Environmental River Enhancement Programme

Annual Report 2018

IFI/2019/1-4486

Iascach Intíre Éireann
Inland Fisheries Ireland

EREP 2018 Annual Report

Inland Fisheries Ireland & the Office of Public Works

Environmental River Enhancement Programme

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

A new 5-year agreement (2018 – 2022) between the Office of Public Works (OPW) and Inland Fisheries Ireland (IFI) saw the EREP programme for 2018 focussing on a series of agreed investigations. These would provide the 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, adult lamprey spawning and locations of potential barriers to fish passage. Knowledge of larval lamprey distribution is relevant to OPW foremen when scheduling works on specific channels. An understanding of barriers to fish passage and sediment transport 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 maintenance work reaches identified barriers.

The 2018 programme included-

1. Detailed survey of the upper Inny catchment
    1. Fish Population Index (FPI) surveys at a series of sites
    2. River Hydromorphology surveys (RHAT) covering the fish sites
    3. A survey of potential barriers to fish passage (in excess of 700 potential sites)
2. Specific scientific studies
    1. On-going examination of 'spontaneous recovery' of habitat post-maintenance in a tributary of the R. Stonyford
    2. Thermal studies involving impact of tree cover on surface water temperature in tributaries of the Brosna
3. Long-term monitoring study repeat surveys
    1. R. Camoge (1998-2001)
    2. R. Dungolman (1993-2001)
    3. R. Attymass (1998 - 2005)
4. Survey of gravel traps in OPW catchments
5. Follow-up on desk study of meanders re-connection with site visits
6. Synergies with other IFI studies pertinent to OPW

1 Scientific Investigations and Monitoring

1.1 The Inny Survey Programme and Water Framework Directive

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 drainage schemes negatively impact channel hydromorphology (hydrology, channel form (including instream and riparian condition) and channel continuity (longitudinally and laterally)). The physical impacts, in turn, influenced and controlled the biology of the instream fauna (fish and invertebrates) as well as 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 selected waterbody into one of the following categories: High; Good; Moderate; Poor; or Bad. This is the underlying aim with the timed electric fishing survey programme (FPI) that IFI has developed and has been rolling out annually as part of the EREP deliverables. The FPI Survey 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. Rapid Hydromorphology scoring (River Habitat Assessment Technique: RHAT score) provides a quality rating for a suite of hydromorphology elements. By collecting both fish and hydromorphology data using WFD-compliant methods at all study sites, EREP can compare data sets from multiple locations 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 elements 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 RHAT scores may have a large influence on the overall RHAT score. IFI has commonly noted that many OPW-maintained channels have a range of features e.g. tree and riparian vegetation, a range of instream depth values and varied instream bed types. Many would score well in the RHAT assessment but the overall score might be reduced 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 alter river bed and banks 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 a natural river flow regime and permits unimpeded migration of biota up- and downstream 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. These impediments can interfere with upstream migration of fish species e.g. elver life-stage of European eel, adult lamprey and Atlantic salmon migrating to spawning locations as well as downstream migrations of adult silver eels and salmon smolts.

The aim of the Inny barriers survey was to examine all potential barriers sites, based on a desk-assessment method, and to collect baseline information of structures considered being 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 works are necessary to offset the adverse effect of the barrier. This would constitute legitimate use of Capital Works funds by OPW.

In many cases, the remedial works would address any adverse structural effects such as scouring 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.

The Inny is a relatively large catchment and the EREP team divided it into two for survey purposes with Ballinalack being the dividing location. The lower Inny, downstream of Ballinalack, was surveyed in 2017 for fish species, habitat and barriers. The survey continued in 2018 with coverage of the upper Inny catchment from Ballinalack up to Lough Sheelin and its tributaries for fish species, habitat and barriers.

1.1.1 Fish Population Index (FPI)

Survey Introduction

The Northern Inny Basin was surveyed during the months of August - September 2018. In total 43 sites were sampled in order to determine the density, distribution and population structure of the fish communities (Figure 1.1) along with the hydromorphological and water quality pressures which could be affecting them.

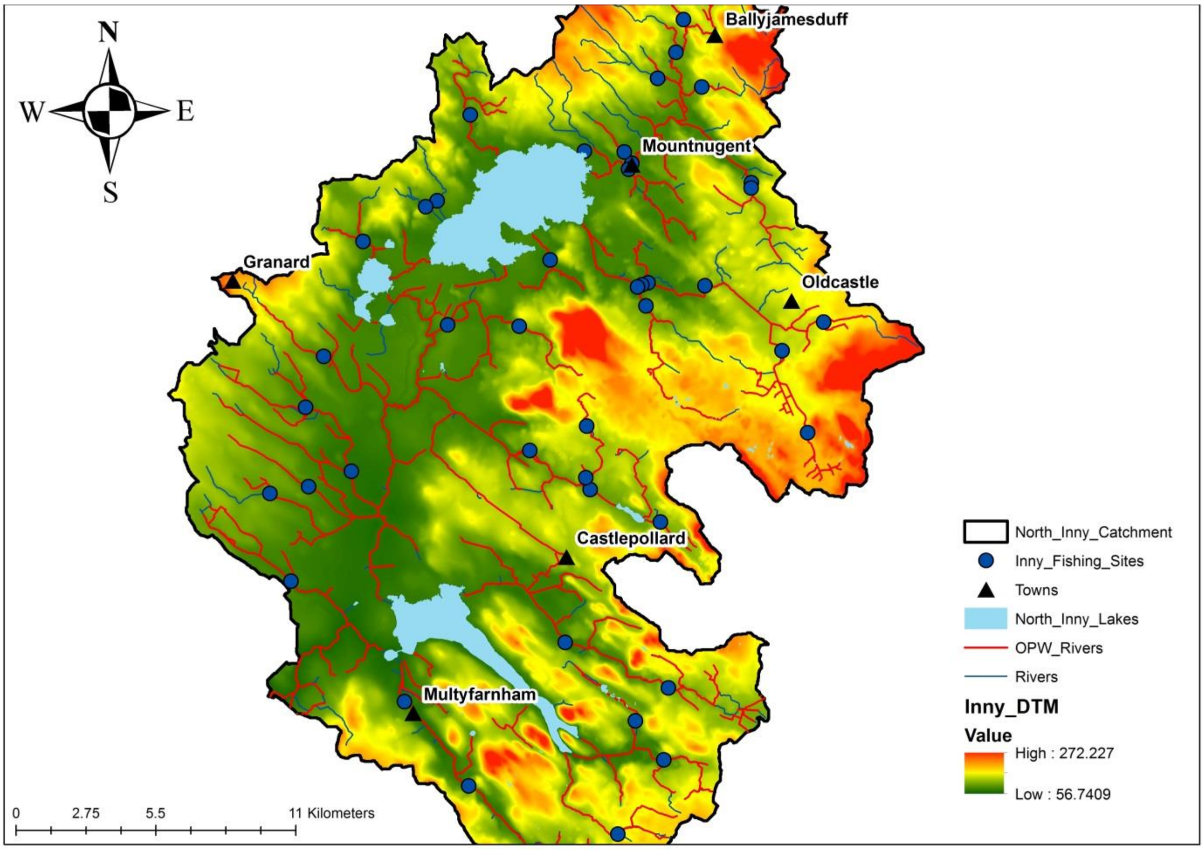


Figure 1.1. Digital terrain map (DTM) of the Northern Inny Basin and locations of electrofishing sites fished during the FPI Survey 2018 (Blue Dots).

The River Inny and its tributaries were subject to OPW arterial drainage works between 1959 and 1963. The River Inny provides a natural boundary between Westmeath and its bordering counties Longford and Cavan. The entire Inny Catchment covers an area of 1229km^2, characterised by regions of flat, boggy land with some isolated relatively steep-sided hills (272m). The northern section (632km^2) of the catchment displays more diversity in the landscape as it borders an extensive drumlin belt.

