative effect on flow velocity, a positive effect on stream depth and a negative effect on substrate with a shift from gravel and cobble substrate to fine material. This process is evident in digital terrain maps that illustrate physical descriptor responses to varying macrophyte cover in different years (Figures 2.14 and 2.16).

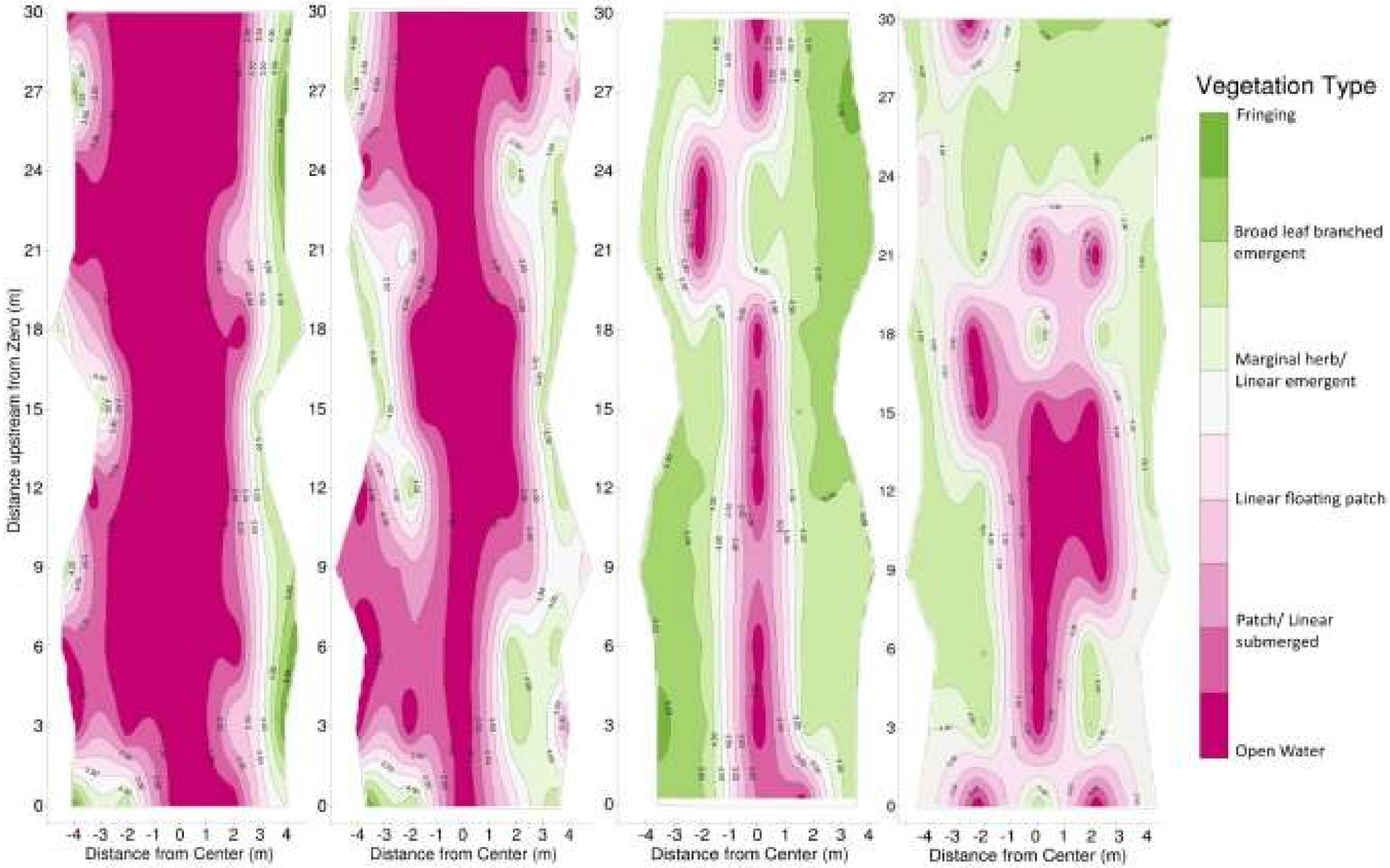

Figure 2.14. Isolines estimated around point values of the vegetation type index (morphotypes) for Study Site 3 (Figure 2.15), illustrating changes in the extent and type of macrophyte cover in 2013, 2014, 2016 and 2017 (from left to right).

Figure 2.15. Study Site 3 showing changes in macrophyte cover 2013, 2014, 2016 and 2017 (from top left to bottom right). Changes in Plant cover, Velocity, bed type and depth are graphically represented in figures 2.14. and 2.16.

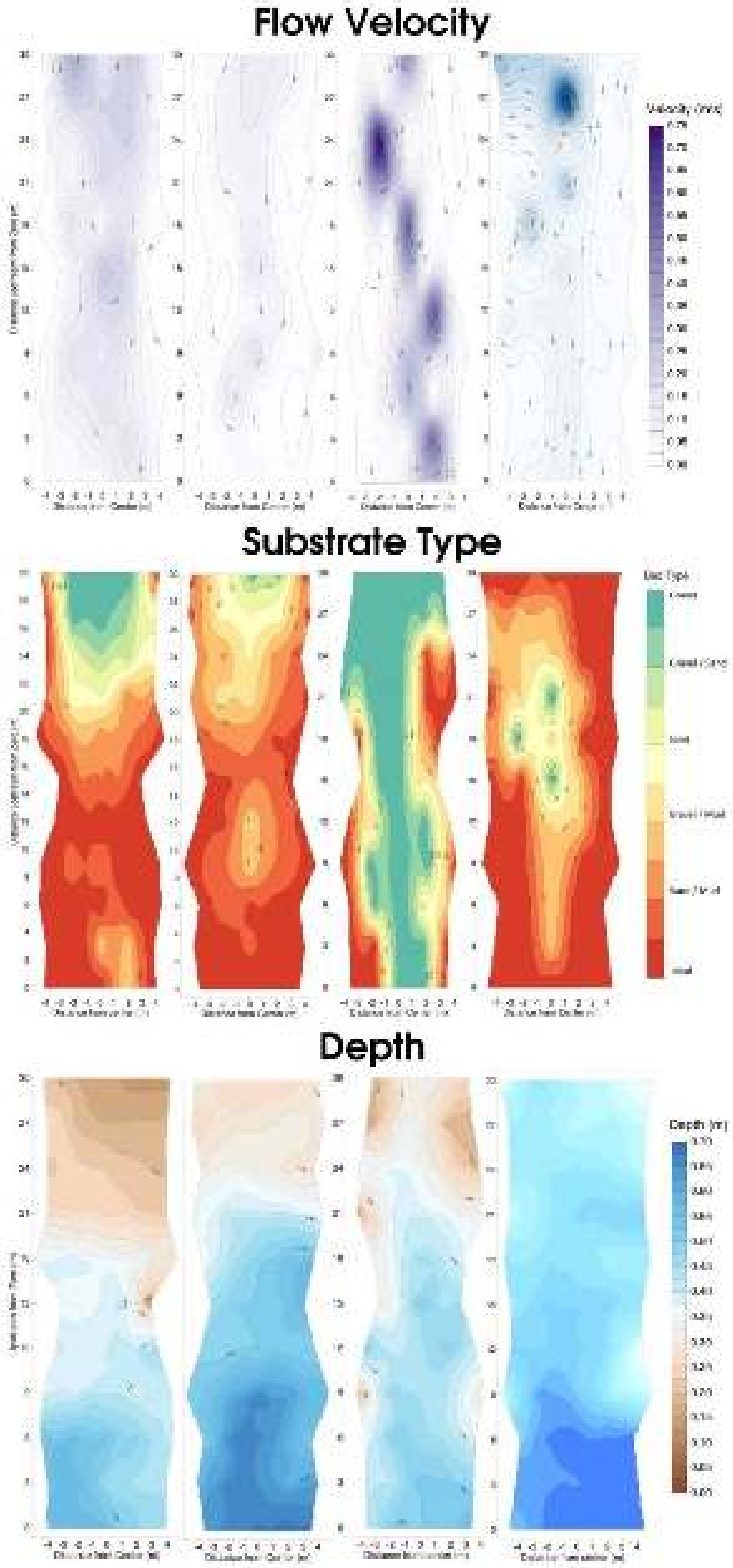

Figure 2.16 Isoline maps interpolated around point observations of flow velocity (top), substrate type (middle) and depth (bottom), observed during 2013, 2014, 2016 and 2017 (left to right) at the same site as is shown for macrophyte cover and type in figure 2.14.

Fish community structure

928 fish were captured measured and released in the five survey sites over the five years. Brown trout (*Salmo* trutta L.) was the most abundant species, followed by roach (*Rutilus rutilus* L.), three-spined stickleback (*Gasterosteus aculeatus* L.), Lamprey *sp.* (*Lampetra Sp.* L.), salmon (*Salmo salar* L.), European eel (*Anguilla anguilla* L.), Perch (*Perca fluviatilis* L.), Crayfish (*Austropotamobius pallipes* Lereboullet.) and Pike (*Esox lucius* L.). The fish population breakdown over the sampling period is given in Figure 2.17.

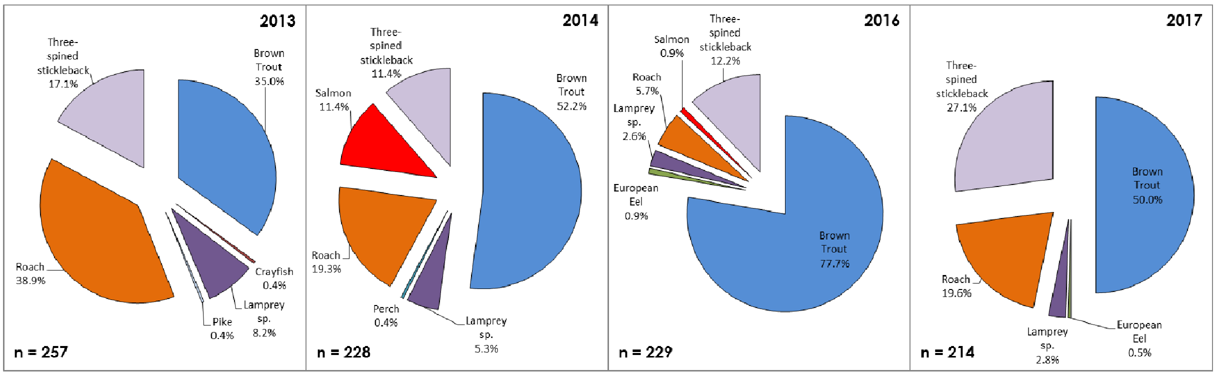

Figure 2.17. Composition of the fish community captured in the five Stonyford survey sites 2013, 2014, 2016 and 2017

Mean minimum density (no/m²) with 95% confidence intervals for the four most abundant species is given in figure 2.18. There has been significant changes (G = 0.244434, DF = 9, P = >0.05) in the frequency of the four most abundant species over the four sampling years. This is due to fluctuations in brown trout density and a reduction in lamprey *Sp.* and roach numbers.

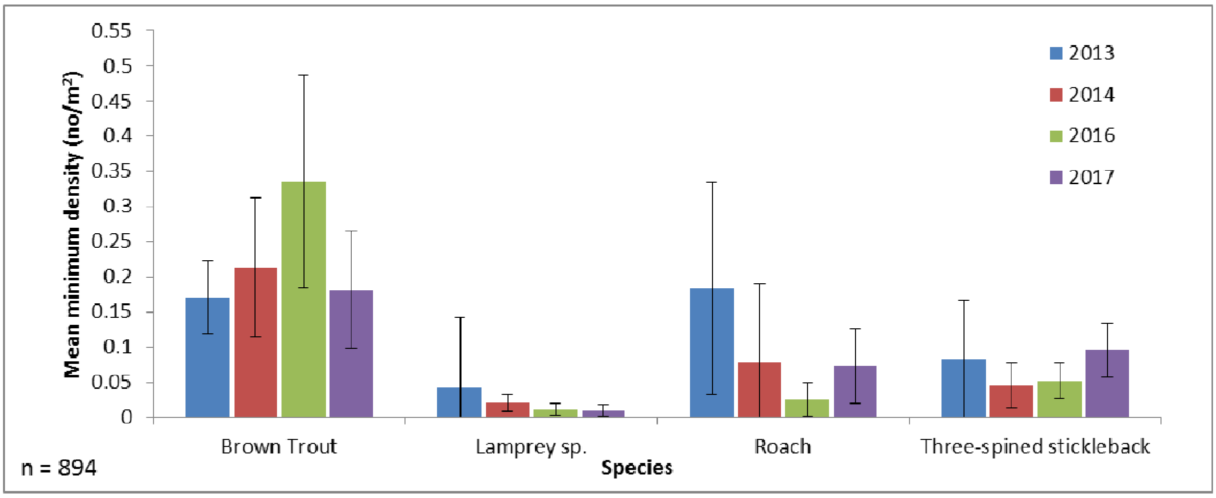

Figure 2.18. Mean minimum density (no/m²) with 95% confidence intervals of the four most abundant fish species in the Stonyford River experimental sites 2013, 2014 and 2016.

Interaction between trout abundance (minimum density no\m²) and percentage vegetation cover over the four year sampling period is given in Figure 2.18. This demonstrates a bell shape curve response of trout numbers to vegetation cover. This suggests that maximum trout density is reached at intermediate levels of instream vegetation cover (~55%), a potential "green zone" of maximum trout density (Figure 2.19).

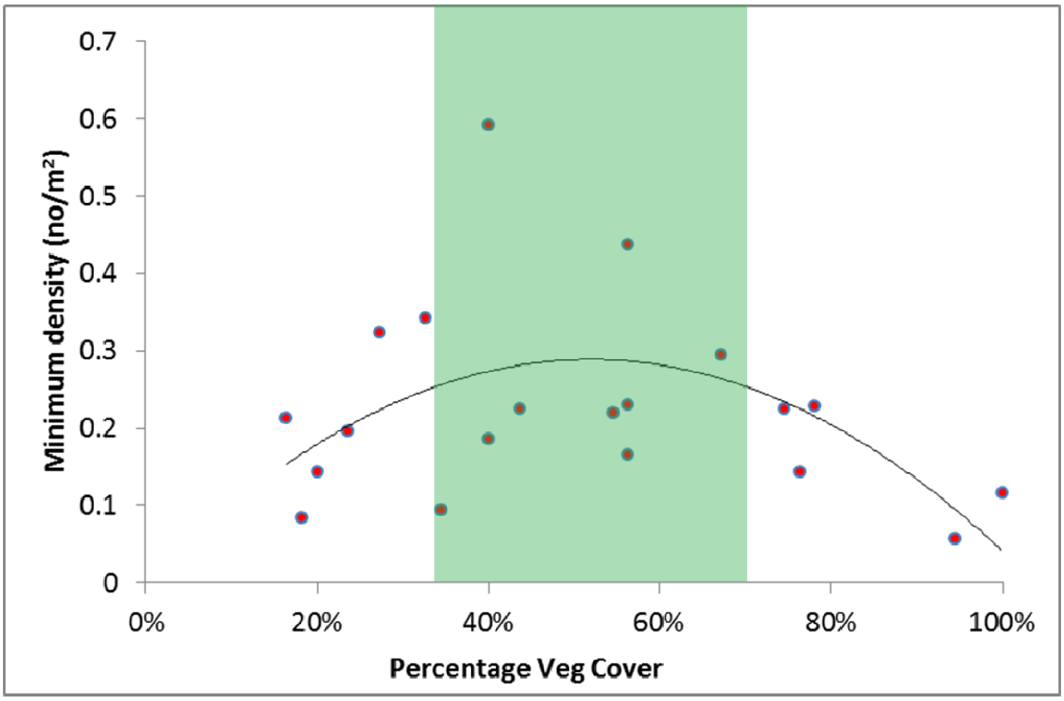

Figure 2.19. Interaction between brown trout minimum density (No\m²) and percentage vegetation cover over the four year sampling period. The green box represents a hypothetical "green Zone" of maximum trout densities.

2.2.6 Discussion

Recovery of channelized rivers is associated with increasing structural and hydraulic diversity. The present study suggests that variations in flow and depth are created by instream plants, with subsequent effects on substrate composition. Instream recovery toward a more natural river occurs as establishing plants block and deflect flow, leading to changes in water velocities. Associated recovery in substrate likely follows macrophyte-driven flow manipulation and the mobilisation of fine sediment in the mid-channel through flow constriction and accelerated velocities that 'wash' gravels.

Early analysis of the fish community composition indicates that increased structural and hydraulic diversity led to increased brown trout habitat and therefore increased brown trout densities. Trout densities are responding to increased velocities driven by plant narrowing in the channel. This in turn drives changes to bed type which appear to suit juvenile salmonids. This positive salmonid-velocity feedback was curtailed in 2017 by extensive BBLE growth choking the channel. The four years of data suggests that maximum trout densities occur at an intermediate level of plant cover - the "green zone". At this point plant cover has its greatest effect on both velocities and bed type. Extreme levels of vegetation cover will reduce brown trout habitat and therefore there densities.

Increased brown trout and salmon recruitment could have been facilitated with the availability of fresh gravels exposed through flow constriction and accelerated velocities. Intermediate macrophyte cover levels may function as refuge habitat and reduce population mortality. The presence of a population of salmon in the 2014 and 2016 surveys, but not in the other years, probably reflects the channel's small base width and non-optimal habitat for salmon spawning and juvenile rearing.

Bio-geomorphic feedbacks play an important role in both macrophyte development and channel morphology. It is proposed that this set of sites will be monitored in the medium to long-term to provide further insights on the impact of fencing and maintenance events on the instream and riparian plant communities, fish life and the physical dimensions of the channel.

2.3 Brosna Tributaries Temperature Experiment

2.3.1 Introduction

Climate change is expected to modify the thermal regime of Irish rivers. Increased water temperatures will affect many aspects of fish ecology including growth, metabolism, feeding rates, spawning, timing of migration and the availability of resources such as food. Temperatures may increasingly reach levels that are lethal to fish and to other aquatic organisms and these elevated lethal levels may persist for longer. Therefore, temperature management for river biota is required, and this will include assessment of the vulnerability of river catchments to potential changes in their thermal regimes.

There are various mechanisms that can affect stream temperatures, including solar radiation and a combination of convection and conduction heating. Channel water temperatures are driven by a variety of variables that include elevation, rainfall, air temperature, solar angle, inflowing tributary temperature and flow, quantity of upland vegetation cover and others. Temperature buffering is provided by channel morphology and orientation, by the extent of shading provided by bankside and instream vegetation and by ground water inputs.