The geology of the catchment is mostly underlain with impure limestone, with some sections in the north underlain by metamorphic and volcanic rocks. The northern Inny basin contains Lough Sheelin and Derravaragh, two large midland lakes which are not located on the main Shannon channel.

The River Inny rises near Oldcastle in County Meath and flows through Lough Sheelin, Kinale, Derravaragh and Iron before entering the River Shannon at Inny Bay. The river has an overall length of 89km. The major tributary rivers which are included within the northern Inny basin are the Mount Nugent River (C62), Glore (C50), the Yellow River (C43) and the Gaine (C37).

In completing the 2018 FPI survey, 38 bank-based and 5 boat-based electrofishing sites were fished. The boat sites were located on the Upper Inny, upstream of Lough Sheelin, the Glore and the Gaine. No boat fishing was undertaken on the main stem of the River Inny.
In total, 1238 fish were captured, measured and returned during the survey. Brown Trout (n=852) was the most abundant species, followed by Stickleback (n=213) (Figure 1.2.).

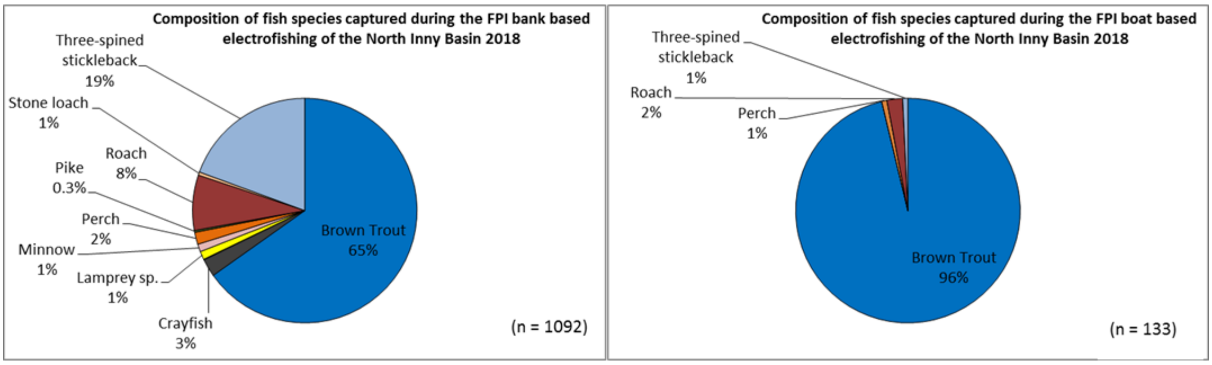
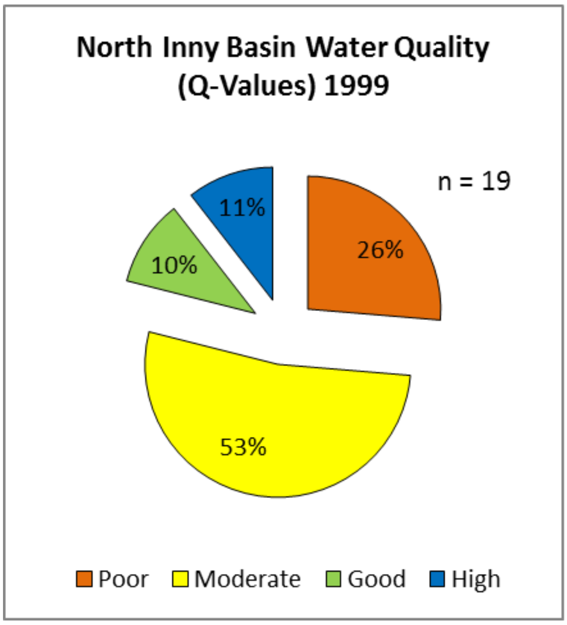


Figure 1.2. Composition of fish species captured in the North Inny Basin FPI survey using bank and boat based electrofishing equipment.

1.1.2 Water Quality- Q-Values (1999, 2017)

The EPA's long-term water quality investigations, using invertebrate Q-values, indicate that the water quality in the northern Inny basin has degraded somewhat from 1999 – 2017 (Figure 1.3), based on findings from 19 sites. In 1999, 11% (n=2 Sites (Glore (C50) & Yellow River (C43)) of sites were classified as "High Status". In 2017 no High status sites were recorded. Over the 18 year period, the total of Moderate status sites has decreased and the number of Poor status sites has increased (Figure 1.3)



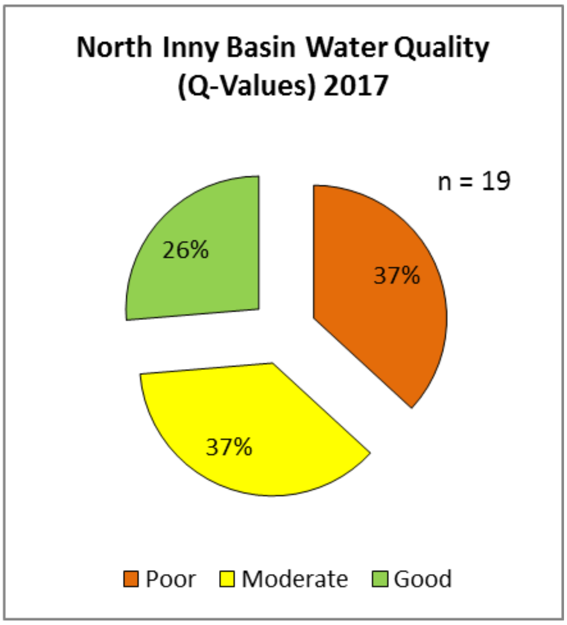


Figure 1.3. Results from EPA Q-Value (1999 and 2017) monitoring sites in the North Inny Basin.

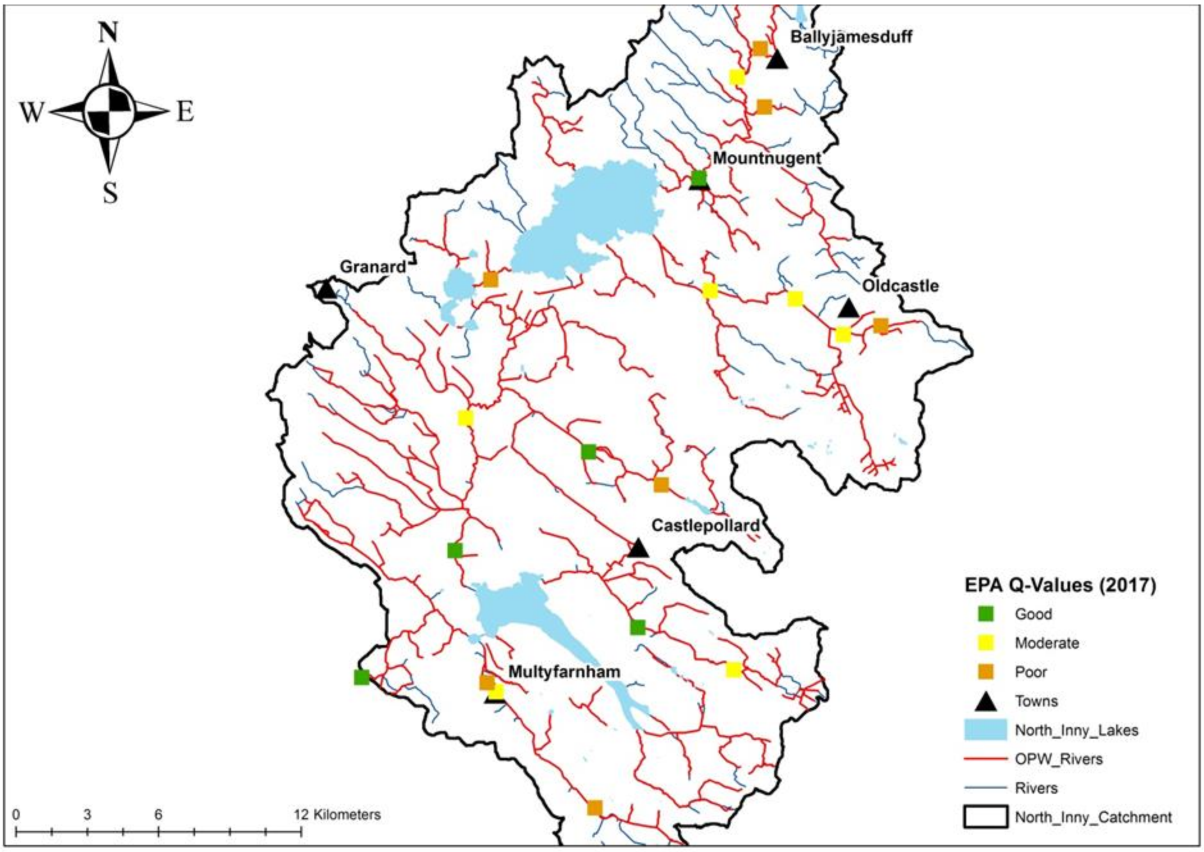
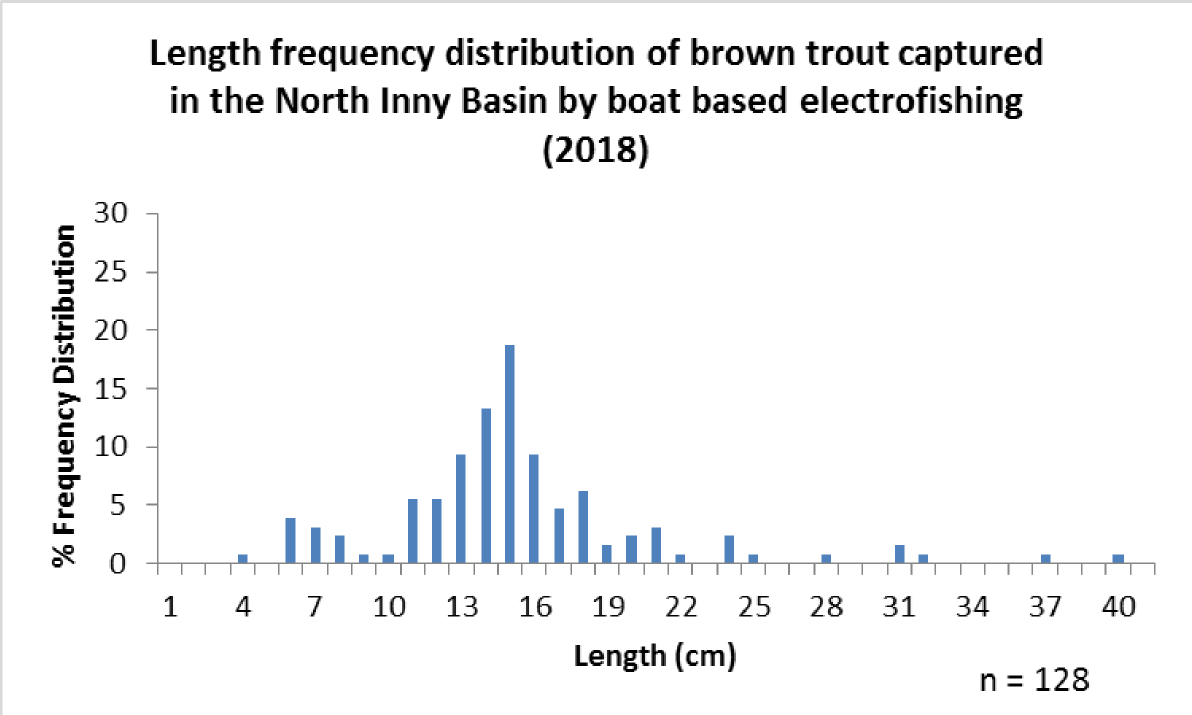


Figure 1.4. Locations of Q-Value results for 2014 in the North Inny Basin.

1.1.3 Fish Communities and Brown Trout Populations (1997, 2018)

The fish community in the north Inny Basin was dominated by brown trout (*Salmo trutta*). Trout were present at 77% of the sites surveyed. Only a small percent (1.2%) of the brown trout captured during the survey were of angling importance (11 trout >28cm in length) (Figure 1.5). The larger tributary boat sites produced numbers of coarse fish and pike (Esox lucis). The lengths of pike captured, measured and returned ranged from 15-32cm.

During the 2018 bank based electrofishing 0+ and 1+ brown trout were captured. Fish under 10cm were classified as 0+ brown trout i.e. those spawned in the previous winter. Trout of length 10-18cm were classified as 1+ year old fish. The bank/handset fishing sites, in water no deeper than 0.5m, were acting as brown trout recruitment and nursery areas. Boat based fishing, aimed at deeper sites; captured brown trout of a larger size range (up to 39cm) (Figure 1.5). Adult trout move to deeper areas after spawning for better feeding opportunities. The survey results show the importance of a range of different channel sizes for the different life stages of brown trout.



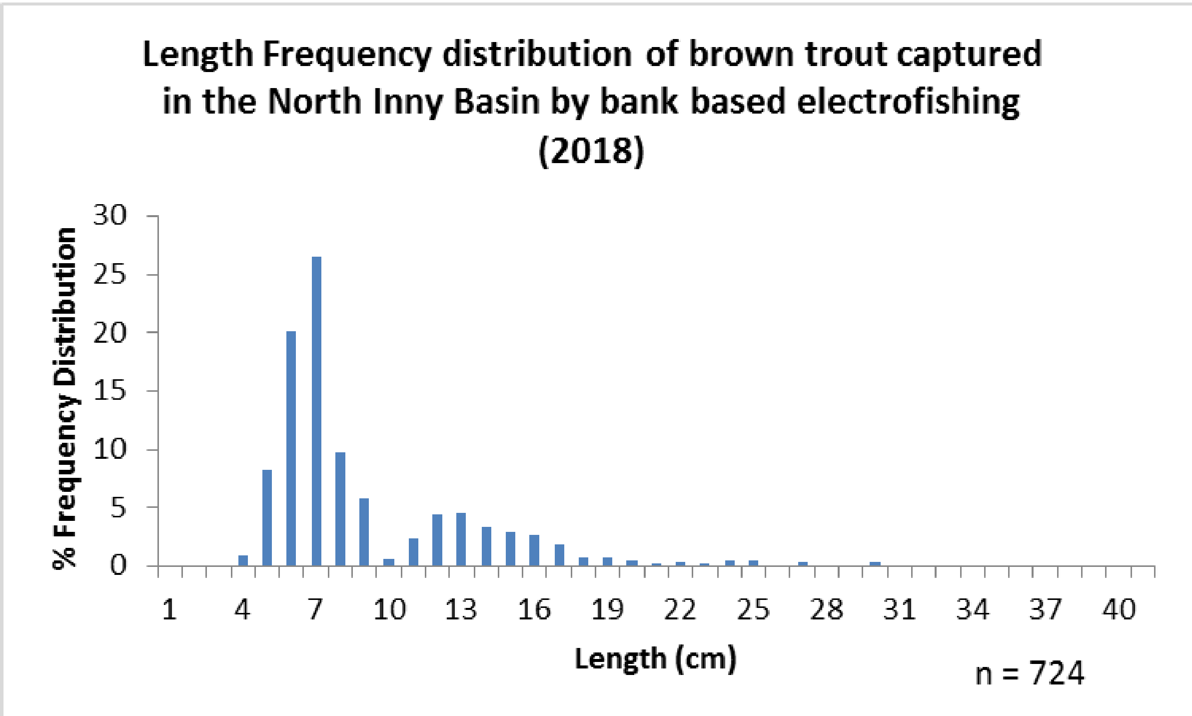


Figure 1.5. Length frequency distribution of Brown trout captured by boat (top) and bank (bottom) based electrofishing from the North Inny FPI Surveys in 2018.