Channel morphology affects the temperature regime within a given channel because the effect of solar radiation on water temperature at the stream surface depends on stream width, depth, and flow velocity. For a given stream discharge, a shallower, wider channel heats up and cools down faster than its deeper, narrower equivalent. Riparian shade is usually the most influential regulating factor in small to moderate sized channels (stream order 1-3) with its importance decreasing in larger channels. The effect of instream plant cover on buffering river water temperature may also be important. However, the consequences of emergent macrophyte or plant growth on water temperature patterns has not been widely studied.

In unmodified or undrained channels instream/groundwater exchange processes buffer against the influence of air temperature and heating by solar radiation. In contrast, channelized rivers are particularly susceptible to rapid warming from solar radiation due to their simplified form, as a consequence of straightening and widening, which can reduce depth and increase exposed surface area, and of removal of instream or riparian vegetation cover. Repeat maintenance can commonly lead to removal of instream vegetation. However, current maintenance practice of OPW emphasizes the retaining of substantial levels of tree cover where they are not causing a significant obstruction to flow and audit outcomes confirm that this practice is strongly implemented. Channelized rivers are isolated from their floodplain by design, limiting their connectivity to the alluvial aquifer. This also reduces any buffering effect on water temperature. This is significant in Ireland, where approximately 16,130km of rivers are channelized and managed for conveyance on a regular basis.

2.3.2 Study Area

The current study builds on earlier work, undertaken within EREP, examining the relationship of tree cover to water temperature (O'Briain *et al.*, 2017). It again considers the linkages of temperature and riparian tree cover but the scale of channel is larger than previously. In addition, the choice of channels, all adjacent essentially lowland channels in the Brosna Arterial Drainage scheme, enabled comparison of two surface-water fed channels with a ground water fed channel. One of the surface fed channels had heavy riparian tree cover. The other had very little as was the case with the groundwater fed channel. Both channels with low tree cover had a history of heavy instream growth of tall emergent plants, dominated by flaggers (*Sparganium erectum*).

The Tullamore Silver, the Tullamore and the Clodiagh are all tributaries of the Brosna in the Shannon catchment. Both the Tullamore Silver and the Tullamore are alkaline, moderately enriched channels with high conductivity, the Clodiagh is moderately enriched but with low conductivity. The 15 study sites in the three catchments (Figure 2.20) were chosen to represent the different river types in the catchment, to maintain equilateral distance between each site and for safety of access.

The four study sites on the Tullamore Silver were in an 8.3 km section of uniformly low gradient (0.005), from ~800m upstream of its discharge point into the Clodiagh River (New Bridge) to the quarry at Ballyduff Bridge. These sites had an average wetted width of 5.24m, depth of 0.74m and average max depth of 1.36m.

The five study sites on the Tullamore River extended from Ballycowen Bridge upstream through Tullamore Town to Clonmore Bridge, covering ~12.7km of channel of uniformly very low gradient (0.002). These sites had an average wetted width of 5.98m, depth of 0.73m and average max depth of 1.23m.

The five study sites on the Clodiagh extended from Annamoe Bridge upstream through Charleville Demesne to Clonard Bridge, covering ~8km of channel of low gradient (0.005) interspersed with more moderate gradient (0.008) sections. These sites had an average wetted width of 8.24m, depth of 0.32m and average max depth of 0.63m. In both the Tullamore and Tullamore Silver rivers the hydraulic regime is continuous glide and the floral regime was characterized by two main types, an *Apium* sp. - or water cress-dominated mixed flora in shallow (0.5- 0.75 m) reaches on a hard stony-clay bed and a *Sparganium erectum* L. or 'flagger'-dominated flora in deep (0.75-1.5 m) glides on silt overlying firm sandy clay. The hydraulic regime in the Clodiagh is predominantly one of shallow riffle-glide or glide over a sandy-clay bed with a minimal amount of mixed flora.

The channels hold good stocks of brown trout (*Salmo trutta L.*) with angling until mid-May each year. The three rivers were arterially drained in the early 1950's and are maintained on a five year cycle, the most recent occasion being in 2016. This work is currently executed by hydraulic excavators.

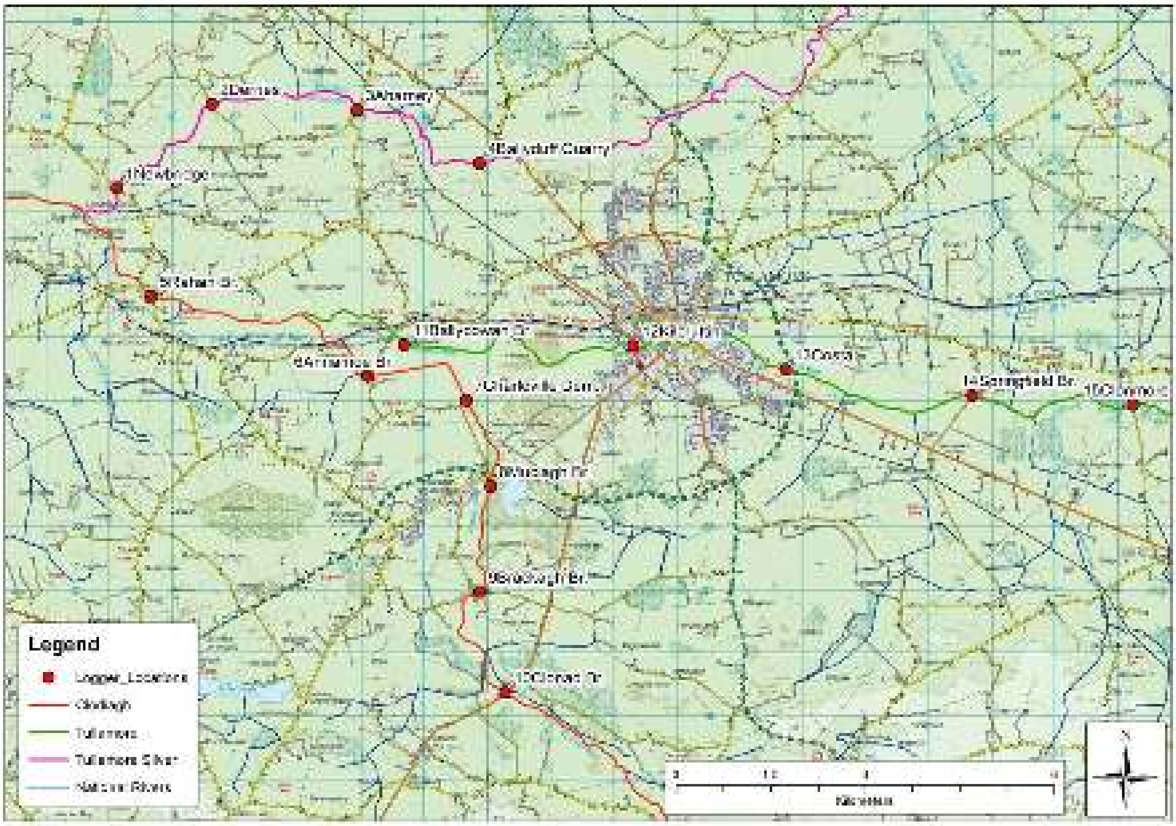

Figure 2.20. Deployment location and site name of temperature loggers in the Tullamore Silver, Tullamore and Clodiagh Rivers, Brosna Catchment

The three rivers are significantly channelized. However their hydrologies differ in a number of aspects. The Clodiagh rises in the Slieve Bloom Mountains and its discharge is predominantly generated by surface water runoff (Monettia Bog is a factor). It is a spaty river with water levels rising and falling rapidly. The Tullamore and Tullamore Silver Rivers are lowland passive meandering low gradient channels where water levels rise and fall slowly. The groundwater component of the Tullamore Silver's discharge is significant as it is underlain by an extensive aquifer. The river is fed by Sillogue Well at Durrow Abbey (average abstraction rate of 3,500 m^3/day) and there are also numerous springs around the main spring at Sillogue. The Tullamore River is largely surface-water fed. However, the most downstream recording station in this study, at Rahan Bridge, is also affected by groundwater with the springs at Agaill buffering water temperatures.

2.3.3 Environmental Data

Riparian vegetation cover assessment

Broad-scale photo-interpretation of riparian vegetation was undertaken using an open-access web-based software, i-Tree Canopy (www.itreetools.org), and Google Earth high resolution imagery (Images dated: 19/4/2015). i-Tree canopy is part of i-Tree, a software suite from the US Forest Service that was adapted for this study to assess riparian vegetation cover. Polygon shape files of the riparian corridor for each of the 15 sample sites were created using ArcMap 10 and uploaded for analysis.

The i-Tree Canopy used a series (350) of randomly generated points to produce an estimate of riparian cover type. Cover type was estimated within the average bankfull width for the total length of each sample site (800m). Each randomly generated point was classified according to user-defined cover classes (bare, improved grassland, rough pasture, hard surface (urban), tall herb, tree and open water). Using this data, a statistical estimate (with standard errors) of cover in each class was calculated.

Physical river characteristics

A series (x10) of depth and width profiles were recorded over a 100m length immediately upstream of each temperature logger. Components of the River Hydromorphology Assessment Technique (RHAT) were used to assess the level of physical channel modification and to provide a morphological quality rating based on criteria within the Water Framework Directive.

Instream vegetation was assessed using a modified plant survey combining techniques utilised in O'Briain *et al.* (2017) and The Modular River Physical Survey (MoRPh) (Gurnell *et al.*, 2018). By assessing plant morphotypes in 10 transects over a 500m reach, plant species were categorised according to their morphology and growth habit (Broad leaf branched emergent, Fringing, Linear emergent, Linear floating patch, Marginal herb, Patch submerged and Linear submerged) and the position they occupy in the channel.

Water temperature

Temperature data loggers (Onset HOBO Water Temperature Pro v2 Data Logger, accurate to 0.01°C) were deployed in discrete sample sites (Figure 2.20.) in summer (June to August) in 2017. All loggers were initially cross-calibrated over a range 0 – 30°C. Each logger was secured to the riverbed (depth = <5cm up off bed) inside a PVC pipe to shield the logger from direct sunlight. Loggers were set to record water temperature every 30 minutes in order to acquire representative temperature data.

2.3.4 Results

The i-Tree canopy results revealed broadleaf trees to be the dominant riparian cover type in the three river corridors. Open water (i.e., no overhead cover) was most prevalent on the Tullamore River. At the reach scale, riparian cover ranged from continuous broadleaf tree cover on both banks to closely cropped or bare banks. Where present, riparian tree cover width was typically 1-2m deep. Site 7 and site 8 on the Clodiagh were exceptional, having substantial riparian tree cover where they pass through woodland/parkland (Table 2.1).

Table 2.1. Physical parameters recorded from the 15 sites in the Tullamore Catchment including percentage tree cover calculated using i-Tree Canopy,daily mean and daily mean maximum temperatures

Site	Site	River	Hydrology	Wetted Width (m)	Mean Depth	Max Depth	% Tree Cover	Daily Mean Temp	Mean Daily Max Temp
1	Newbridge	Tullamore Silver	Ground/ Surface Water	4.8	1.0	1.7	19.1	13.9	15.1
2	Derries	Tullamore Silver	Ground/ Surface Water	5.8	0.7	1.4	24.8	13.6	14.8
3	Aharney	Tullamore Silver	Ground/ Surface Water	5.7	0.7	1.1	39.1	13.3	14.2
4	Ballyduff Quary	Tullamore Silver	Ground/ Surface Water	4.7	0.6	1.3	55.7	13.4	14.2
5	Rahan	Clodiagh	Ground/ Surface Water	8.1	0.7	1.1	34.9	14.4	15.3
6	Annamoe	Clodiagh	Surface Water	8.0	0.3	0.6	58.9	14.4	15.4
7	Charleville Dem	Clodiagh	Surface Water	10.6	0.2	0.5	90.0	14.4	15.4
8	Mucklagh	Clodiagh	Surface Water	8.2	0.4	0.7	65.7	14.2	15.2
9	Brackagh	Clodiagh	Surface Water	7.2	0.3	0.7	61.4	14.4	15.5
10	Clonad	Clodiagh	Surface Water	7.8	0.3	0.6	40.0	15.6	17.1
11	Ballycowan	Tullamore	Surface/ Ground Water	6.9	0.6	1.1	17.7	14.6	15.7
12	Kilcruttin	Tullamore	Surface/ Ground Water	8.3	0.9	1.6	40.3	15.0	15.7
13	Costa	Tullamore	Surface/ Ground Water	6.8	0.9	1.5	15.4	15.2	17.0
14	Springfield	Tullamore	Surface/ Ground Water	4.8	0.7	1.1	11.4	14.5	16.7
15	Clonmore	Tullamore	Ground/ Surface Water	3.4	0.5	0.9	12.9	13.1	14.6

Physical channel assessment showed a scale of anthropogenic modification as expressed by hydromorphology scores (RHAT), with one site having good-high hydromorphology, while other sites were substantially modified (Table 2.2). Observed differences in these scores among sites were mainly explained by substrate condition, channel form/flow type and floodplain connectivity. Modified sites were characterized by the absence of large woody debris (LWD), channel re-alignment, lowering of the river bed and artificial widening with associated low mean water depth. The modified sites were largely cut off from the floodplain, a consequence of drainage scheme design.

Table 2.2. Hydromorphology scores (RHAT), WFD Class and percentage instream plant cover

Site	Site	River	Hydromorph Scores (0 - 1)	WFD Class	Broad leaf branched emergent (BLBE)	Fringing (F)	Linear emergent (LE)	Linear floating patch (LFP)	Marginal herb (MH)	Patch submerged (PS)	Linear submerged (LS)	Open Water (OW)
1	Newbridge	Tullamore Silver	0.4	Poor	2.1	7.6	11.3	0.0	5.1	1.1	18.6	54.2
2	Derries	Tullamore Silver	0.3	Poor	10.2	8.8	25.3	1.0	6.7	2.3	22.5	23.2
3	Aharney	Tullamore Silver	0.4	Moderate	11.9	5.9	20.8	0.5	3.7	3.0	13.1	41.1
4	Ballyduff Quary	Tullamore Silver	0.5	Moderate	1.3	2.5	13.2	1.0	2.9	0.5	12.3	66.4
5	Rahan	Clodiagh	0.5	Moderate	0.8	5.4	0.9	0.1	2.4	1.6	3.6	85.2
6	Annamoe	Clodiagh	0.5	Moderate	0.3	1.7	1.8	0.0	0.5	0.0	0.0	95.7
7	Charleville Dem	Clodiagh	0.8	Good	0.2	1.2	0.0	0.0	0.7	0.1	0.0	97.8
8	Mucklagh	Clodiagh	0.6	Moderate	0.2	1.8	0.3	0.0	1.0	0.2	0.0	96.5
9	Brackagh	Clodiagh	0.6	Moderate	0.2	0.2	0.0	0.0	0.3	0.0	0.0	99.4
10	Clonad	Clodiagh	0.5	Moderate	0.5	1.6	0.0	0.0	1.1	0.2	0.0	96.5
11	Ballycowan	Tullamore	0.5	Moderate	4.1	10.2	7.4	0.6	2.3	10.5	6.5	58.5
12	Kilcruttin	Tullamore	0.4	Poor	6.7	9.9	4.3	0.6	3.5	3.5	11.0	60.4
13	Costa	Tullamore	0.4	Poor	0.3	8.3	6.7	0.6	1.6	0.0	4.1	78.4
14	Springfield	Tullamore	0.3	Poor	0.6	9.5	5.5	0.0	3.6	0.0	6.5	74.4
15	Clonmore	Tullamore	0.3	Poor	0.6	9.5	5.5	0.0	3.6	0.0	6.5	74.4

Observed mean maximum daily temperatures in June ranged among sites from 14.2 to 17.1 °C (Figure 2.21). June mean temperature range varied from 13.1 to 15.2 °C. Modified sites (low tree cover and Hydromorphology score) experienced greater temperature maxima than more natural sites.

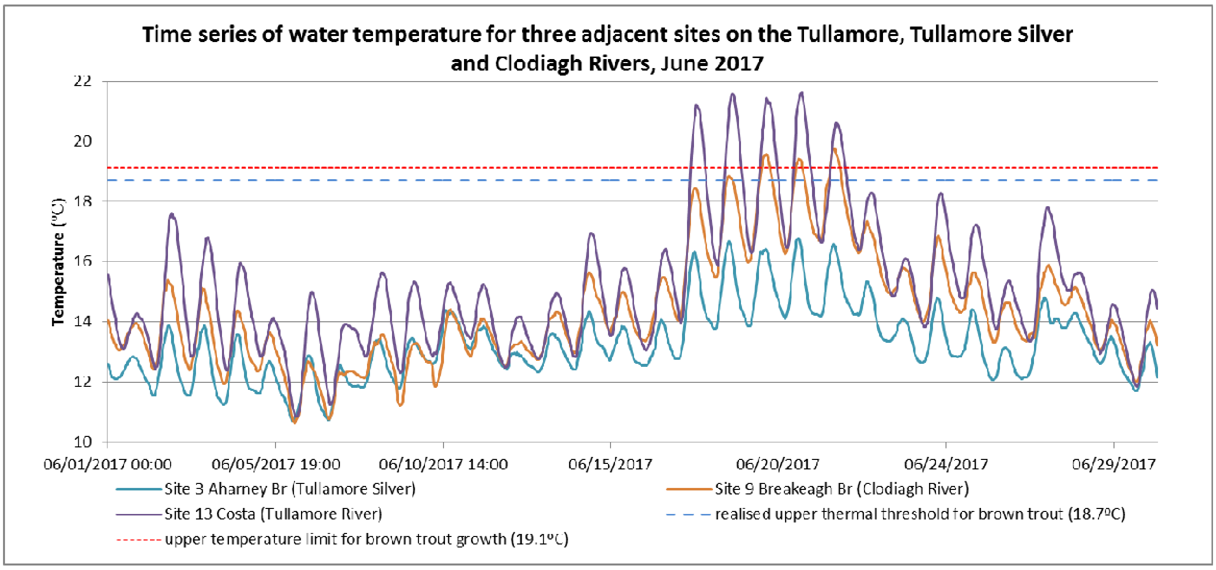

Figure 2.21. Water temperature recorded from three adjacent sites on the Tullamore, Tullamore Silver and Clodiagh Rivers in June 2017. The dashed blue line shows the realised upper thermal threshold for brown trout (*Salmo trutta*) distribution. The dashed red line shows the upper temperature limit for brown trout growth.

The realised upper thermal threshold for brown trout (>18.7ºC) is the temperature which dictates the observed summer distribution brown trout. Above 18.7ºC, trout migrate out of an area to find thermal refuge. The upper temperature limit for brown trout growth (>19.1ºC) is the threshold at which brown trout cease to grow. Water temperatures exceeded the realised upper thermal threshold for brown trout (>18.7ºC) and the upper temperature limit for brown trout growth (>19.1ºC) in both the Tullamore and the Clodiagh but not in the Tullamore Silver.