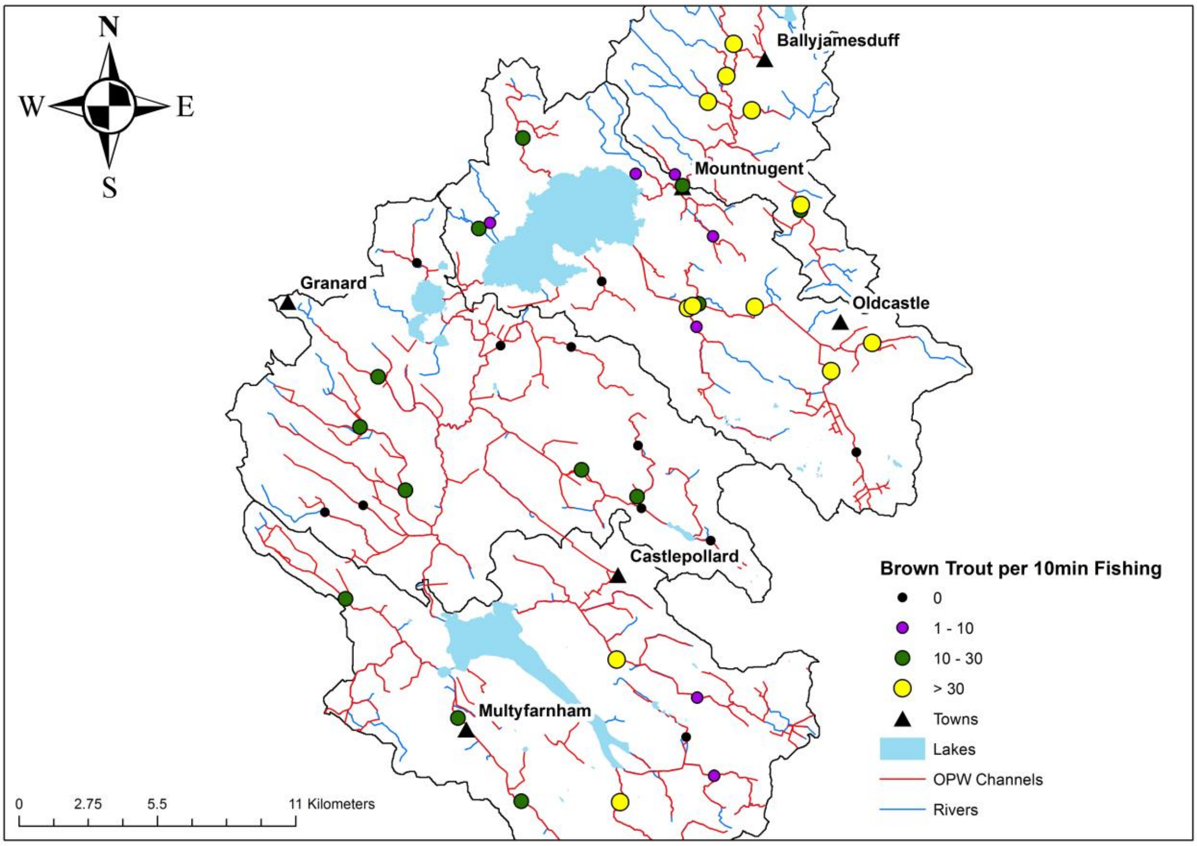


Figure 1.6. Brown Trout numbers captured per 10 minute electrofishing session at each site in 2018.

1.1.4 Ecological Quality Ratio (EQR) for the fish community in the Inny

Ecological quality status is based on the composition and abundance of different biological quality elements, including fish fauna, with supporting elements of hydro-morphology and chemical and physico-chemical parameters. The outputs of the assessment tools are expressed numerically as Ecological Quality Ratios (EQRs) in the range between 1 and 0, with High ecological status represented by values close to 1 and Bad ecological status by values close to 0. Five class boundaries are defined along this range corresponding with the five ecological status classes of High, Good, Moderate, Poor and Bad. (Kelly *et al.,* 2016)

The WFD and its transposing legislation require an evaluation of eco-system quality in rivers, lakes and transitional waters, based on a variety of 'quality elements', including fish. To be WFD Compliant three key attributes of the fish community - species composition, abundance and age structure - must be included in the scheme for freshwater fish classification. The classification is based on an evaluation of current status of the fish community relative to the value of its reference condition i.e. the fish community in a high status location.

In 2017 – 2018, numerous sites, previously fished in a 1997 EU TAM-funded study, were re-surveyed and EQR Scores generated. From the 37 sites fished in 1997, 8 were upgraded from Poor to Moderate Status with 22 sites remaining as Poor. Three sites downgraded from Moderate Status to that of Poor Status and 4 sites remained as Moderate Status for both years. Following the 2017/18 Survey, 28% of sites on the Inny were graded as Moderate status and 71% were classified as in POOR status (Figure 1.7). The basic WFD requirement is for Quality Elements, fish in this case, to be of GOOD status. Thus all of the sites on the Inny would fail to meet WFD criteria, based on fish.

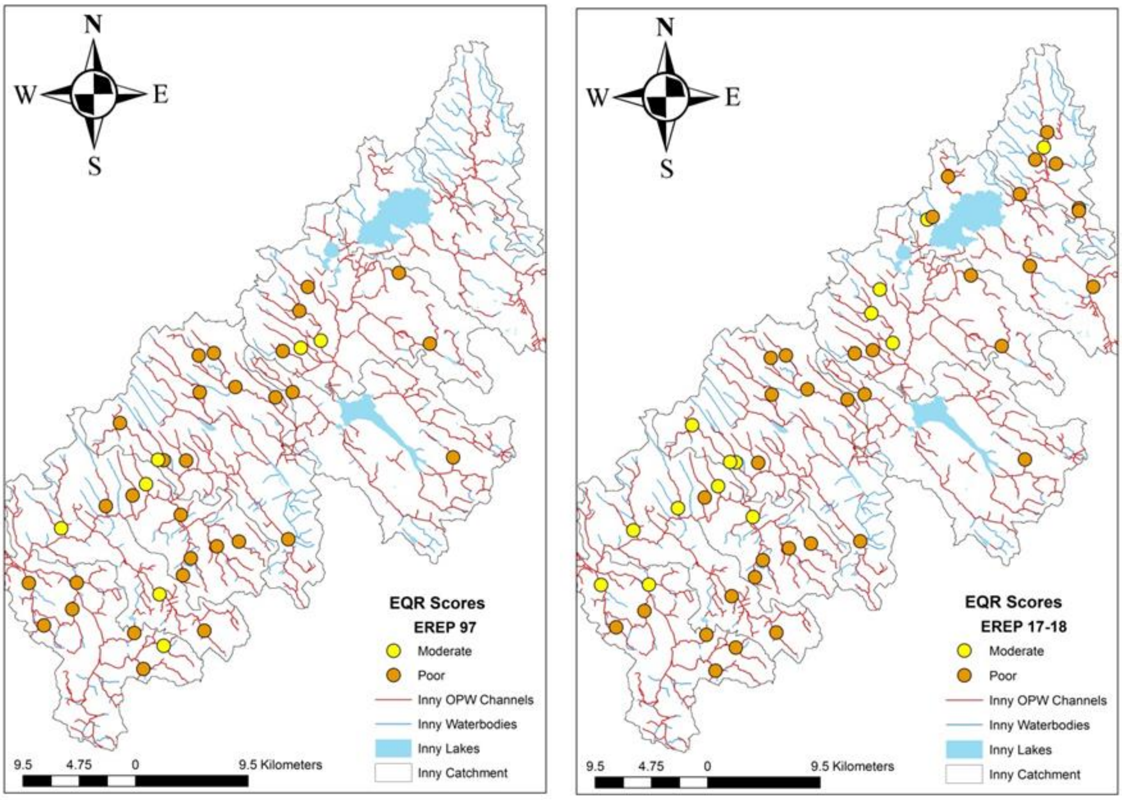
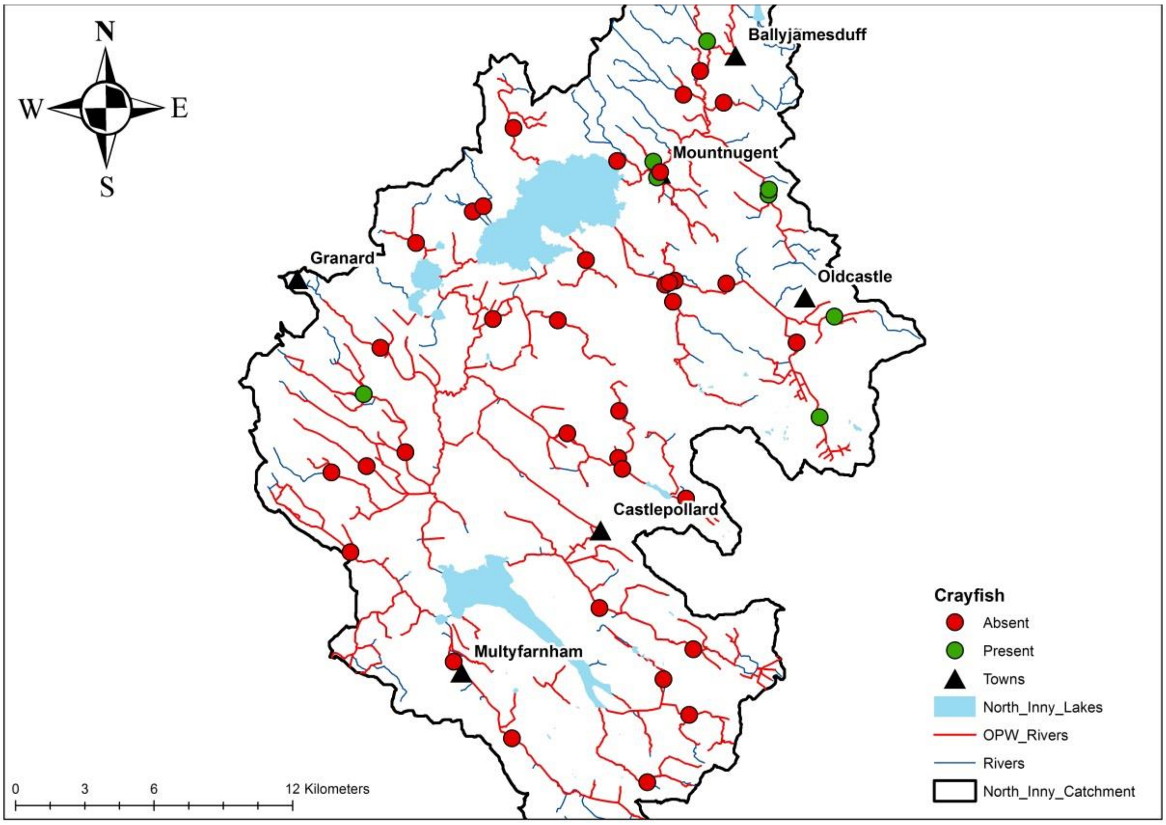


Figure 1.7. Maps displaying locations of fishing sites and EQR Results generated for the entire Inny catchment (Left map; 1997 and Right map; 2018)

1.1.5 Crayfish and Lamprey Distribution (Presence/ Absence)

During the FPI Survey, presence and absence of Annex II Habitats Directive species, crayfish and lamprey, were recorded. The distribution of Crayfish and Lamprey around the North Inny Basin was very limited (Figure 1.8). This distribution data is of value to OPW to include in its GIS information layers for foremen planning channel maintenance.



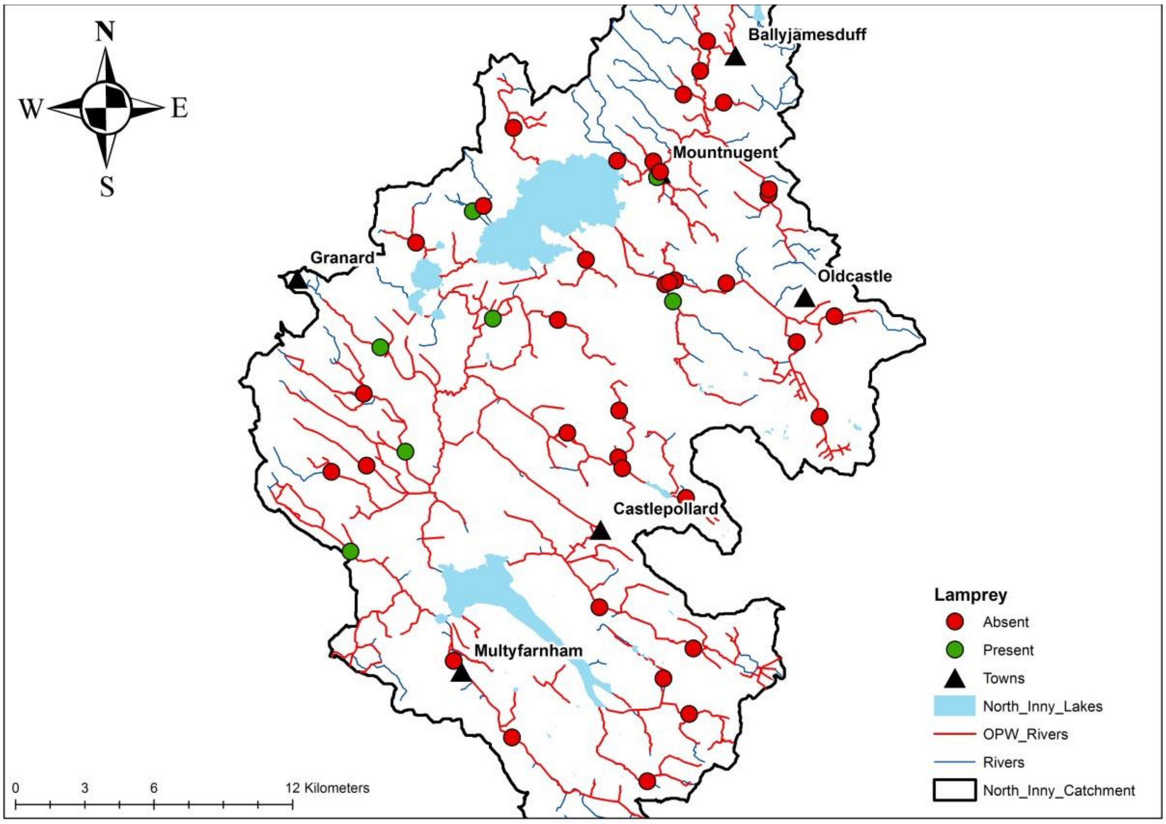


Figure 1.8. Presence/Absence Crayfish and Lamprey sp. throughout the Northern Inny Basin 2018 (Red Circles; Absent, Green Circles; Present).

1.2 North 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, channel dimensions, topography and substratum, continuity and connectivity (longitudinal, lateral, vertical and temporal), sediment regimes and sediment transport and the interaction of all these components in both space and in time. Man-made features such as bank protection works, artificial barriers (weirs, dams) and modifications to processes (gravel traps) are also included in assessment of hydromorphology status.

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 UK Environment Agency's 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-five sites on the upper Inny were surveyed for hydromorphology using the RHAT in 2018 (Figure 1.9). Only two sites passed the WFD minimum requirement of Good status, with 12% categorised as Moderate, 76% as Poor and 4% classified with a Bad status. There is potential for increasing this RHAT score in a number of the Inny tributaries and the main stem itself.