The effect of canopy cover on mean daily maximum water temperature is given in Figure 2.22. The rivers broadly separate out into three distinct groups with canopy cover affecting each in a largely similar manner (slope of the line). The greater the percentage canopy cover the lower the maximum daily mean temperature. However, the intercept of the regression line with the X-axis is different for each river indicating the effect of canopy cover is different for each river.

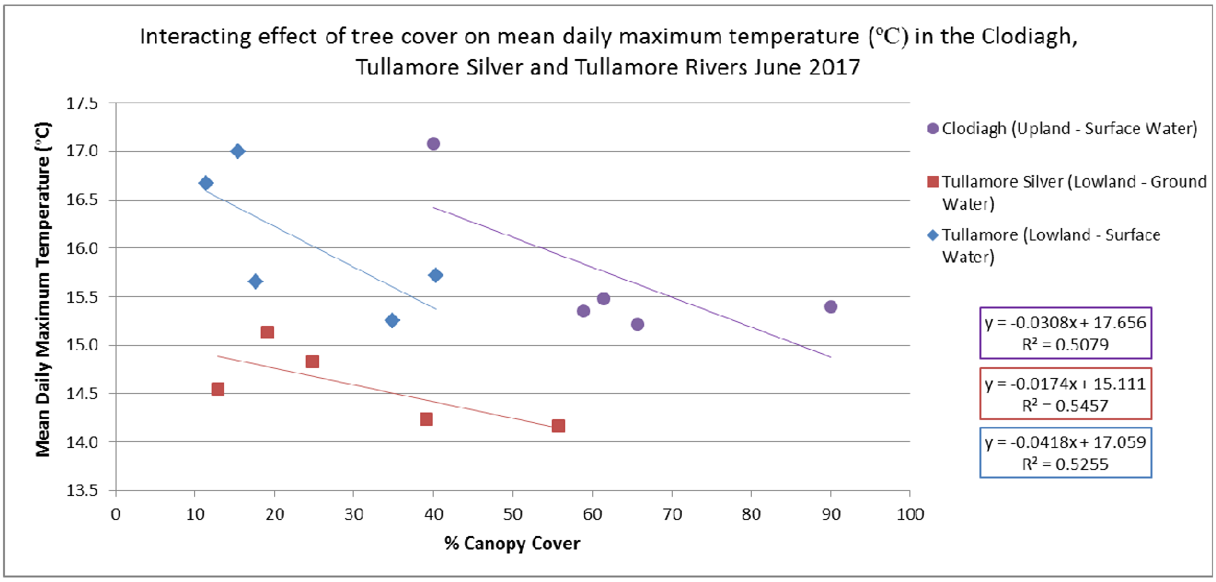

Figure 2.22. The effect of percentage canopy cover on mean daily maximum water temperature in the Clodiagh (Purple), Tullamore Silver (Red) and Tullamore Rivers (Blue)

Water temperature >18.7ºC is the realized upper thermal threshold for brown trout distribution. Above this temperature brown trout have been shown to disperse from an area seeking cold water refuge. The water temperature in the Tullamore Silver did not exceed 18.7ºC in June 2017, primarily due to groundwater springs buffering river water temperatures. The effect of canopy cover on the number of periods (30mins) water temperature exceeded 18.7ºC in the three rivers is given in Figure 2.23. This shows that increasing canopy cover reduced the number of periods when water temperature exceed 18.7ºC in the Tullamore River. The poor relationship between canopy cover and the number of periods (30mins) water temperature >18.7ºC in the Clodiagh River (Figure 2.23, R^2 value of 0.0248), implies that canopy cover >40% may have little effect on temperature buffering in the Clodiagh River. The water temperatures recorded in Figure 2.23 for the Clodiagh are probably more representative of ambient air temperature.

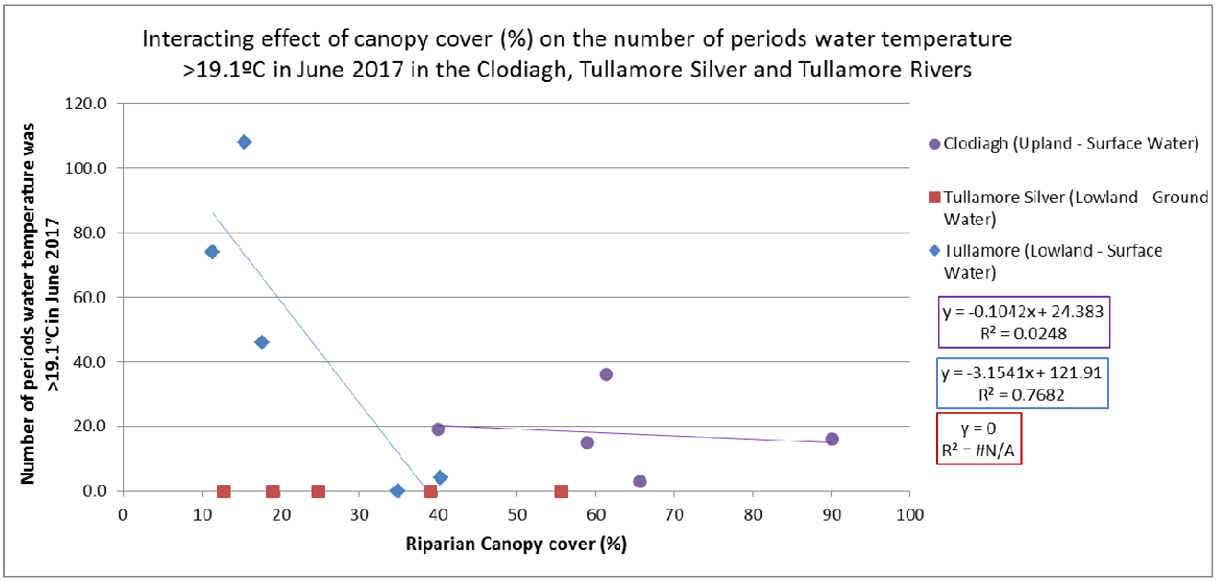

Figure 2.23. The effect of percentage canopy cover on the number of periods (30mins) water temperature >19.1ºC (the realized upper thermal threshold for brown trout distribution) in the Clodiagh (Purple), Tullamore Silver (Red) and Tullamore Rivers (Blue)

The effect of instream emergent and floating vegetation was also examined (Figure 2.24). Floating and emergent macrophytes appear to have the ability to mitigate water temperatures, with increasing vegetation cover suppressing the number of days the thermal threshold of >19.1ºC was exceeded. Both canopy cover and Instream Vegetational cover reach a maximum impact on decreasing water temperatures at ~40% cover, there similar slopes may indicate it's through similar mechanisms. Figures 2.23 and 2.24 also emphasize the effect of groundwater in the Tullamore silver, where no days exceeding 18.7ºC were recorded.

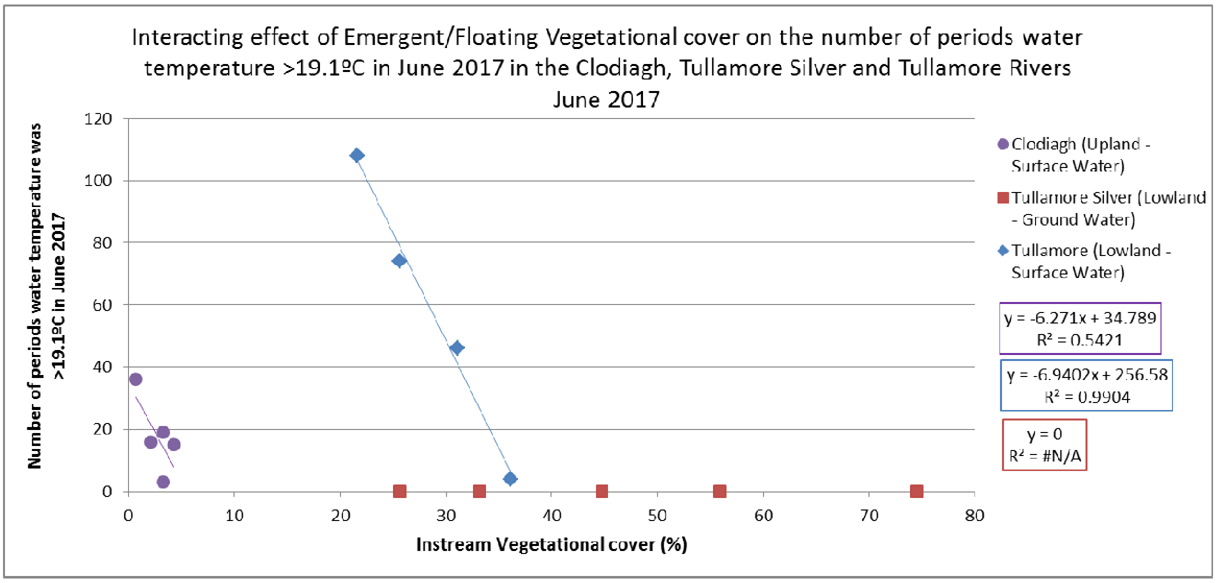

Figure 2.24. The effect of percentage macrophyte (Emergent/Floating) cover on the number of periods (30mins) water temperature >19.1ºC, the realized upper thermal threshold for brown trout distribution in the Clodiagh (Purple), Tullamore Silver (Red) and Tullamore Rivers (Blue).

2.3.5 Discussion

This current study investigated the effect of riparian tree cover and instream plant cover on water temperatures during summer 2017 on three rivers in the Brosna River basin. The Tullamore Silver and the Clodiagh site at Rahan Bridge were found to have low mean maximum temperatures and low mean temperatures due to a prominent groundwater influence, compared to the Tullamore and Clodiagh Rivers which are predominantly surface water fed. The groundwater influence buffers the effect of both direct solar and convection heating, resulting in a more thermally stable temperature regime. The Tullamore Silver sites did show diurnal heating but not to the extent observed in the Tullamore and Clodiagh Rivers.

The Tullamore and Clodiagh rivers differ in both percentage tree cover, depth regime and instream plant cover, as the Clodiagh had extensive riparian cover (40-90%) compared to the Tullamore where it is much reduced (11-40%). The morphology of the Clodiagh (moderate energy – mobile bedload) coupled with its high level of canopy cover precludes the growth of instream macrophytes (average = <3% cover). The Tullamore had between 25-42% instream macrophyte cover. Being so physically and ecologically different, it is also probable that heat transfer mechanisms for these two channels are also different. The Tullamore is probably heated through direct thermal heating (sunshine) while the Clodiagh is probably heated through both direct thermal heating and thermal conduction.

Previous studies have shown that riparian tree cover regulates maximum water temperatures through reduction of direct solar radiation. This buffering effect leads to significantly reduced maximum temperatures during summer months. A previous study undertaken within EREP in the Broadmeadow catchment (Dublin) indicated that during warmer summers, an approximate level of 42% riparian tree cover over an 800-m reach can mediate stream temperatures to levels (<18.7 °C) that are within the preferred physiological range of brown trout.

This study identifies the ability of instream macrophytes to mitigate direct thermal heating of rivers. The implications for this riverine canopy/water temperature dynamic are extensive. Instream management of this riverine canopy through active management (removal: Maintenance) or herbivory (cattle) has the ability to degrade stream habitat and elevate water temperatures. The geographic scale of this degradation is potentially extensive once the systematic removal of the riverine canopy via livestock grazing and/or river maintenance is taken into account. It is important to note that aquatic macrophytes are easily managed as part of a restoration strategy to improve water temperatures. Other approaches to providing shade along rivers, such as extensive riparian plantings, may be effective in the long-term, but would require many years to meet shading objectives. In comparison, spontaneous recovery via aquatic macrophyte growth provides considerable short-term benefits and should be considered in other channels exhibiting emergent macrophyte growth.

In the context of a warming climate, these results highlight the potential of riparian tree cover and the riverine instream canopy to moderate high extremes and strong fluctuations in the water temperature in mid order rivers.

Responses of stream fauna to climatic warming are complicated by interactions between thermal effects and multiple stressors including organic pollution and habitat degradation. It has been shown that dissolved oxygen becomes increasingly limited with increasing water temperature. This reduces the thermal thresholds of fish. Moreover, this effect is more pronounced in organically polluted systems as increasing temperature and pollution interact to reduce available dissolved oxygen.

These results demonstrate the important roles of riparian tree and aquatic macrophyte cover in moderating river water temperatures. Interventions around both may be an accessible management tool in terms of application, cost, and time for environmental managers. Complementary restoration focused on hydrogeomorphological function is also likely to be necessary to support thermal resilience in cold-water streams.

2.3.6 Management implications and relevance of this study

- Tree cover provides shading over a channel and assists in lowering the instream water temperature at a site, which is relevant in the context of climate change
- In the absence of a significant groundwater interaction the absence of tree cover or low levels of tree cover do not provide any buffering against increase in water temperature
- The OPW maintenance strategies in regard to tree management is required to be recognized as an appropriate Enhanced Maintenance baseline protocol and to be supported and strengthened
- The Capital Works strategy of fencing channels, within the OPW_IFI shared EREP study, has a role in regard to conservation and protection of tree cover, particularly young trees, from grazing by livestock.
- The beneficial aspects of tree cover are further identified in the current report (see Long-term study on River Clodiagh)
- The value of water depth as an element in thermal regulation is identified. The Enhanced Maintenance strategy of over-digging the channel bed to create two-stage channel forms and/or those with a wedge-shaped cross section, can create deeper-water niche areas in drained rivers which fish can use in conditions of elevated water temperature (refuge habitat). This strategy can be implemented using Topic 10 in the OPW's Environmental Guidance on channel maintenance. The digging strategy has been shown to be effective in creating such deeper-water habitats while also controlling or restricting the excessive growth of tall instream emergent plants such as *Sparganium erectum* ('flaggers').
- This study also identifies the value of instream vegetation in moderating the heating effect on water due to climate warming. Removal of instream vegetation is considered to improve channel conveyance and, hence, is a common objective in channel maintenance operations. The Enhanced Maintenance guidance to which OPW is now operating calls for retention of vegetation stands along the channel margins as this provides cover elements for wildlife and for fish. It also permits sediment deposition with potential for colonization by larval lamprey. A

further benefit from retaining this cover along channel margins is provided by the temperature outcomes of the present study.

2.3.7 Long-term

It is planned to continue this study into 2018 with further recording of temperature and oxygen levels at the selected stations, along with appropriate habitat monitoring.

This study is designed to provide real information on issues relevant to OPW's channel maintenance procedures and to assist in future-proofing against the impacts of climate change and temperature increase on the river channels managed by OPW. Such forward planning should help to identify maintenance strategies – both new and existing – that can be implemented to help manage the adverse effects of water temperature rise in Irish rivers.

2.4 Long Term Study: River Clodiagh (C8 (1) Brosna Catchment) Riparian Canopy Recovery

The Clodiagh River is a tributary of the Brosna. It rises in the Slieve Bloom Mountains and flows north to its confluence with the Tullamore River before entering the Brosna. A significant length of this channel was arterially drained in the 1960's, extending from the gravel traps at Clonaslee downstream to its confluence with the Tullamore river (~29km).

As an arterially drained river it is highly channelized, being widened and deepened to increase its capacity for flow volumes. Channelization or river drainage is an engineering practice used to control flooding, drain wetlands, improve river channels for navigation, control stream-bank erosion and improve river alignment. As a result, during flood flow this river can facilitate and efficiently move more water.

Channelization has major ecological consequences for the aquatic biota in the river channel, and can also substantially alter wildlife resources associated with the riparian habitat. Most cases of river channelization results in the creation of a homogeneous habitat within the channel cross section. Channelization of medium gradient channels like this section on the Clodiagh River, results in a simple trapezoidal-shaped channel, devoid of characteristic instream flow sequences and without vegetation and in-stream 'cover' which may be of considerable importance to many organisms. Channelization of streams creates a loss of structural complexity, simplified flow patterns, and a loss of various microhabitats that support aquatic biota. The removal of instream structure can reduce the number of fish both directly, by limiting the amount of habitat available, and indirectly, through the loss of benthic macroinvertebrates, greater fluctuation of stream levels, water temperature and altered substrates types.

2.4.1 Clodiagh 1996 Maintenance

In 1995, the OPW engineers identified sections of the Clodiagh River as requiring radical channel maintenance, in order to achieve its conveyance requirements (Figure 2.25). This resulted in its bed and banks being returned to the original scheme specifications. This radical maintenance involved large-scale tree removal throughout the channel and was carried out in 1996. An Example of this maintenance and the subsequent denaturalization is given in figure 2.26. This is site 4, which is immediately downstream of Annamoe Bridge and is the bottom most survey site in this study.

Four sites were surveyed in 1996 (Figure 2.25.) and post-maintenance surveys were carried out annually to 2000 and in 2002, 2004 and 2017. In 1996 sites 1, 3 and 4 were radically maintained pre survey; site 2 was treated as a control and had minimal maintenance in 1996. This long term monitoring is important to identify the biological and physical recovery of channels post radical maintenance (Figure 2.26).

2.4.2 Fish Community Composition and Physical Measurements

The channels physical attributes (depth, width) and canopy cover were recorded at 10 meter fixed intervals in 100m-long sections in each of the four study sites from 1997 onwards. Canopy cover was recorded utilizing a concave spherical densitometer. The Brown trout population was surveyed through depletion boat electrofishing fishing, utilizing two passes, the fish being enumerated and measured after each pass. Over all survey years species encountered in order of decreasing abundance were brown trout, salmon, minnow, crayfish and pike, all fish were measured and released.

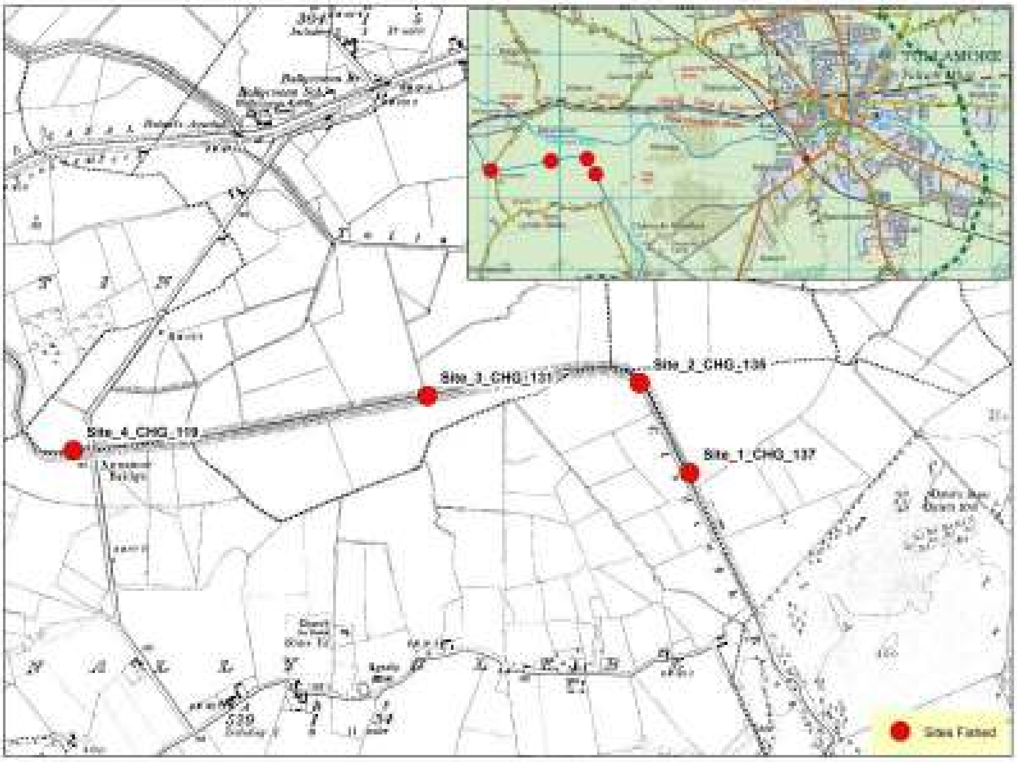

Figure 2.25. Clodiagh Survey site locations (inset: in relation to Tullamore). (Red Circles) *Note: Straightened channel.

2.4.3 The Effects of Maintenance on the Clodiagh Brown Trout population

The effect on the trout population of the 1996 maintenance was a shift from older (2+, >19cm) fish to a population dominated by 1+ trout (12-19cm). This shift in population demographics can be seen in Figure 2.27. and 2.28. There was a shift back to larger 2+ trout in the population in 1999 and 2000. However this was only temporary with 0+ and 1+ dominating the population in each successive sampling event (Figure 2.27. and 2.29). The changes in length frequency over the extended time period point to other factors influencing the trout populations. The shift to younger, smaller fish following the disturbance of the maintenance operation has been recorded in other studies and with a range of fish species. It is generally considered to be linked to a 'simplification' of habitat with loss of features that create complexity, such as variability in water depth and bed materials and of larger woody material. The shifts in trout population structure over time may be linked with the zero or limited development of depth variation in the study sites, demonstrated in this review. There has been no major development of pool areas within the study sites, apart from the undisturbed control site. Such development would allow a shift in the trout population structure, with larger numbers of bigger trout begin present on a consistent basis.

Brown trout densities (no\100m^2) were calculated for the four fishing sites (Figure 2.28). The 1996 data represent pre-maintenance results for sites 1, 3 and 4. Site 2 was retained as a control site. No works were undertaken in this location and this site is taken as representative of the other sites pre maintenance. As shown in figure 2.28 trout densities in maintained sites 1, 3 and 4, were reduced considerably post maintenance. Comparing (t-test: unequal variances) trout densities in the control site (1996-2004) against the maintained sites (1996-2004) indicated that the maintained sites differed significantly from the control (site 2 (t = 5.51835, DF = 8), site 3 (t = 5.88152, DF = 8), and site 4(t = 4.72769, DF = 8,)) P = <0.05. This suggests that extreme maintenance as carried out in 1996 may have a significant impact on a trout population up to 8 years post works.

In 2017 trout densities in the maintained sites have recovered to pre-1996 levels. However, the trout population length frequency demographic is still significantly different comparing 1996 to 2017. A Mann-Whitney U test was used to compare the median length of the trout population in 1996 to 2017 (U = 21739.5, n1 = 201, n2 = 513) they are significantly different P = <0.05. This is explained as the trout population in 2017 is dominated by fish <20cm, compared to 1996 when a greater proportion of the trout population was >20cm (Figure 2.27. and 2.29).

Figure 2.26. Site 4 (Chg 119) on the Clodiagh downstream of Annomoe Bridge, top to bottom: immediately post maintenance 1996, 2002, 2004 and 2017

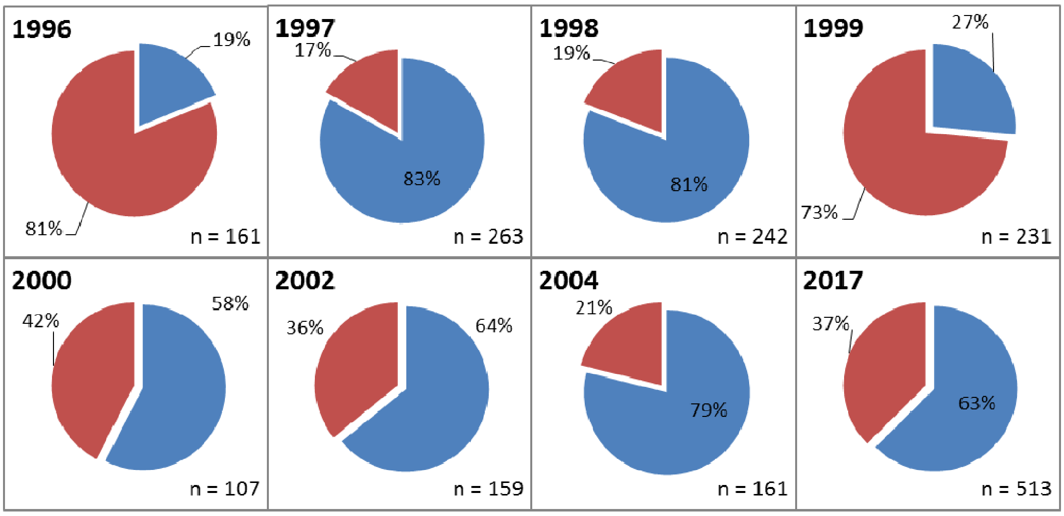

Figure 2.27. The Population demographic of the brown trout sampled in the Clodiagh Pre (1996) and post maintenance (1997 – 2017), (Red represents 2+ adult trout (>19cm) the Blue 0+ and 1+ trout (<19cm))

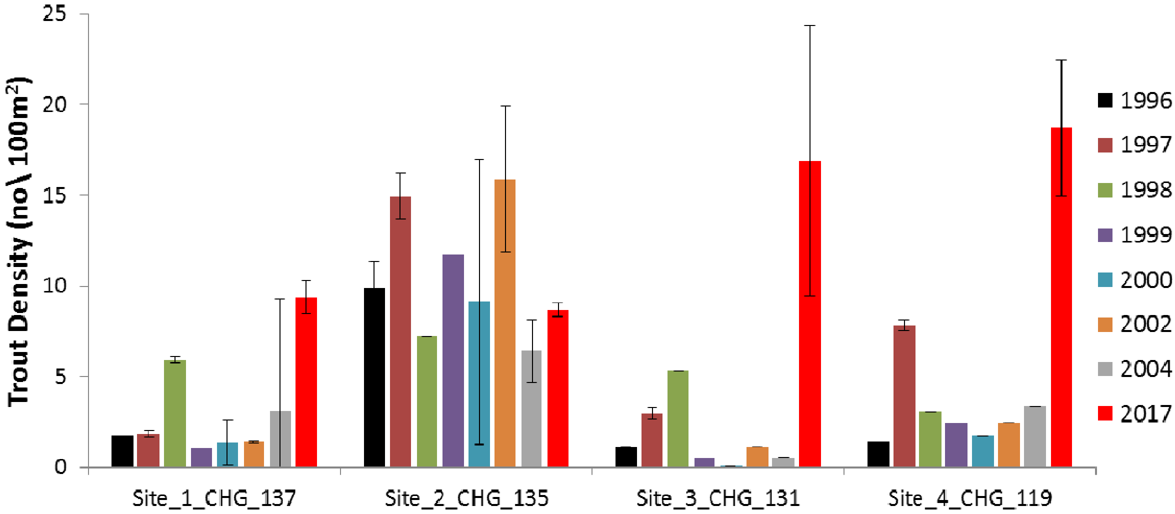

Figure 2.28. Trout densities (no\ 100m²) in the sampling sites on the Clodiagh River from immediately post works in 1996 to 2017. (Site 2 is the control site which received no maintenance in 1996)

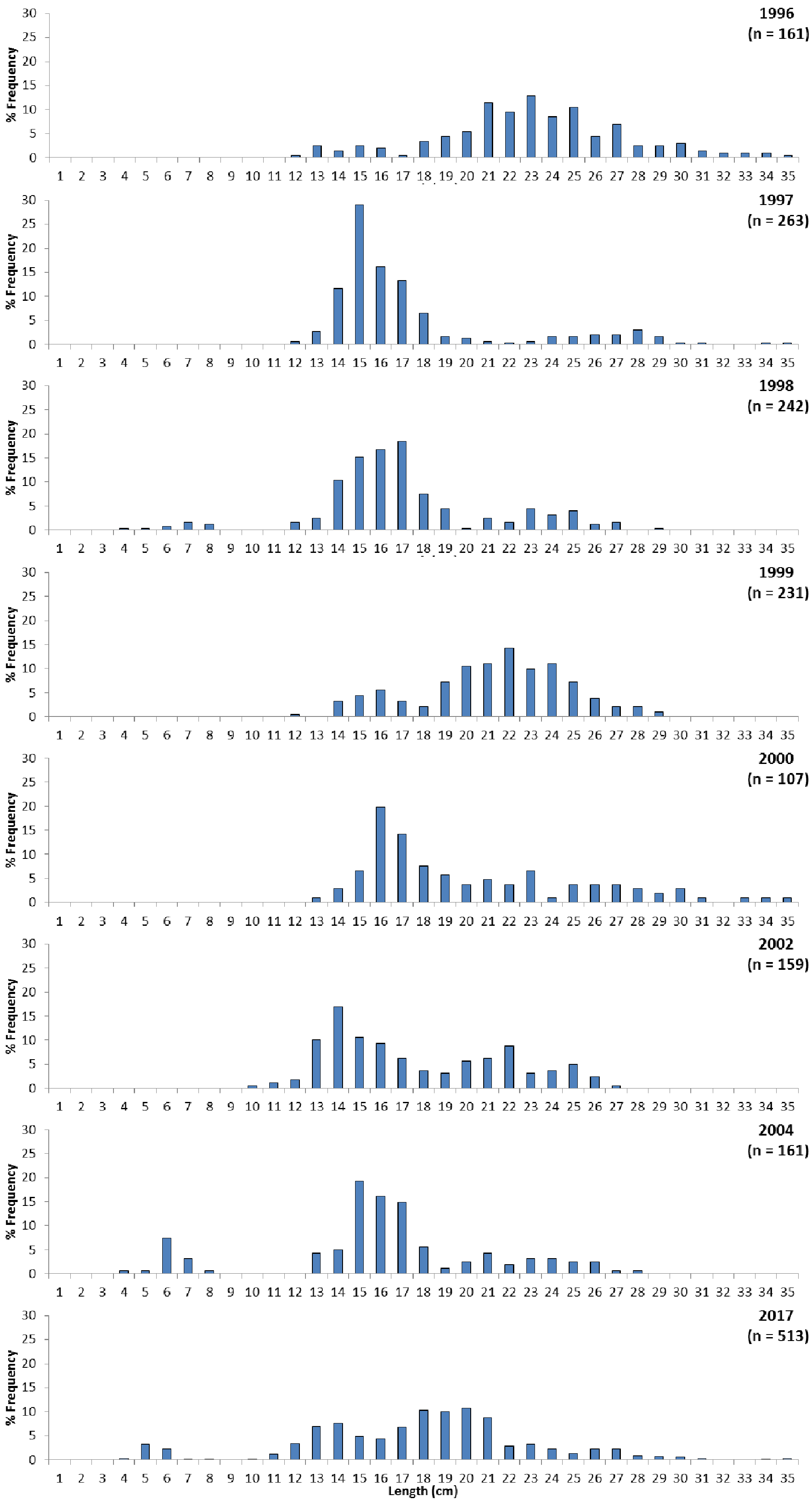

Figure 2.29. Length frequency distributions of the brown trout sampled in the four survey sites on the River Clodiagh Pre (1996 - Top) and post maintenance (1997 – 2017)

2.4.4 The Effects of Maintenance on Water Depth

The effect of maintenance on the average water depth (m) (and standard deviation) of sites 1, 3 and 4 from 1996 to 2017 is shown in Figure 2.30. Site 2 is the control site and received no maintenance. Taking site 2 to represent the mean depth and standard deviations of sites 1, 3 and 4 pre-maintenance (1996) the change in channel depths and depth variations post maintenance is conspicuous. The average depth in the maintained sites from 1997 to 2017 was 0.22m in the control sites the average depth remained at 0.39m with an average difference between maintained and control sites of 0.16m.

The error bars in figure 2.30 show the standard deviation of the water depth in all sites, high standard deviation indicates that the data points are spread out over a wider range of values. The larger the error bars the larger the variations in depth are present in the site. This indicates that maintained sites were made shallower with a less diverse range of depths compared to the control sites and after 21 years little recovery has occurred.

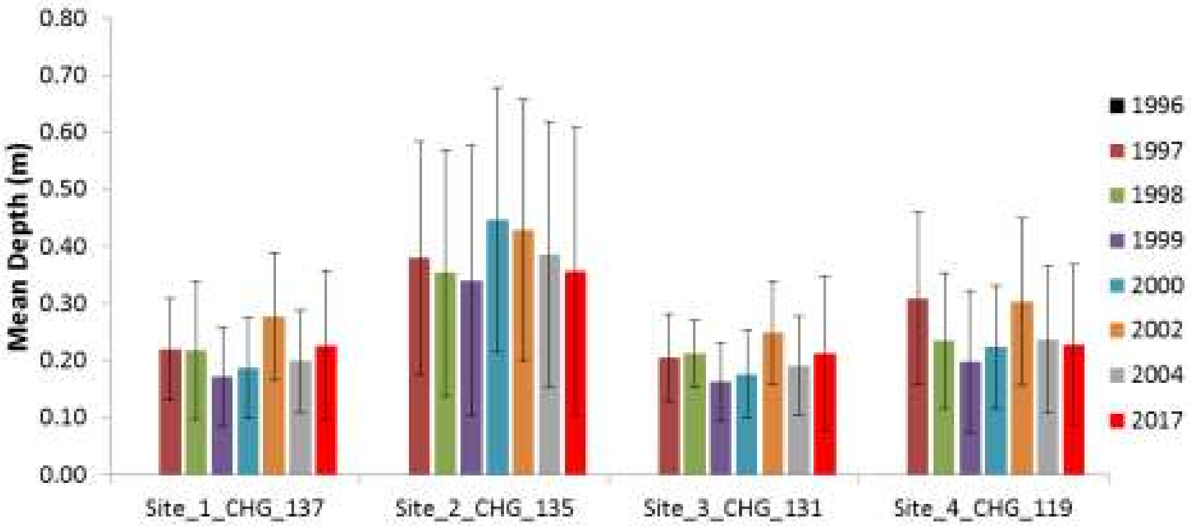

Figure 2.30. Showing the mean depths (m) and their standard deivations present in the maintained (site 1, 3 and 4) and control (Site 2) sites on the Clodiagh River 1997 to 2017

A graphical representation of water depth as recorded in maintained site 4 between 1997 and 2017 is given in figure 2.31. This figure underlines the unchanging nature of the channel with little morphological change in the channel.

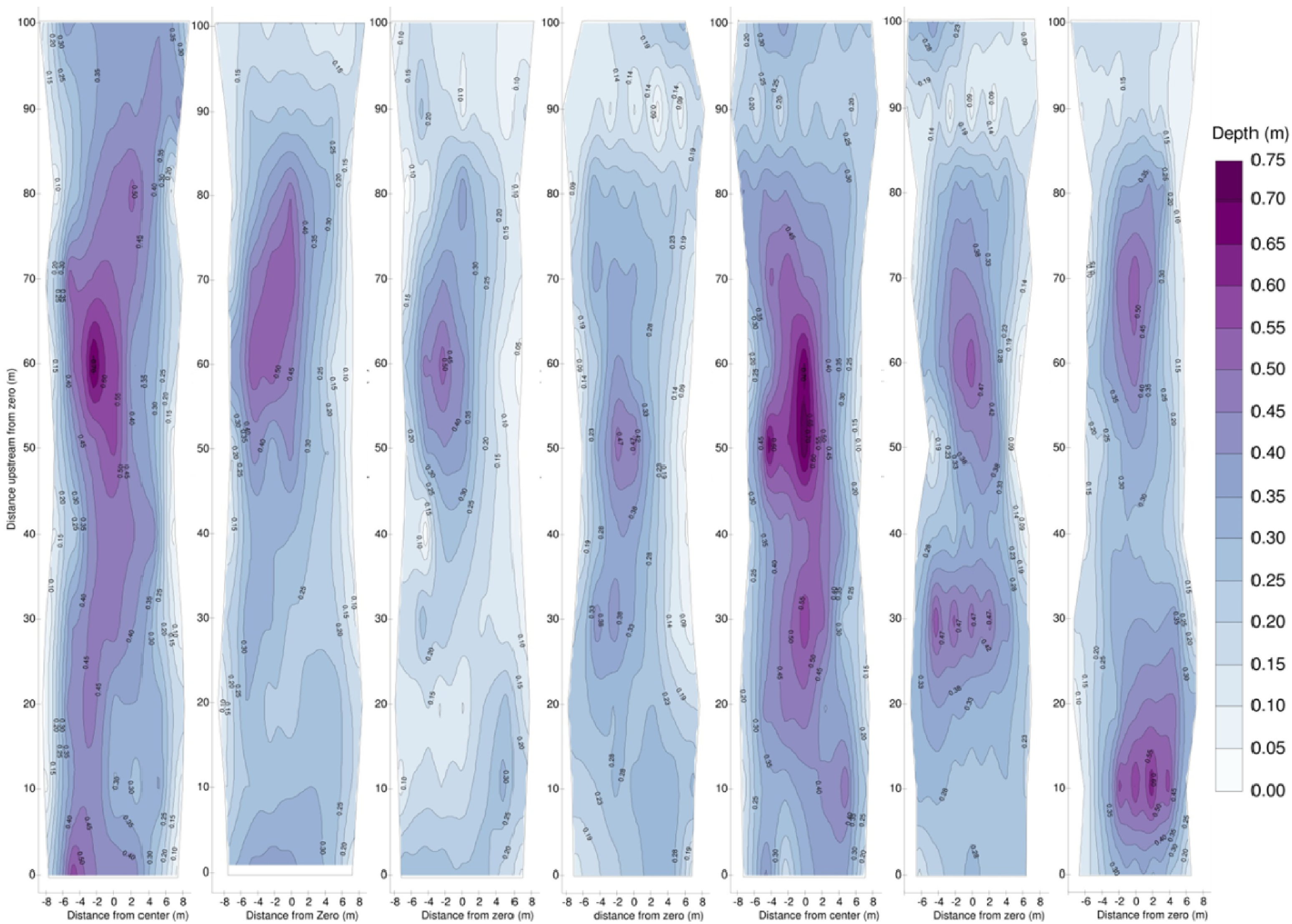

Figure 2.31. Depth contours (m) from maintained site 4 on the Clodiagh River post works (Left to Right, 1997, 1998, 1999, 2000, 2002, 2004, 2017)

2.4.5 The Effects of Maintenance on Canopy Cover

The effect of maintenance on Canopy cover in sites 1, 3 and 4 from 1996 to 2017 is shown in Figure 2.32. Site 2 is the control site and received no maintenance. Taking site 2 to represent the average canopy cover of sites 1, 3 and 4 pre-maintenance (1996) the change in canopy cover post maintenance is evident. The average canopy cover in the maintained sites was reduced from approximately 50% to ≤20% in site 1 and ≤8% in sites 3 and 4 during the works. In the 21 years post works the maintained sites have recovered to or exceed the level of canopy cover pre works. Canopy cover recovery is shown graphically in Figure 2.33.