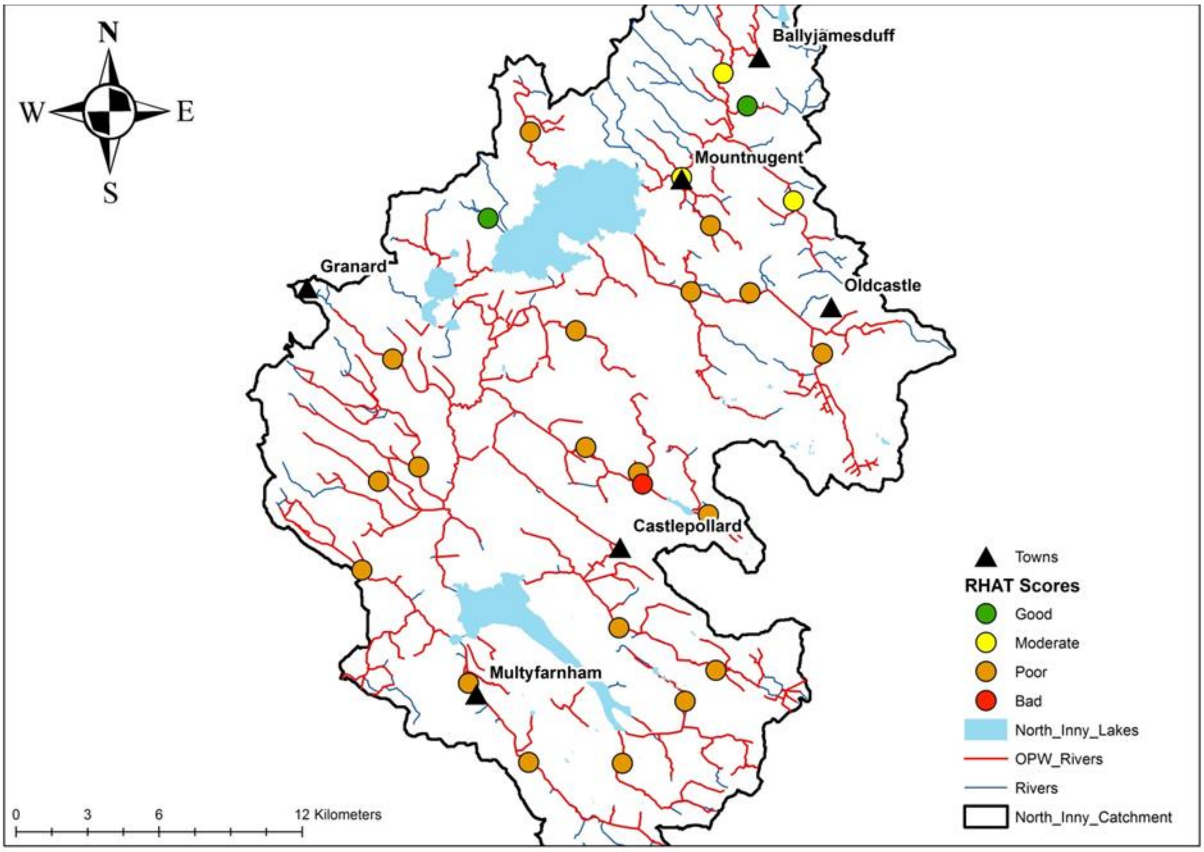


Figure 1.9. River Hydromorphology Assessment Technique (RHAT) results from the North Inny Basin taken during the FPI Survey 2018.

All of the sites assessed during this survey were located in the Inny OPW Drainage Scheme. With only two of these sites passing the WFD requirements of “Good” hydromorphological status, it is evident that drainage/maintenance works may be a significant contributing factor for channels to be in an unsatisfactory hydromorphological condition.

The overall RHAT score is developed from the individual scores given to 8 attributes, each of which is scored independently when on site (Figure 1.11). Each component is scored from 0-4, with 4 being the highest possible score given per element. It is not surprising that Flood Plain Connectivity, Bank Vegetation and Bank Structure & Stability scored the lowest (0.475 – 0.609, see Figure 1.11), as these categories are directly affected by the act of arterial drainage with isolation of the channel from the floodplain and the over-widening and deepening of the river bed resulting in the creation of a trapezoidal channel cross section. (See Figure 1.10, graph displaying RHAT Scores for each element for a drained and un-drained 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, natural processes will lead to a more natural condition in the river with riparian and instream vegetation growth, sediment deposition etc. but recovery can be impacted adversely by channel maintenance. Unsympathetic maintenance not adhering to the "10-steps of environmentally friendly maintenance", developed by OPW and IFI, will adversely impact on the recovery of 5 of the 8 RHAT components and prevent improvement in RHAT scores. Rigorous positive 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 2, 3, 8, 9 and 10)
- Bank structure and stability (Step 1, 2, 5 and 6)
- Bank vegetation (Step 1, 2, 5 and 6).

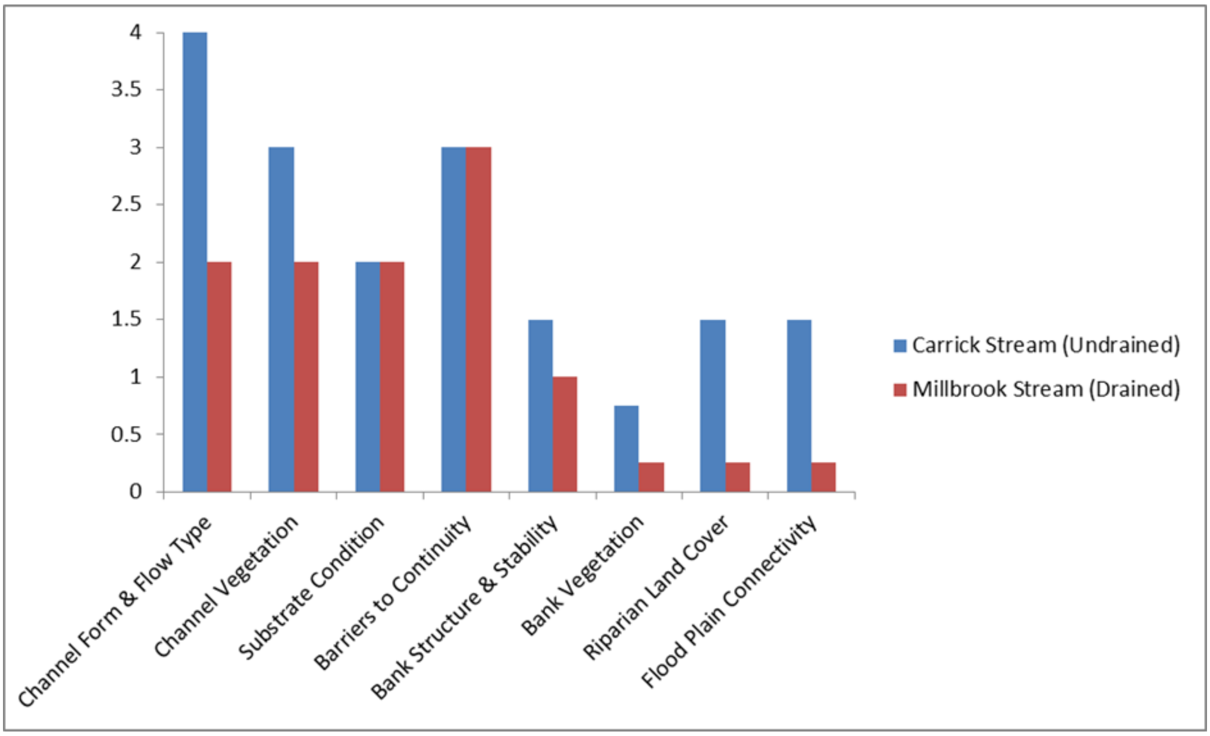


Figure 1.10. Values for the 8 scoring components of RHAT for an un-drained channel and an OPW-drained channel surveyed in the North Inny Basin during the 2018 FPI Survey.