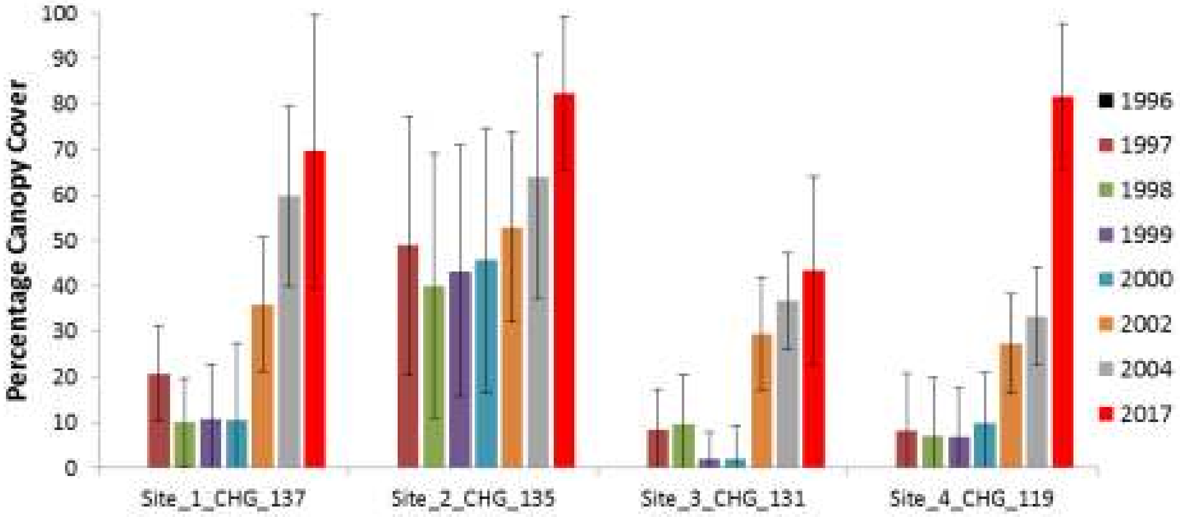

Figure 2.32. Showing the mean canopy cover and there standard deivations present in the maintained (site 1, 3 and 4) and control (site 2) sites on the Clodiagh River 1997 to 2017

A graphical representation of canopy cover as recorded in maintained site 4 between 1997 and 2017 is given in figure 2.33. This figure underlines the recovery of the riparian zone post maintenance in 1996 and how severe the maintenance was in terms of tree removal.

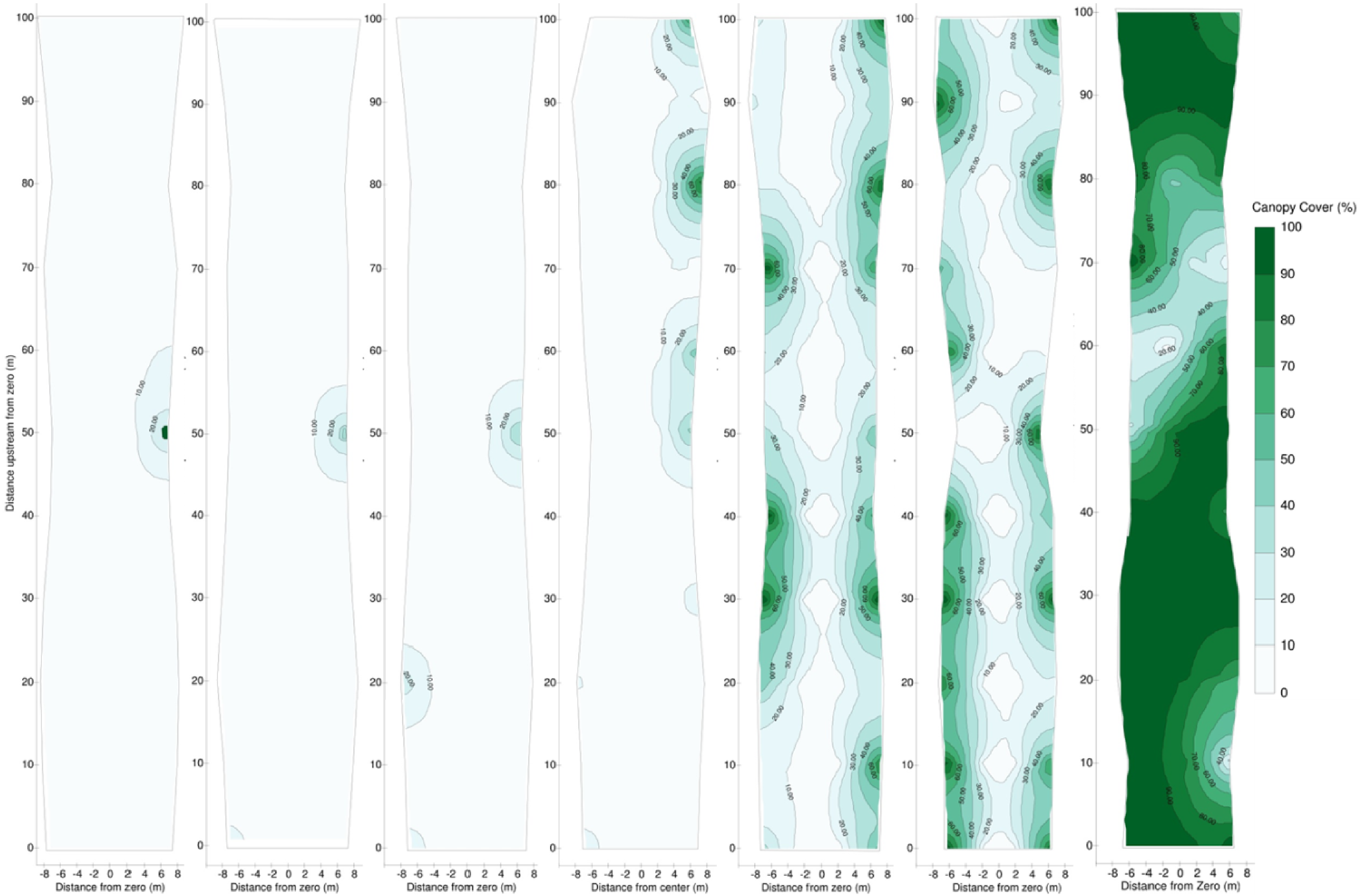

Figure 2.33. Canopy cover contours from maintained Site 4 on the Clodiagh River post works (Left to Right: 1997, 1998, 1999, 2000, 2002, 2004, 2017)

2.4.6 The Interacting effects of Canopy Cover and Depth on Trout Densities

The interacting effects of canopy cover and depth on brown trout abundence (no/100m^2) was investigated using a generalized linear mixed-effects model (glmer). Glmer is an extension to the generalized linear model in which the linear predictor contains random effects (e.g. year) in addition to the usual fixed effects (e.g. Canopy cover/depth). This model was fitted using the glmer.nb mixed modeling package, utilising a nonbinimial distribution. In the model, depth was recorded as a count of water depth exceeding 0.39m in each site and canopy cover was the mean perecentage canopy cover through each site. Variance inflation factor between the co-variates was low <1.5, indicating that vairous components added to the model are not significantly interacting with each other. The effect of water depth and mean percenatge canopy cover on trout densities are shown in figure 2.34.

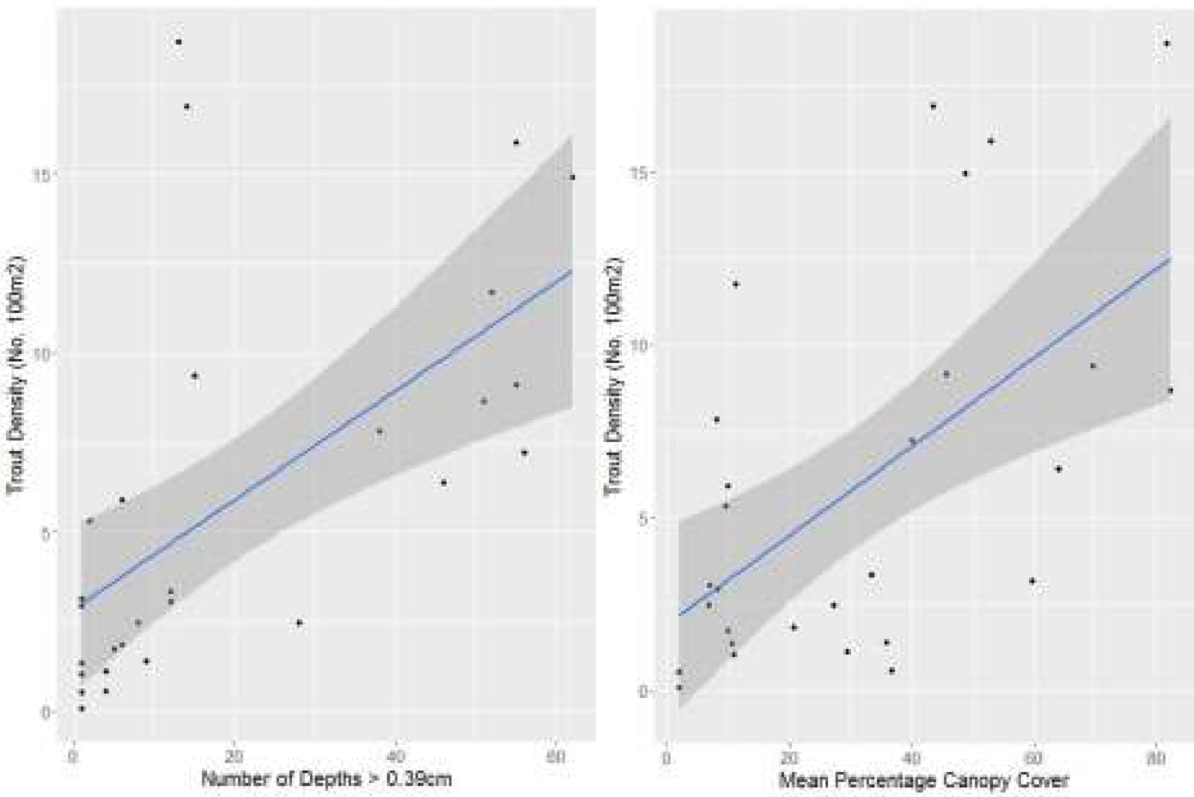

Figure 2.34. Relationships between water depth (Number of depths >0.39m in a site) and mean percentage canopy cover on trout densities (no/ 100m^2)

The effect of depth (Number of depths >0.39m) and canopy cover on trout density were both positively significant (Figure 2.34). The effect of depth was highly significant (Z = 1.232, SD 0.547, P = 0.001) while the effect of canopy cover was significant (Z= 2.131, SD 0.331, p = 0.033). There was also a significant negative interaction between depth (Number of depths >0.39m) and mean percentage canopy cover (Z -2.539, SD -0.308, p = 0.011) (Figure 2.35). Figure 2.34 plots the changes in the coefficient of one variable (depth) in a two-way interaction term conditional on the value of the other included variable (Canopy Cover). The plot also includes simulated 95% confidential intervals of these coefficients.

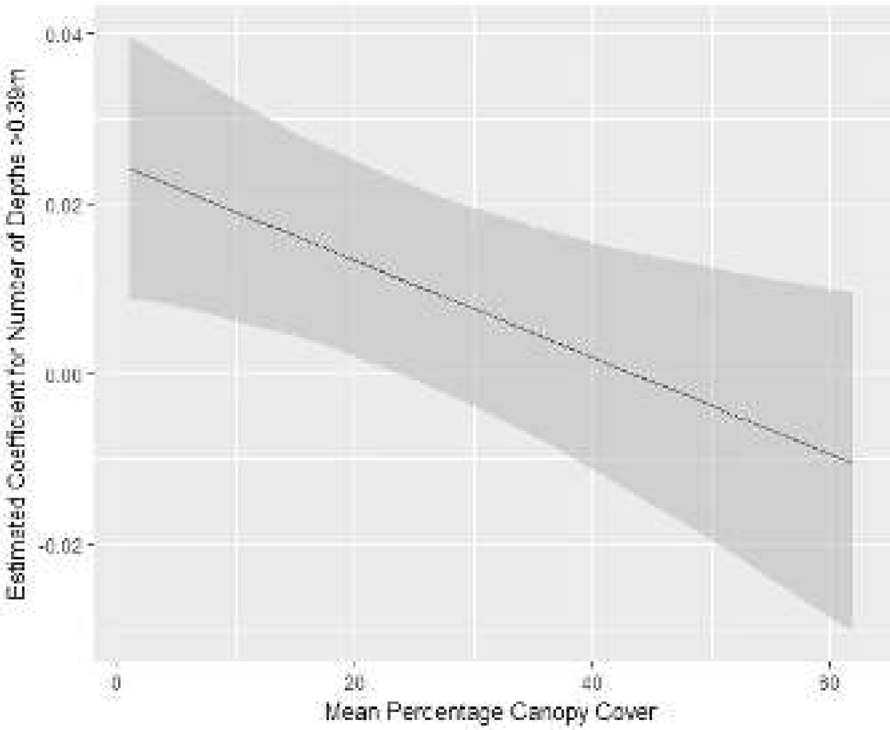

Figure 2.35. The coefficient of the interactive terms, Number of depths >0.39m and Mean percentage canopy cover, the relationship is negative and statistically significant at a 0.05 level.

Statistical analysis indicates trout abundance responds positively to both increases in depth and canopy cover. Greater depths represent an increased availability of both habitat and habitat diversity. An increase in canopy cover may represent an increase in available refuge habitat as canopy provides protection from predators. Canopy cover also provides protection from excessive solar heating during low flow summer warming events.

The simplified habitat left post maintenance (1996) lacked instream features and with no large woody habitat (LWH) or instream plants available to produce hydraulic roughness, therefore no depth variations were created or sustained. This issue may be exacerbated by the bed load of sand which is predominant in this section, as sand fills any depth variations not sustained by a permanent instream structure (LWH/vegetation). The negative relationship between the depth and canopy cover may be explained as canopy cover shades out instream plants reducing instream depth diversity. Canopy cover may shade out bank slope vegetation and lead to channel widening and a shallower, simplified habitat due to bank toe erosion. Clearly, a management intervention via Enhanced Maintenance that could optimise the balance of canopy cover and water depth could be of benefit to both OPW (conveyance management) and IFI (enhanced habitat for trout).

Figure 2.36. Upstream of Annamoe Bridge on the Clodiagh River in July 2017, showing uniform depths and velocities with a high level of canopy cover, no instream vegetation and little large woody habitat.

2.4.7 Management implications - potential river enhancement action

The predominance of depths greater than 0.39m was statistically most relevant to trout abundances. As shown in Figure 2.30. depth variations in the experimental sites have not recovered to a level comparable to the control site. Increasing depth and depth variations would increase habitat diversity and further improve trout densities in the experimental sites. In parallel, significant canopy cover has the potential to reduce depth and depth diversities by tunnelling. Therefore, an appropriate action at the Clodiagh study area would be to use some of the larger trees, growing at a low stage level in the riparian zone since the 1996 maintenance, as large woody instream habitat. Cutting and fixing these trees into the channel bottom at a low stage level would create depth and depth diversities by facilitating bed scour and sediment redistribution. Fixing these structures in place where the trees were harvested (canopy clearance) would allow vegetation to colonize these structures fixing them in place. The addition of LWH has the potential to significantly enhance the ecological potential of the experimental sites and support higher gravel abundance, depths and depth variations, greater flow diversity, improved hydraulic regime and therefore support higher trout densities.

2.5 Re-meandering Programme

2.5.1 Introduction

Ox-bow lakes are formed as a river cuts through a meander neck resulting in a shorter flow path. The continuous flow and natural processes of the river, including deposition, causes the original meander to be blocked off, creating a disconnected U-shaped lake. Over-time these lakes are silted up to form marshes and result in meander scars visible from aerial photography. This process happens naturally in some rivers but in regards to OPW channels, man is responsible for the alterations made to the rivers natural course.

Duties undertaken in 2017 in regard to this new project consisted of a desk-based study to examine a small number of meanders in OPW schemes and assess the feasibility of reconnecting these to the parent channels in specific flow conditions, in the context of biodiversity and wetland habitat creation.

2.5.2 Desk Study

The assessment of OPW channels with meanders suitable for reconnecting was undertaken by a desk study. This desk-based study, designed to identify potential meanders, was completed using the programme ArcMap, a geographic information system (GIS). By the projection of numerous layers including historic 6" maps, aerial imagery along with a shapefile displaying all OPW channels, suitable former meanders could be identified. Scanning each channel, it was evident the interference that the arterial drainage schemes had on the rivers natural flow path. With drainage the main aim of the schemes, many rivers were straightened significantly, either in the 19th century or since 1945 by OPW, to improve the flow of the river.

Examining each channel with the historic map projected it was possible to locate where meanders (now often ox-bow lakes or areas of rough pasture) once occurred. Some of these meanders are completely visible to date (aerial imagery), with others completely ploughed under. Some areas, once part of a natural river course, are now used for intensive agricultural purposes, forestry, infrastructure (roads and railway lines), recreational areas (golf courses and football fields) and often residential purposes in some urban areas (Figure 2.37).

When determining if each meander/ox-bow had potential for the re-meandering project, many factors were considered. These included; land use of meander, surrounding land use, tree extent on the meander and access. Ideally, suitable meanders selected would have no agricultural purpose (rough pasture), have surrounding tree cover and perhaps have some water accumulated within the ox-bow (Figure 2.38).