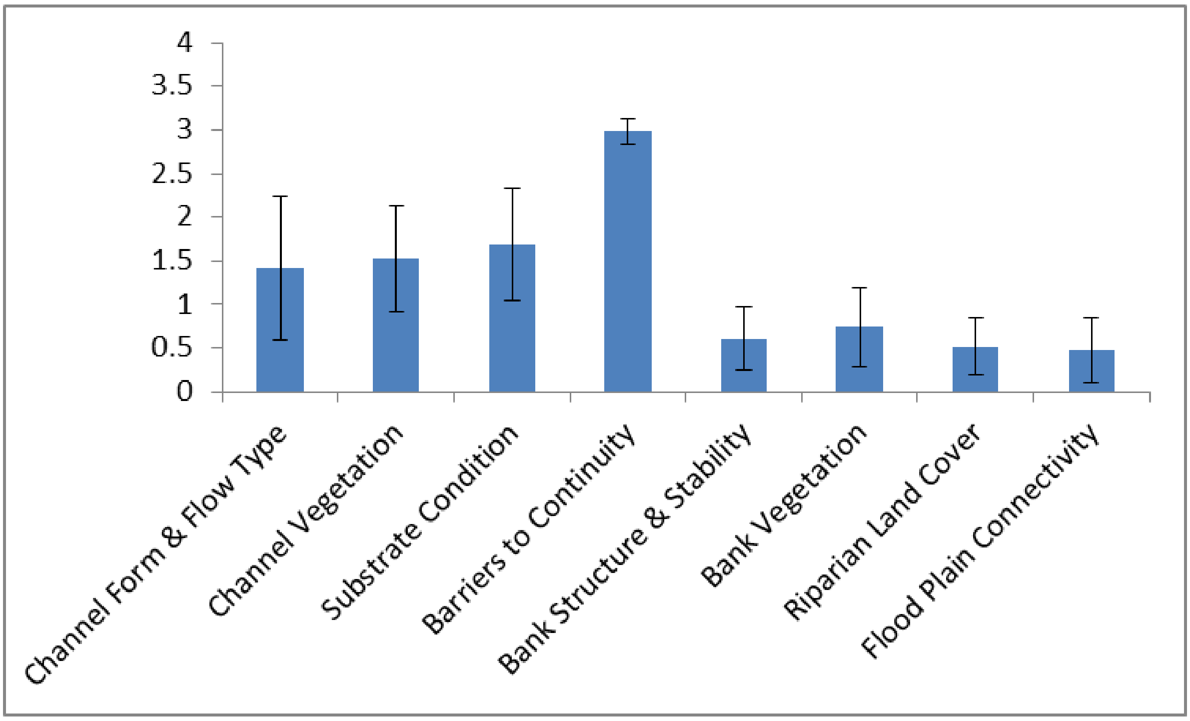


Figure 1.11. Mean and Standard deviation of the 8 components which comprise a RHAT status score (for WFD compliance) for all sites surveyed in the Inny Catchment (North and South) during FPI Surveys 2017 – 2018 (n = 51).

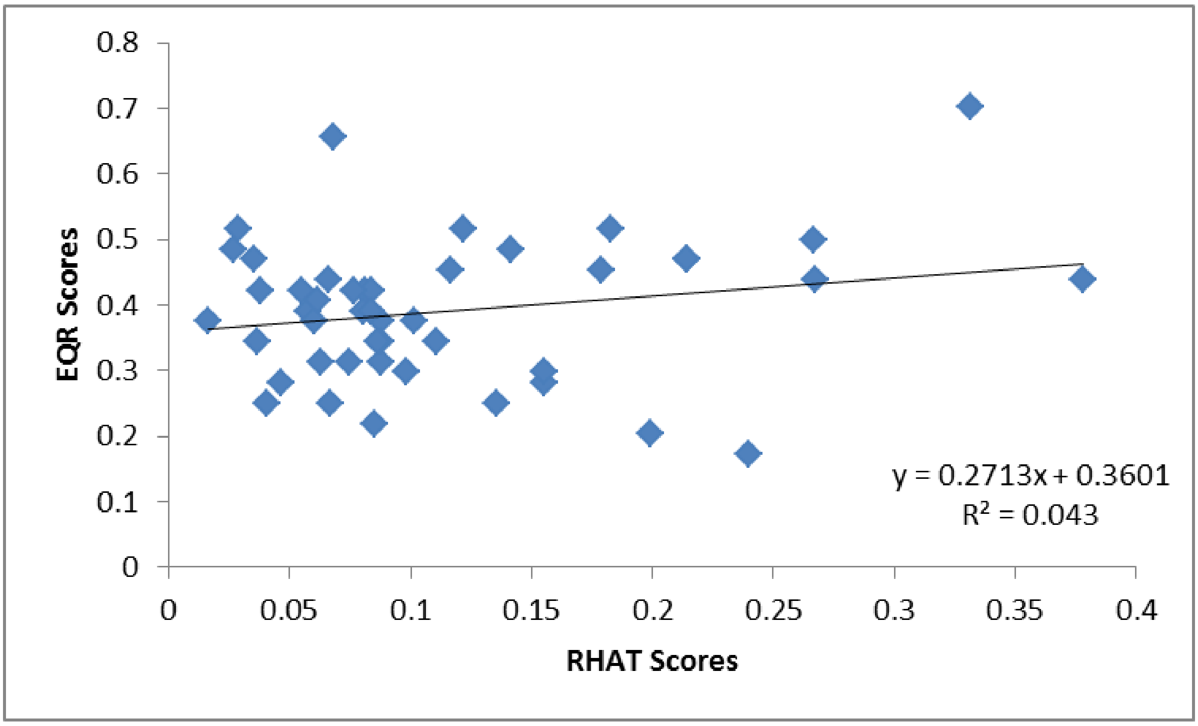


Figure 1.12. Scatter plot displaying low level of correlation (R2=0.043) between paired Hydromorphology EQR Scores (RHAT) and fish EQR Scores generated for survey sites (n = 46) in the overall Inny catchment, 2017 – 2018 (n = 51).

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

Barriers have been identified as being a major impact factor on all fish species, both migratory (such as salmon and eel) and resident species that undertake localised movements. The issue of barriers is relevant in the WFD, in the context of hydromorphology and continuity.

A barrier assessment survey was undertaken on the Northern Inny Basin in 2018 to identify natural and man-made barriers to fish passage and sediment transport. This was achieved by combing 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 in a tablet format developed for IFI. Throughout the North Inny Basin a total of 756 potential barriers were identified during the desk based study (Figure 1.13).The survey process is intended to record man-made barriers as well as natural barriers. However, it is implicit in the WFD that natural 'barriers' should not be interfered with.