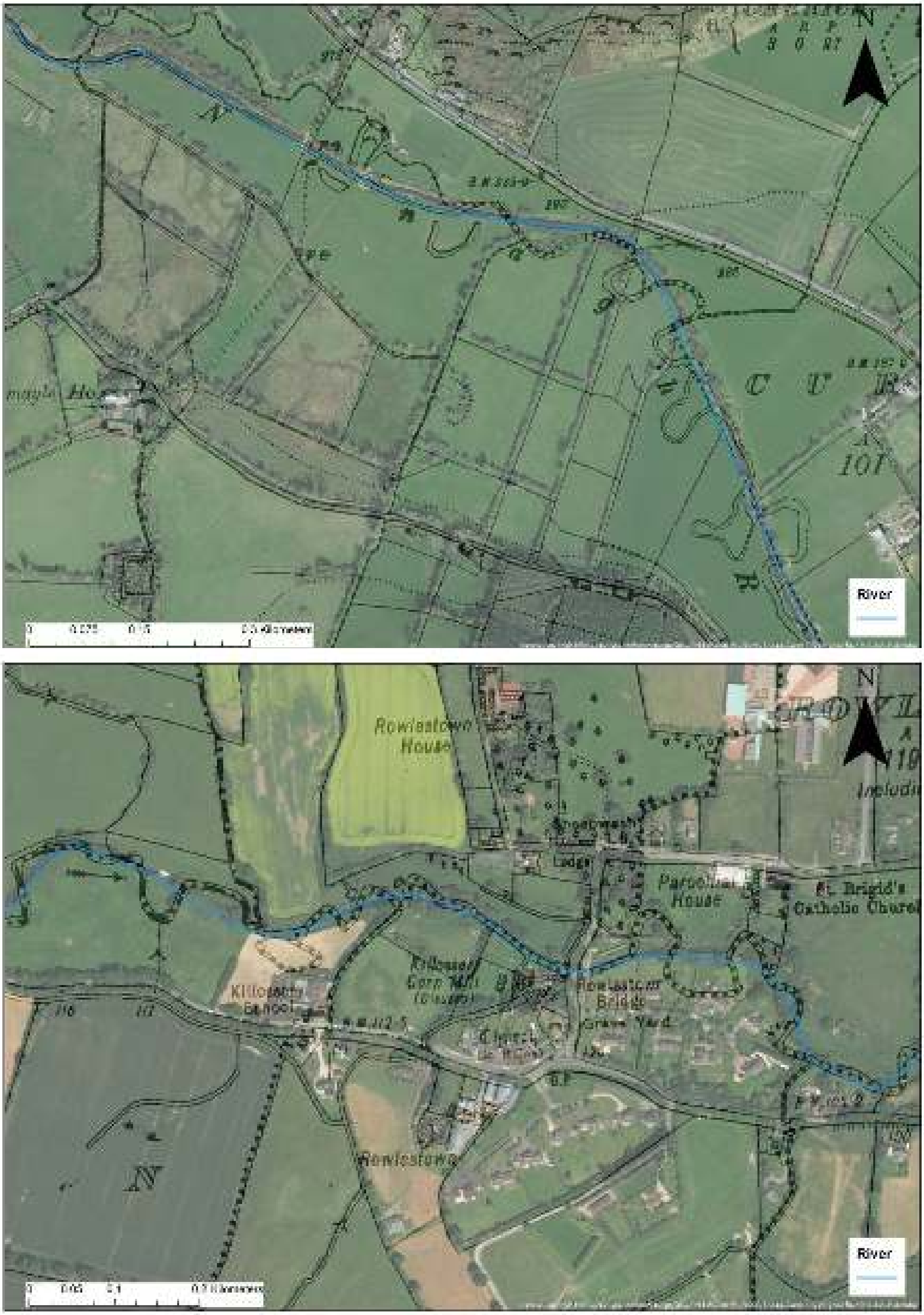

Figure 2.37. Historic maps over-lapping aerial imagery showing the extent of straightening in OPW channels in both Rural (Nenagh River) and Urban Areas (Broad Meadow River, Swords).

Figure 2.38. Maps displaying ox-bows/historic meanders with potential (Y) along with examples of ex-meanders with no potential (N) (Nenagh & Kilmor River).

A total of 61 potential meanders were selected during the desk study (Figure 2.39). Now that the selection is completed, each meander will be assessed individually. Of the 61 suitable sites a small number of these will be selected and scheduled for site visits during 2018. Issues of access and specific suitability will be assessed during the site visits.

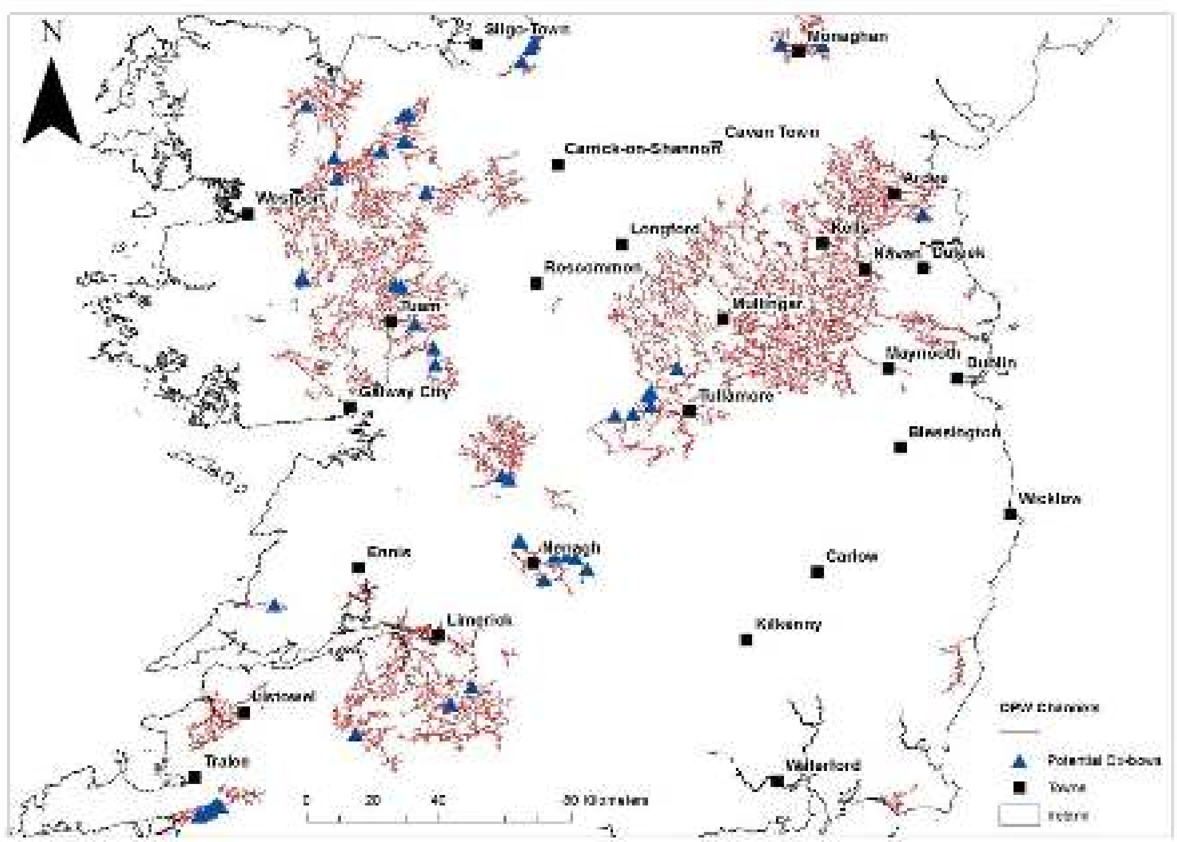

Figure 2.39. Map displaying potential sites in selected OPW schemes during the pilot desk study.

2.5.3 Why reconnect?

Similar projects have been completed in other EU countries (England, Denmark and Germany). Evaluation of these developments indicated an obvious improvement in habitat complexity, channel morphology and biodiversity. Studies of macroinvertebrates, fish fauna and aquatic vegetation in the River Gelsa and other Danish streams have shown positive results since the rivers were re-meandered. (Roni, 2005).

In Germany, a section of the River Spree was subjected to a re-meandering project under a 'REFORM' Scheme, completed over a three year period (2004-2007). During this development four meanders were reconnected to the main river course increasing its flow path by 2.7kms. Since extending the flow pattern of this river it was stated that flood frequency downstream has been reduced, along with an increase in biodiversity and habitat variation in the new channel. (Wolter, 2014).

The Little Ouse River example, Thetford, Norfolk (1994)

This river displays similar characteristics to many OPW channels in Ireland. The Little Ouse is a low gradient river draining an area of mixed land uses, including agriculture and forestry. This river was subjected to arterial drainage work over a period of 30 years resulting in 900m of river being completely bypassed by a newly modified uniform channel.

Following reconnection of the old river channel, studies showed that the original meandering channel is now sustaining a diverse aquatic invertebrate community, with stone fly, mayfly and snail species which are not present in the uniform bypass channel. There is also evidence that chub and dace are using the reconnected reach as spawning and nursery grounds and wildfowl and wader birds including lapwing have been recorded at the site (Gregory, 2014). This is one example of a substantial evidence base which indicates the benefit of incorporating historic meanders back into the flow regime of rivers to improve biodiversity.

2.5.4 What follows the Desk Study?

OPW channels display trapezoidal characteristics to encourage flow and have reduced connectivity with their flood plain. As run-off from land and near-by hills increases due to climate change, water volume within these channels may increases significantly. Lacking a natural connection with their floodplain, these channels may convey unsustainably large volumes of water downstream. Re-connecting meanders will provide some capacity to retain volumes of flood water and potentially reduce downstream flooding events, along with improving habitat and fauna diversity.

From the 61 sites identified as having potential for development, sites displaying different factors (stream order, surrounding land use and gradient) will be selected for potential re-connection. The overall development 'plan' for these meanders is to excavate a channel shadowing the flow path of an ex-meander which will be "flooded" during certain, agreed, high water levels. The depth of the channels dug will depend largely on the depth of the adjacent channel, and median flood water levels. Understanding flow patterns and water levels of adjacent rivers is vital prior to the development of these sites. Engineering surveys are essential in selecting any trial sites. Agreement of landowner, OPW and IFI in regard to any selected site would be essential for study success. Surveys would be necessary at each selected site before and after development and would include levelling, physical habitat and biodiversity assessment. A long-term monitoring would determine positives and negatives of the proposed project.

2.6 Long Term Study: River Dungolman (C8 Inny Catchment)

2.6.1 Introduction

The Dungolman River survey has been on-going for a 24 year period. The aim of the study was to determine the impact of maintenance and enhanced maintenance on fish populations and vegetation structure in a channel where substantial lateral berms had developed. At each sampling year, each site was electro-fished and a plant map composed. This report investigates the effect of works on the brown trout population of the Dungolman River through this 24 year period.

Maintenance of the river was scheduled to start in 1994 by the OPW as part of their arterial drainage maintenance scheme, and so a pre-maintenance survey of the study sites (x3) was undertaken. Two of the three sites were altered; a control site was selected and left with no maintenance work undertaken. The Experimental Site had the berm lowered to water level, the standard maintenance site had all berms removed down to channel bed level.

In 2000, the survey was changed slightly with additional sites added prior to a repeat maintenance cycle event. A total of five treatment plots were selected prior to maintenance in 2000 and these were resurveyed in 2001 and 2002, and again in 2017. Of these five sites, three had been subject of study in the period 1993-1998.

2.6.2 Post Maintenance 1994

The brown trout population sampled immediately post works (1994) showed a decline in 1+ trout numbers in the control site relative to the experimental site (Figure 2.40), whereas the population of 2+ trout increased in both sites following works. In 1995, the trout population of both year classes was considerable higher in the control compared to the other sites being examined.

There is a reduction in the population density of all brown trout age classes in each of the three sites in 1996 compared to previous years 1995 and 1994. This dramatic decrease in trout population numbers is not due on site works. A report by the Central Fisheries Board 1997 stated that there was a fish kill in 1996, following the discharge of deleterious material into the water body. This unexpected event in 1996 impacted adversely on brown trout year classes at each of the study sites, and may have eliminated any difference in the rate of recovery following maintenance. In 1997, the population density of 1+ trout increased substantially at all three sites, although the population of 2+ and older trout remained at its depleted state recorded in 1996. The population density of brown trout increased in 1998, in relation to 2+ and older fish, at each of the three sites all values exceeded those recorded in 1993 prior to maintenance. However the standard maintenance site carried a very low number of 1+ trout in 1998 relative to the other two sites (Figure 2.40).

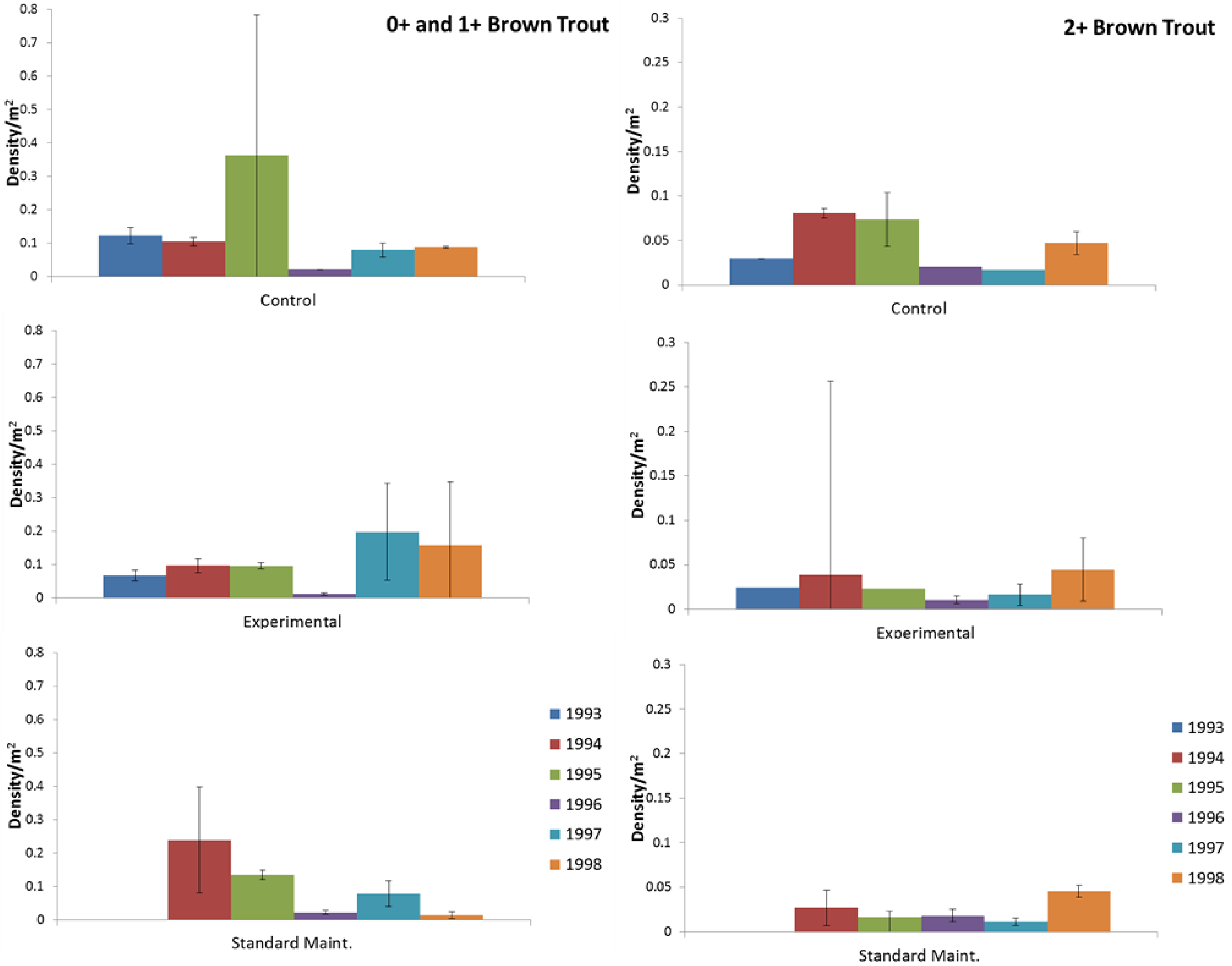

Figure 2.40. Displaying brown trout densities per m² at each of the three sites for every year of the survey (0+, 1+ and 2+ Brown Tout) +/- 95% CL.

Figure 2.41 displays brown trout electrofishing density data (all year classes) collected during each year of this particular survey (1993-1998). This graph shows that experimental maintenance did not have a significant impact on trout population densities, with trout densities increasing over the sampling period in a similar mode to the control site. The standard maintenance site while being similar to the experimental maintenance in 1994 and 1995, trout density levels do not recover to levels observed in the enhanced maintenance site in 1997 and 1998 (Figure 2.41).

The control site displays an expected trend of recovery with density numbers increasing. In 1996 a fish kill was recorded, which was responsible for the significant decrease in population density/m² for all three sites. Standard maintenance negatively influencing the fish densities in this water body, experimental maintenance appears to mitigate this impact. The experimental maintenance undertaken in this programme is now enacted in the "10 steps of environmentally friendly maintenance".

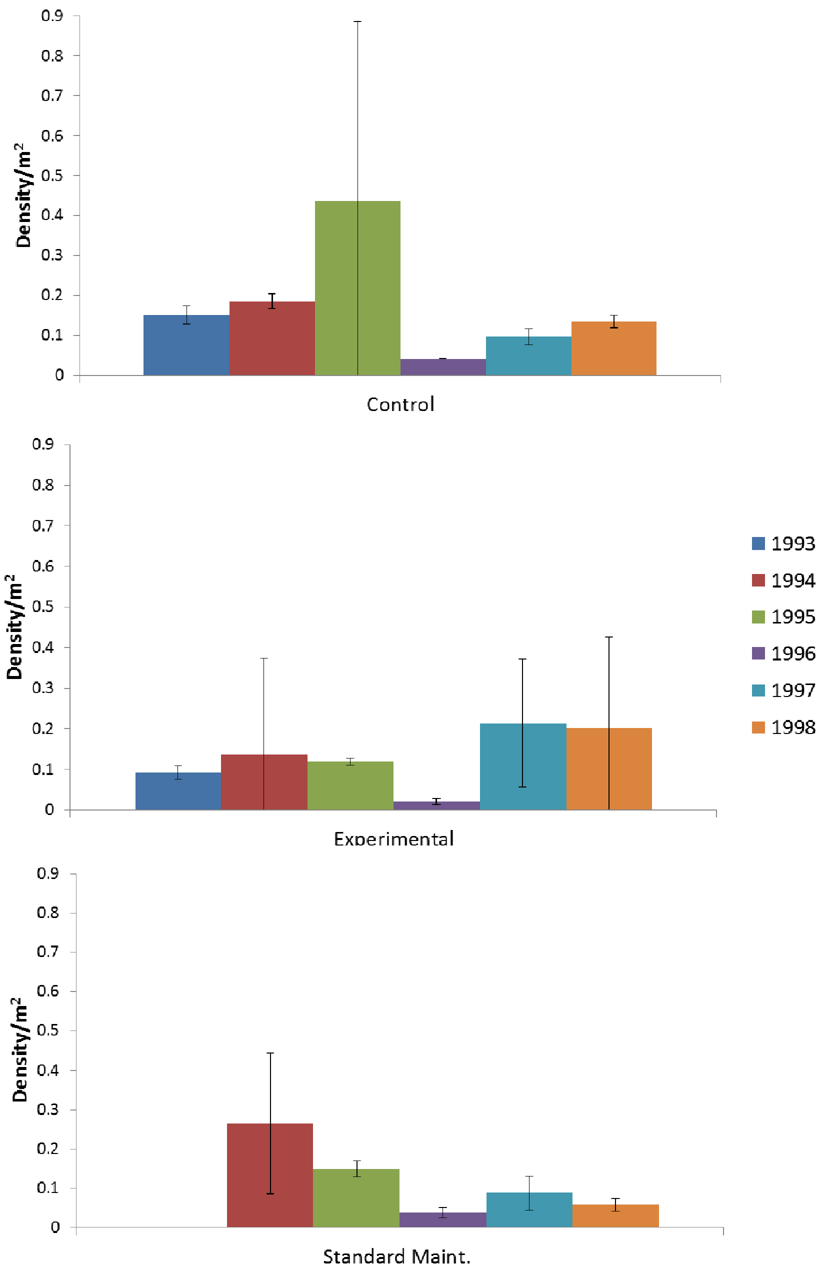

Figure 2.41. Density (Number per m²) for all brown trout age classes (0+, 1+ and 2+) at each site during each year (1993 - 1998).

2.6.3 Post Maintenance 2000

In 2000, the Dungolman survey was modified. In the modified survey a total of four treatment plots and a control were selected prior to maintenance in 2000 and these were resurveyed in 2000, 2002, and again in 2017. Of these five sites, three had been subject of study in the period 1993-1998 (Sites 3, 4 and 5, Figure 2.42).

Channel maintenance was again undertaken in 2000. On this occasion, the Experimental Site 3 had its berm topped to water surface level, in line with developing environmental maintenance practise. The fish data from all sites including the three long term study sites showed a substantial increase in trout densities at all sites in 2001 (1 year post works), relative to 2000, but decreases were evident in 2002. The fish data from the three long-term sites showed a substantial increase in density 1+ trout at all sites in 2001, relative to 2000, but decreases were evident in 2002. These trends has been exhibited in other surveys following maintenance, of these sites given the most radical treatment i.e. sites 1-3. The control site carried the highest density of all the sites in each year of the monitoring and retained the most stable trout densities.

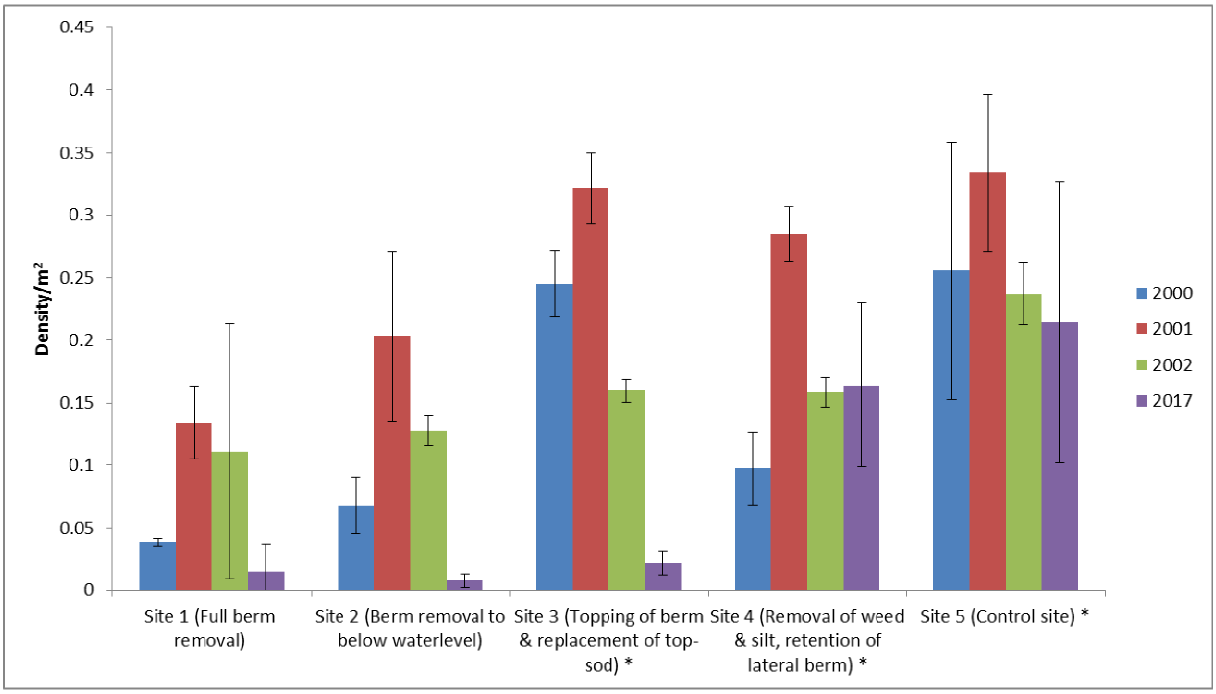

Figure 2.42. Brown trout density per m² for all sites fished from 2000-2017. ***Study sites from previous/original survey.**

2.6.4 Conclusion

The number of brown trout captured during the 2017 survey was relatively low (n=86), compared to previous years (2002, n=303), although brown trout numbers captured over the five sites fluctuated on a yearly basis. Between 2002 and 2017, there was a 15 year period in which the sites were not surveyed. During this time other factors, such as water quality, changes in vegetation structure and maintenance works, may have influenced changes in fish population densities.

During the 2017 survey, a repeat study of channel cross-sections was performed at those locations previously surveyed. In the case of Site 3, it was clear that the berm, retained and managed in the 2000 maintenance event, had now been effectively removed to bed level. It is likely that this happened during some subsequent maintenance operation by OPW. At the same time, the Site 4 and the Site 5 Control sites, upstream of the county road bridge, were left undisturbed by any maintenance work subsequent to 2000.

There was a similar pattern in the trout population densities at all five study sites in the 2000 - 2002 period (Figure 2. 42). The survey of 2017 showed two different patterns. In one the density values in the two sites upstream of the county bridge, Sites 4 and 5, behaved similarly with no evidence of reduced trout density in 2017. This contrasted with the three sites downstream of the bridge, where the trout density values were substantially diminished in 2017, relative to 2001. The removal of the berms in these sites may be a major factor in the reduced trout density values recorded.

Overall, this study concludes that "unsympathetic" maintenance can negatively influence fish abundance in the Dungolman. The historic protocols used by the OPW, configuring channels back to scheme design form, impact fish populations both directly and indirectly. They impact the fish stock directly from the physical work by hydraulic machinery and indirectly by the removal of vital habitat from the riverine systems (berms).

The OPW's environmental guidance is therefore **not** to remove berms completely when maintaining channels, but activities such as topping of the berm or removal of the weed and silt without impacting the berm is advised. Berms are important for creating 2-stage channels, during different flow levels, which in turn creates new habitat and diversity, improving trout numbers. Therefore the rigorous implementation of the 10 Steps to Environmentally Friendly Maintenance will benefit brown trout populations by retaining instream habitat.

3 Barrier surveys – relevance to OPW and survey works undertaken in 2017 under EREP

3.1 Overview of IFI barrier assessment strategy

IFI has developed a two-stage approach to location and assessment of potential barriers to fish passage. Stage I involves implementation of a desk-based protocol that identifies and geo-maps all potential barriers in a catchment followed by visits to all potential sites and data collection at those locations that are clearly an issue in terms of channel continuity – barriers to fish passage or to downstream sediment transport. Stage II involves using the more detailed SNIFFER or WFD III methodology to assess barriers where mitigation measures or possible barrier removal are being considered.

Stage I has a desk and a field component. The desk study uses a protocol whereby all potential barriers or structures in a catchment are identified using GIS layers. The interface of the national roads and rivers layers creates a grid of all channel crossings – all of which may be potential barriers. This is augmented by the historical layer from Ordnance Survey 6″ maps showing marked features such as weirs, stepping stones, fords, etc. The OPW's GIS layer of its recorded bridges provides a further layer to superimpose over the rivers layer.

The final map provides a roadmap, almost literally, for the outdoor survey team to visit all locations during the field assessment. All marked locations are visited for presence/absence of passage issues. Issues or obstacles identified are recorded on a digital form in a ruggedized laptop in a series of dropdown menus. The form permits capture of GPS location of any feature for survey as well as taking photographs. Data can be downloaded later into a master database for extraction and analysis.

The Stage II procedure involves application of a detailed assessment procedure at any structure where barrier mitigation or removal work is being considered. The IFI uses the SNIFFER III protocol for this purpose. The SNIFFER process examines the structure and identifies the number of possible routes or "transversal sections" (TS) that fish species could use to pass over the structure. Each transversal is then examined separately and discrete measurements taken relevant to it. At the later desk-based analysis stage the results from all of the transversals for any structure are taken into account in assessing its overall passability score. At each transversal velocity measurements at 0.6D and at bed level are required at five points across each of three transects, at the inlet or entry point, mid-point and at the foot or outlet from the transversal. The hydraulic head, is recorded along with 'natural' river width, length of the structure, plunge pool depth etc. In addition to measurements, the SNIFFER protocol requires the recording of certain 'subjective' elements including the presence of standing waves, the degree of turbulence associated with each transversal and any masking effect due to debris collecting on the structure.

Each fish species is treated uniquely and there are four passability scores: 0 (complete barrier), 0.3 (partial barrier high impact), 0.6 (partial barrier low impact) or 1 (no barrier). The overall passability score for each TS is the lowest score or the most detrimental obstacle to passage at the TS (e.g. Barrier height, velocity). The overall passability score for the entire structure is equal to the TS with the highest score i.e. most passable transversal. To calculate scores, a series of criteria are applied at each TS, based on the species and/or life stage being considered. These criteria are based on published data describing the swimming and leaping abilities of a discrete set of fish species/life stages recorded in Britain. The SNIFFER protocol considers both upstream- (adult salmon, adult lamprey, juvenile eel) and downstream migrations (salmon smolts; adult silver eel). The protocol also facilitates passability performance of fish passage solutions or fish passes.

3.2 Survey of potential barriers in the lower Inny basin – Inny Catchment Drainage Scheme

Barriers to fish passage have been identified as being a major impactor on anadromous fish species. The issue of barriers is relevant in the Water Framework Directive (WFD), in the context of hydromorphology and continuity.

A barrier assessment survey was undertaken on the South Inny Basin to identify barriers to fish passage. This was achieved by combining a desk based survey which digitally identified potential barriers, using historical maps and recent aerial imagery, with a field survey using electronic barrier survey forms on a tablet format developed for IFI. Throughout the South Inny Basin, a total of 762 potential barriers were identified during the desk based assessment (Figure 3.1). The survey process is intended to record man - made barriers as well as natural barriers. However, it is implicit in the Water Framework Directive that natural 'barriers' should not be interfered with.

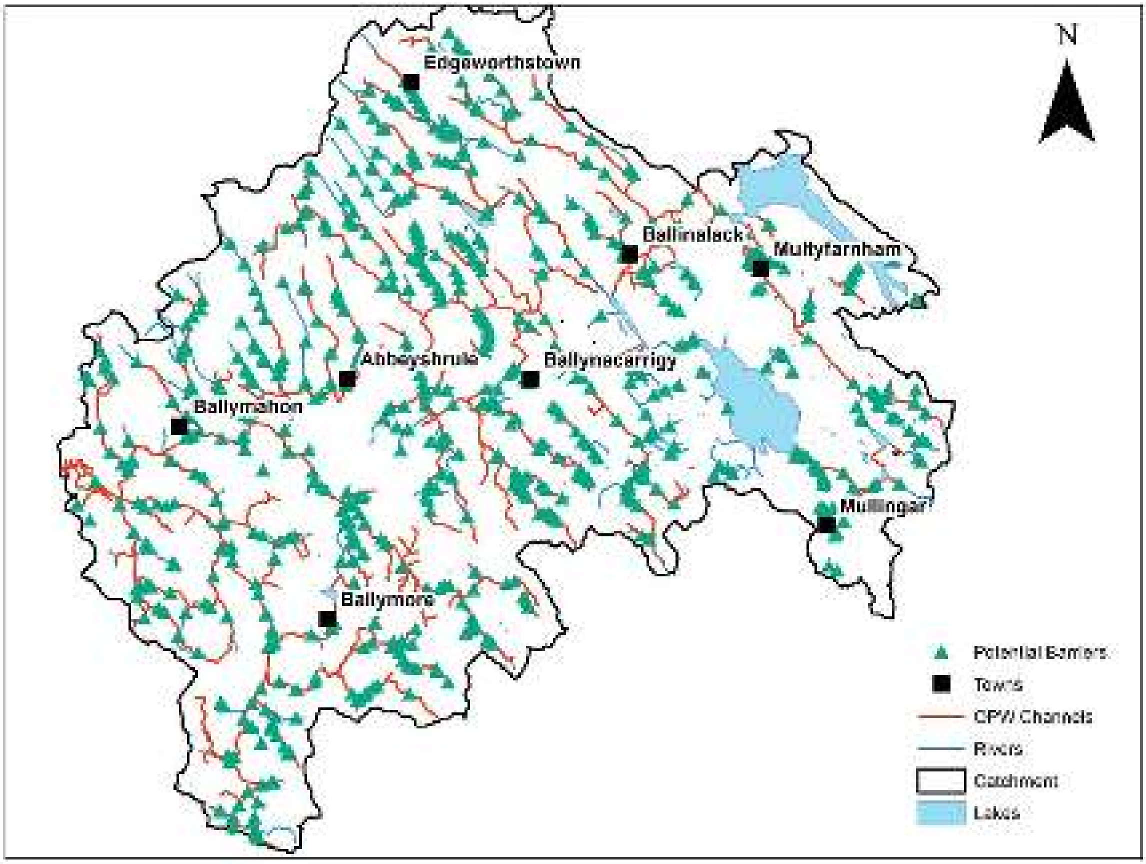

Figure 3.1. Map displaying all potential barriers (green triangles) within the South Inny Basin (n=762) identified during the desk study.

Progress in 2017

Of the 762 instream structures identified as **potential barriers** in the southern basin, a number (n=23) had been surveyed by IFI regional staff prior to this survey in a Shannon catchment `overview' project. In addition, 34 of the identified potential barriers in the South Inny Basin were actually part of the Brosna Catchment and so, were not included in this survey.

Due to adverse weather conditions, 144 potential barriers have not yet been visited. Excluding the potential barriers that were located in the Brosna catchment, those surveyed previously, and those not visited, a total of 561 potential barriers were visited in 2017. Of these, 35 were classified as barriers to fish migration and were surveyed, with relevant data compilation, in 2017 (Figure 3.2). Combined with previously-identified barriers, a total of 45 of the 561 structures in the Lower Inny basin were classified as barriers to fish migration (8.02%). The total of 762 potential barriers included a large number of road crossings, many of which were considered unlikely to be a problem for fish passage. Only a small number of the road crossings were found to impede on fish passage.

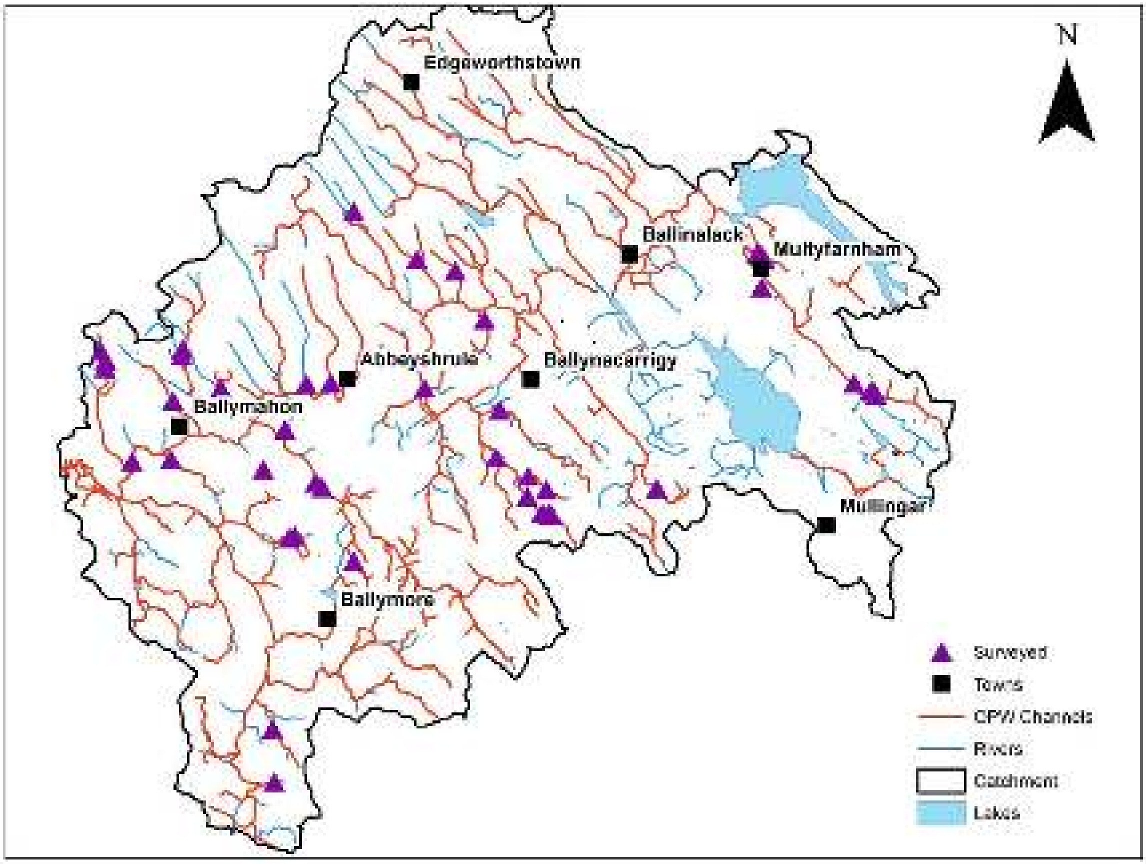

Figure 3.2. Distribution of barriers identified (Purple Triangles) in 2017 (n=35), along with barriers identified prior to the survey (n=10).

Table 3.1. Barriers identified from the various GIS layers examined in the desk study and their onsite assessment in the South Inny Basin survey 2017.

Structure Type	Barrier	Not a Barrier	No Access	Low Discharge	Grand Total
Road Crossing	22	268	6	32	328
OPW Bridge	8	121	4	2	135
Gauging Station		6		0	6
Historic Structure	1	21		7	29
Extra	4	16	2	41	63
	35	432	12	82	561

When visiting or surveying these barriers over a period of five months, it was essential to visit them at similar water levels and a reference level of 1.6m at the OPW Ballymahon Gauge was selected to ensure no potential barriers were flooded out or visited in high flow conditions. During heavy rainfall the River Inny peaked at over 2.5m (Ballymahon OPW Gauge; November 2017 (OPW, 2017)), and due to the low gradient nature of the catchment water levels were slow to recede. As a result the 2017 barrier survey programme was hindered and suspended. Barriers not visited in 2017 will be carried over to 2018 and included in the proposed Northern Inny Basin Survey.

Structures surveyed in the field were assessed using a standardised digital assessment form. The assessment process included measurements of the channel and structure dimensions. One page of the form required an assessment of each structure in respect of its potential to act as a barrier to particular fish species in the survey conditions. These scores are based on expert opinion of the surveying officer in the field as to a fish species ability to pass the obstruction in the channel for the water conditions on the day of the survey (Tables 3.2 and 3.3).

Table 3.2. Barrier types and their estimated effect on adult salmon passage in the South Inny Basin.

Structure Type	Impassable	High	Moderate	Low	None	Grand Total
Bridge Apron	8	3	2	5		18
Bridge Floor			1	1		2
Culvert	6	1		3	1	11
Bedrock Obstruction			1			1
Weir		2	1			3
Grand Total	14	6	5	9	1	35

Table 3.3. Barrier types and their estimated effect on river lamprey passage in the South Inny Basin.

Structure Type	Impassable	High	Moderate	Low	None	Grand Total
Bridge Apron	9	3	1	5		18
Bridge Floor	1	1				2
Culvert	5	1	1	4		11
Bedrock Obstruction		1				1
Weir	2		1			3
Grand Total	17	6	3	9	0	35

Of the 35 barriers surveyed and recoded, 20 were either Impassable or High Risk to adult salmon migration, while 23 were either Impassable or High Risk to river lamprey. The divergent results for adult salmon compared to river lamprey is due to the differing swimming competencies of the two species. Adult salmon has the capacity to swim at a high speed for short distances and to jump, in its attempts to overcome obstacles. On the other hand, the river lamprey has no jumping capacity and a more limited swimming capacity. The lamprey species can make short 'burst' swims and then clamp on to flat surfaces with their sucker-like jaw, enabling them to rest before making another swimming 'burst'.

82 sites were desk-surveyed as having low discharge (ld) or no fisheries potential and 53 of these sites were visually assessed during the survey (Figure 3.3). The data recorded from these 'visited' low-discharge sites were analysed using ArcMap and its tools in order to examine the different attributes that may underlie low discharge sites. By projecting all low discharge barrier sites (n=53) on ArcMap it was possible to measure the distance from the site/point to the source of the channel. Completing this process for each point, it was concluded that on average sites with a distance of less than 1000m of channel length to their source would be viewed as having low discharge. With this in mind, the potential

barriers which had not been visited were projected and those located under 1000m (n=29) from the channel source were inferred to have low discharge (e-ld).

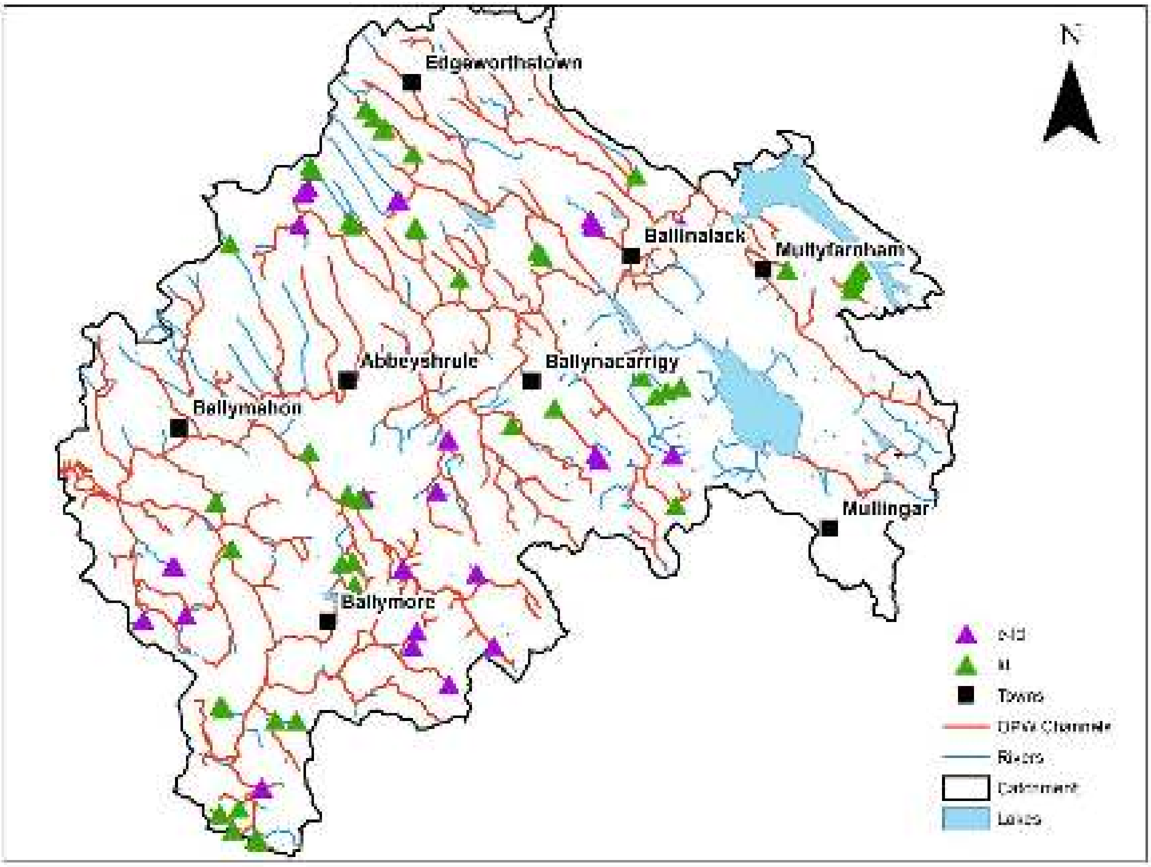

Figure 3.3. Map displaying low discharge sites visited (Purple Triangle; ld) and those desk-classified as low discharge (Green Triangle; e-ld) within the South Inny Basin.

Figure 3.4., 3.5. & 3.6. Some of the barriers surveyed in the Southern Inny Basin during 2017.

(Fig. 3.4 C37 (culvert & ford), Fig. 3.5 C8/8 (bridge apron), Fig. 3.6 C18 (barrier displaying a weir face & vertical drop))

Barriers directly impact fish migration throughout the Inny catchment during regular water levels. These barriers restrict the use of upstream habitat for both resident and migratory fish species. Salmonid species require habitat with plentiful gravels and high water quality for spawning. Such habitat is generally found in the upper reaches of streams to which barriers may be blocking access.

As well as impacting fish migration, barriers influence the continuity and connectivity of the river system along with potentially adjusting natural river processes. The 35 structures identified in this survey represent habitat fragmentation and river discontinuity, altering river hydromorphology and representing a potentially reduced Water Framework Directive classification. These instream structures influence sediment transportation and the flow regime of the river, with some acting as gravel or sediment traps and others ponding water upstream of the structure. Mitigation measures to aid fish passage and sediment transport have the potential to benefit fish communities of the channel by both granting access to previously unreachable sections and by providing downstream dispersal of spawning substrate via sediment transport.

Potential Barriers for Mitigation

Four Barriers surveyed from the 2017 Barriers survey and five from historic barrier surveys have been highlighted for potential mitigation on OPW channels in the lower Inny basin. These barriers to fish passage have high discharge and represent potentially good "value for money" in connectivity mitigation (Figure 3.7).

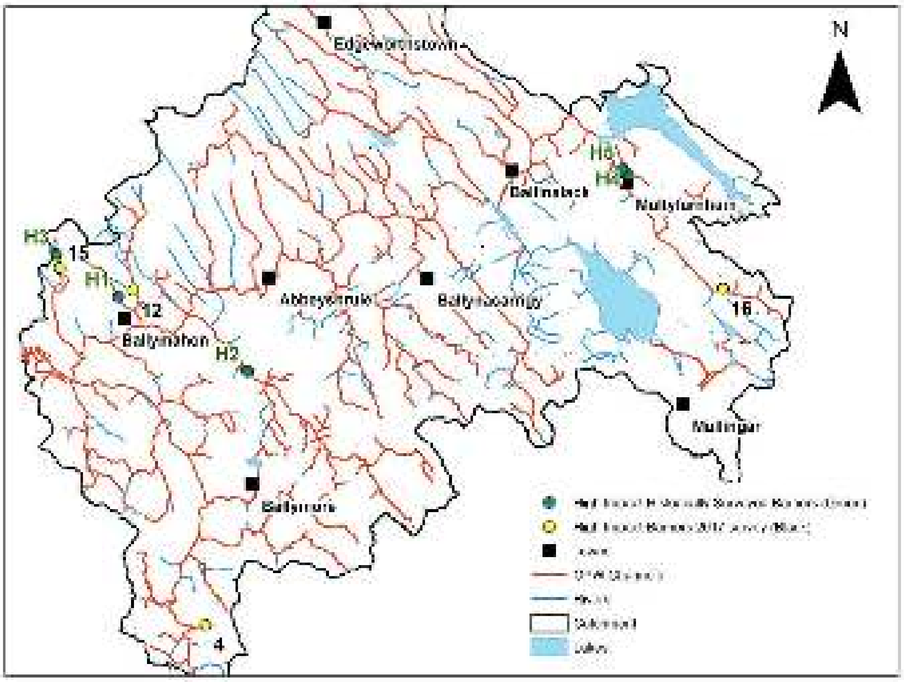

Figure 3.7. Locations of high/ moderate impact barriers on OPW Channels surveyed 2017 and from historic surveys, potentially representing a good investment in mitigation for connectivity (See Figure 3.8 for Images 2017 survey)

Figure 3.8. Images of barriers on OPW Channels, potentially representing a good investment in mitigation for connectivity (See Figure 3.7 for location)

Barrier information for structures in the 2017 Barrier Survey (Figure 3.7 and 3.8)

Barrier 4 – C8 (Chg 19000) Moat – Moyvoughly road – Top of OPW Scheme, culvert with vertical drop at outfall

Barrier 12 – C11/2 (Chg 870) Royal Canal underpass, bridge floor with vertical drop at outfall

Barrier 15 – C9/2 (Chg 1300) Main R392 Road, vertical drop at out fall of culvert. This structure is in significant disrepair

Barrier 16 – C37 (Chg 3720) R394 at Moneylea, Weir with 0.6m vertical drop

Barriers Identified as having a High/Moderate impact in Historic Surveys from Figure 3.7

H1 – C11/1 (Chg 110) - Royal Canal underpass, bridge floor with vertical drop at outfall

H2 – C12 (Chg 4600) – Weir, 0.7m vertical drop

H3 – C9/2 (Chg 2100) - Royal Canal underpass, bridge floor with vertical drop at outfall

H4 – C37/1 (Chg 2600) – Road Crossing/ Culvert at Froghanstown, drop from culvert 0.6m

H5 – C37/ 1 (Chg 2100) – Road crossing/Culvert at Abbey land, drop from culvert 0.4m

3.3 SNIFFER surveys of structures in OPW channels

Within IFI, the larger national focus to date has been on examining large structures in main stem SAC channels that may impede the upstream migration of Atlantic salmon and sea- and river lamprey, some of the Qualifying Interests (QI) within the SACs (Figure 3.1). One of the Conservation Objectives (COs) for sea lamprey status is that adult sea lamprey should have unimpeded access along 75% of the main stem length of each of the SAC rivers. The IFI has a focus on surveying, via SNIFFER, all barriers that may impede upstream sea lamprey migration in the SAC rivers.

Figure 3.1. Large weir on the Kells Blackwater at Headford Estate (Kells), Boyne System, typical of the scale of structure analysed for fish passage by IFI using SNIFFER protocol.

During 2017 this barrier survey programme continued, with surveys in the Lower River Shannon SAC at sites on the Feale and Mulkear of relevance to OPW. In addition, SNIFFER surveys were conducted on particular structures within OPW schemes as a result of requests from IFI RBD colleagues or from specific concerns within the EREP remit. Surveying of specific structures via SNIFFER has been on-going within the EREP since 2015 and this was continued in 2017 with a focus on gravel traps within OPW schemes.

On the Feale, the first major barrier is created by a weir for potable water abstraction at Scartlee, a short distance upstream of the tidal limit. This was previously surveyed and scored as impassable to sea lamprey. Otter have been observed downstream of this weir feeding on sea lamprey adults. Structures on the main stem Feale at Listowel race course and on two tributaries, the Galey and the Shannow, all proved to be problematic for adult sea lamprey at time of survey. These structures were also recorded as being problematic for adult Atlantic salmon (Table 3.4)

Large numbers of sea lamprey have been observed in many years actively spawning on the River Mulkear at Annacotty, downstream of the weir. Modifications to this weir and a breaching of the upstream weir at Ballyclogh were made during the lifetime of the EU-funded Mulkear LIFE project. These measures contributed to an increased dispersal of adult sea lamprey into the Mulkear catchment. A gravel trap at Blackboys Bridge was re-instated during the Cappamore Flood Relief Scheme in the late 1990s and a Denil fish pass installed. This trap was surveyed for fish passage via SNIFFER protocol in late 2017. It was recorded as an impassable barrier to sea lamprey, at time of survey, and of high risk of failing to pass adult salmon (Table 3.4).

Table 3.4. A summary of SNIFFER Surveys completed on structures in OPW channels in 2017, along with their passability scores for adult Salmon, sea Lamprey and trout.

Catchment	River	Barrier name	Barrier type	Fish Pass structure(s) present	Overall SNIFFER passibility score:		
					Adult Salmon	Adult Sea Lamprey	Adult Brown Trout
Brosna	Clodiagh	Clonaslee Gravel Trap	Weir; stilling structure	None	0.6	0	0.3
	Kilcormac Silver	Cadamstown (Upper) Gravel Trap	Weir	Nominal	0	0	0
Mulkear	Bilboa	Blackboys Bridge Gravel Trap	Gravel/sand trap	Denil pass	0.3	0	0.3
Corrib (Mask)	Robe	Salmon weir	Weir	Chute	0	0.3	0.3
Feale	Feale	Racecourse Footbridge, Listowel	Bridge floor	None	0.6	0.3	0.6
	Galey	Shrone Bridge	Weir; stilling structure	1Xchute	0.3	0	0.3
	Shanow	Shanow Bridge	Stepped bridge floor	Nominal	0.3	0	0.3

4 Going forward – development of EREP in 2018 and beyond

The EREP has undergone various revisions, changes of emphasis and degrees of reduction of staffing support since its inception in 2008. This is inevitable in a dynamic project involving two agencies with different, sometimes contrasting, statutory obligations.

A consistent underlying thread has been the shared view that both OPW and IFI benefit from constructive engagement and from joint project work dealing with the river corridor and its management. The realignment of project elements in 2017, with a focus on scientific surveys in OPW catchments and development of management strategies to emerge from the findings was considered successful by both agencies in an initial review of the 2017 outputs. It is envisaged that this strategy will underpin proposed actions in 2018.

The Water Framework Directive (WFD) and its emphasis on (a) ecological quality and on (b) hydromorphology underpins activities with the EREP.

a) The Ecological Quality is summarised in WFD by the Ecological Quality Ratio (EQR) which is categorised in five scores – High, Good, Moderate, Poor and Bad. The requirement of the Directive is for waters to achieve at least Good status in regard to the biological elements such as the fish community

b) The hydromorphology element relates to the quantities of water, the condition of the instream and riparian zones and the lateral and longitudinal connectivity of the channel

The catchment-wide surveys that IFI has undertaken in OPW catchments over several years in EREP provides direct information on both of the elements (a) and (b) above. During 2017 the focus was on the Inny catchment, with a survey of the lower catchment undertaken for fish and morphology, based and scored on WFD criteria, with a subsequent survey of barriers to longitudinal passage for fish. This latter provides OPW with a listing of locations and issues where longitudinal connectivity issues arise and enables these to be examined in the course of maintenance with the potential that some may be addressed directly as Capital Works exercises, within EREP.

A logical extension of the lower Inny surveys of 2017 would be to complete the Inny survey on 2018, focussing on the upper catchment. By extension, this WFD status assessment approach could be applied to the other larger OPW catchments in subsequent years.

In 2017 the IFI was tasked by the Dept. of Housing, Planning and Local Government with producing a series of deliverables in regard to barriers In rivers to fish migration, in the context of WFD and Programmes of Measures. The barriers survey on the lower Inny generated data that can feed directly into this national endeavour, as will any further barriers work within the EREP. Similarly, survey work undertaken as part of the IFI's National Barriers Programme will be available to feed across to the EREP. Another potentially valuable contribution of EREP here is the potential for OPW to identify practical and reproducible strategies to address certain types of barrier issues within its drainage schemes e.g .bridge floors at too high a level relative to the immediate downstream river bed, with potential for bridge scour. The National Barriers Programme will develop measures to address structures and issues impacting on fish migration and OPW would be an important contributor here.

OPW has expressed its satisfaction with the proposal to continue to develop long-term data sets associated with fish and habitat surveys undertaken in shared OPW-fisheries investigations. Some of these data back to the early 1980s and there is a substantial platform of valuable surveys and discrete time-series dating from the initial Environmental Drainage Maintenance (EDM) studies, dating from 1990-2007, and from the EREP investigations commencing in 2008. Such extended-term studies have already proven to be useful in providing information on the response and status of crayfish and larval lamprey to channel maintenance activities. The scientific literature commonly flags and laments the paucity of long-term monitoring of recovery in channel enhancement or impact studies and the OPW recognises the potential for EREP to contribute here and is encouraging of this potential.

The form EREP will take, going forward, is likely to change from year to year with changing pressures and priorities on the two organisations. Thus, OPW continues to identify the relevance of monitoring on crayfish and larval lamprey, with the potential for channel maintenance to impact adversely on these Annex II species groups. There is a concurrence that there are major elements of shared interest between OPW and IFI and these can continue to be explored and investigated under an EREP umbrella.

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