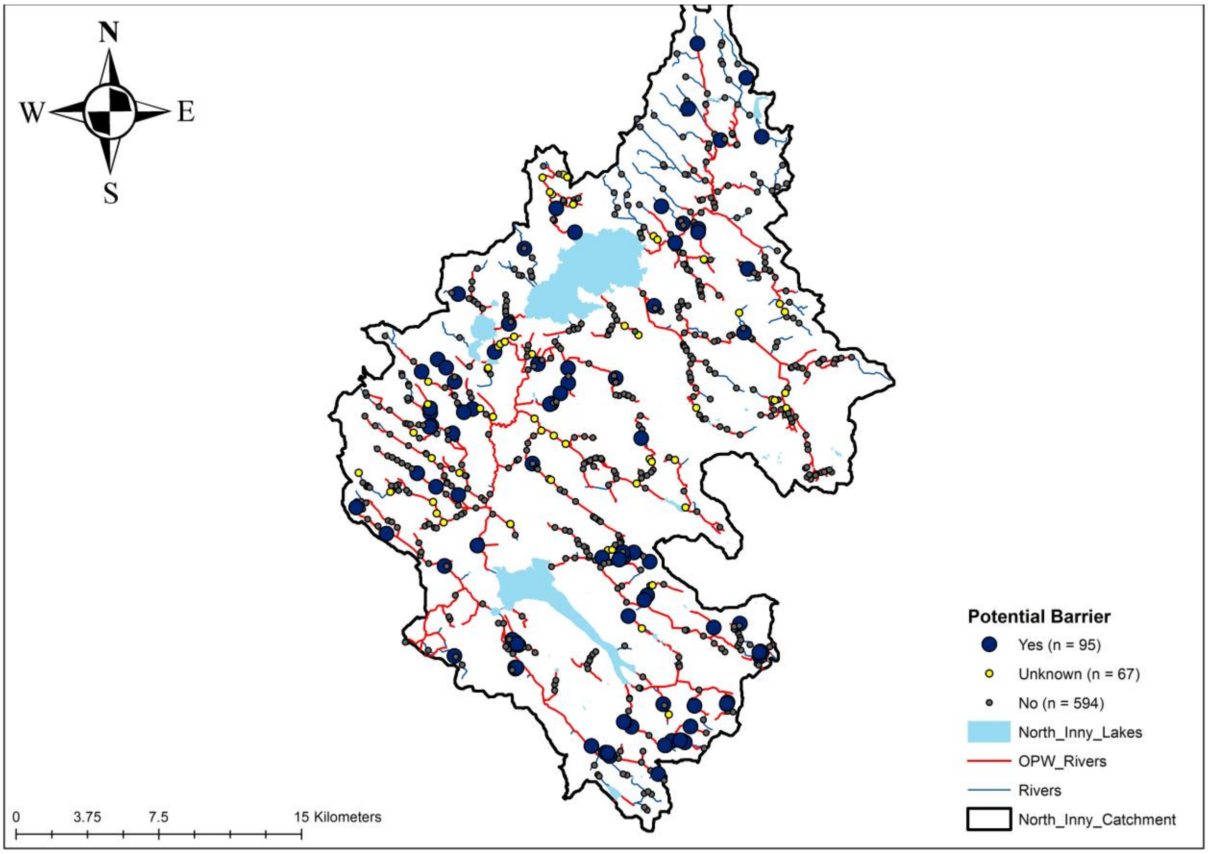


Figure 1.13. Distribution of potential barriers, identified during the desk study, and their classification, from the field study, within the North Inny Basin (n=756)

During 2018 all of the 756 in-stream structures identified as potential barriers were visited. Of these, 95 (12.5%) structures were graded as barriers to fish migration and therefore surveyed. The total of 756 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 (n=10) were considered problematic (Table 1). Of the 95 obstacles hindering fish migration 53% were registered as OPW structures Figure 1.14.

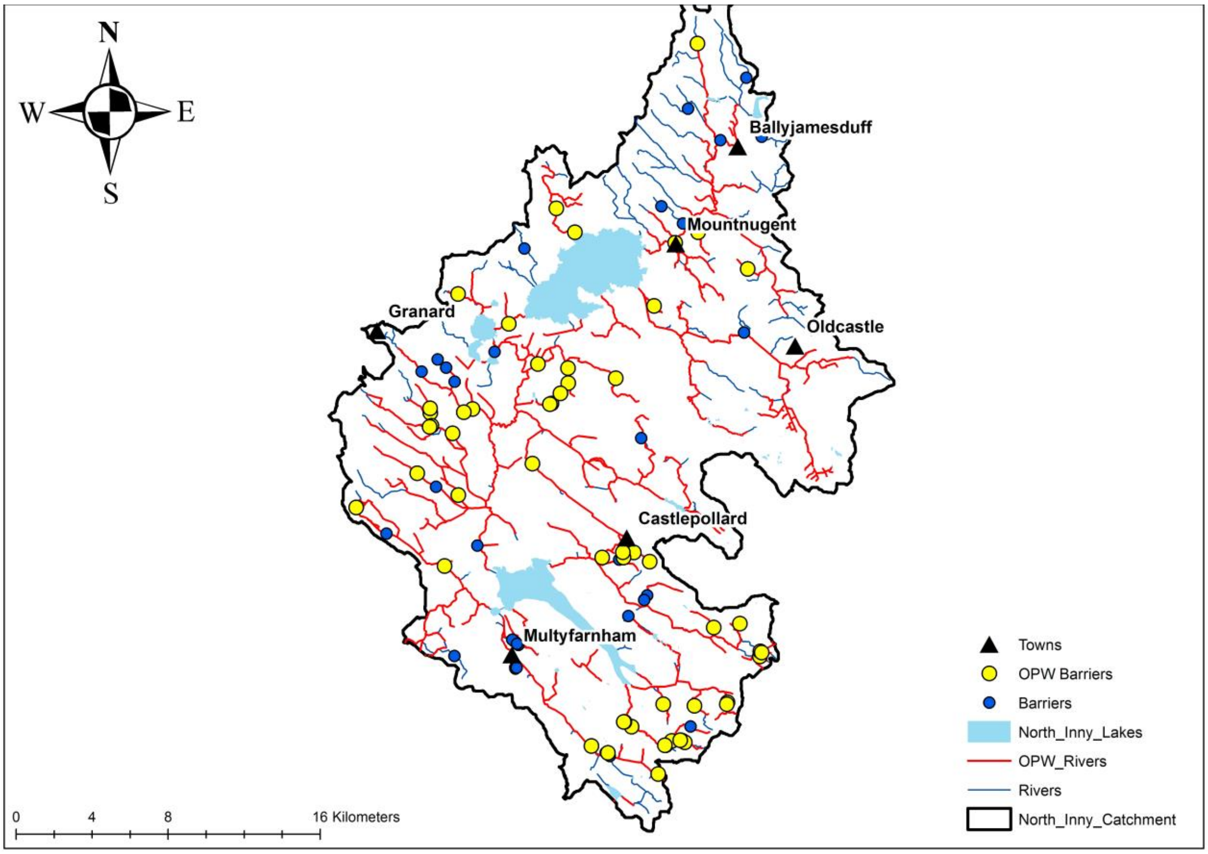


Figure 1.14. Distribution of barriers identified around the Northern Inny Catchment in 2018 (Yellow Circles are OPW registered Structures; Blue Circles are other structures posing problems).

Table 1. Barriers identified from the various GIS layers examined in the desk study and their onsite assessment in the Northern Inny Basin survey 2018.

Structure Type	Barrier	Not a barrier	No access	Grand Total
Road crossing	10	179	20	209
OPW_Bridge	56	393	39	488
Gauging station		7	2	9
Historic structure		8	4	12
Extra	29	7	2	38
	95	594	67	756

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 surveyor 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 (typically of low summer flow).

Figure 1.15. Some of the barriers surveyed in the Northern Inny Basin during 2018 (standard levelling staff used for scaling).

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 95 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 the fish communities in the channel by both granting access to previously unreachable sections and by providing downstream dispersal of spawning substrate via sediment transport.

IFI has generated a GIS layer of the structures acting as barriers in the lower and upper Inny, as surveyed during 2017-18 and has passed this layer to OPW (see Figure 1.16). This layer should inform OPW personnel in planning maintenance work on channels in the Inny system. It is considered that many of the barriers identified and the problems they create, in a Water Framework Directive context, can be addressed by mitigation measures implemented during maintenance.

IFI is proposing that a selection of the barriers identified on the Inny should be examined in 2019 by resident engineer and foreman of OPW with relevant IFI personnel with a view to agreeing on mitigation strategies that can be implemented cost-effectively by OPW during maintenance work. It is envisaged that some of these mitigations would be implemented in 2019. This would provide a template for OPW to roll out to its personnel in other drainage schemes.

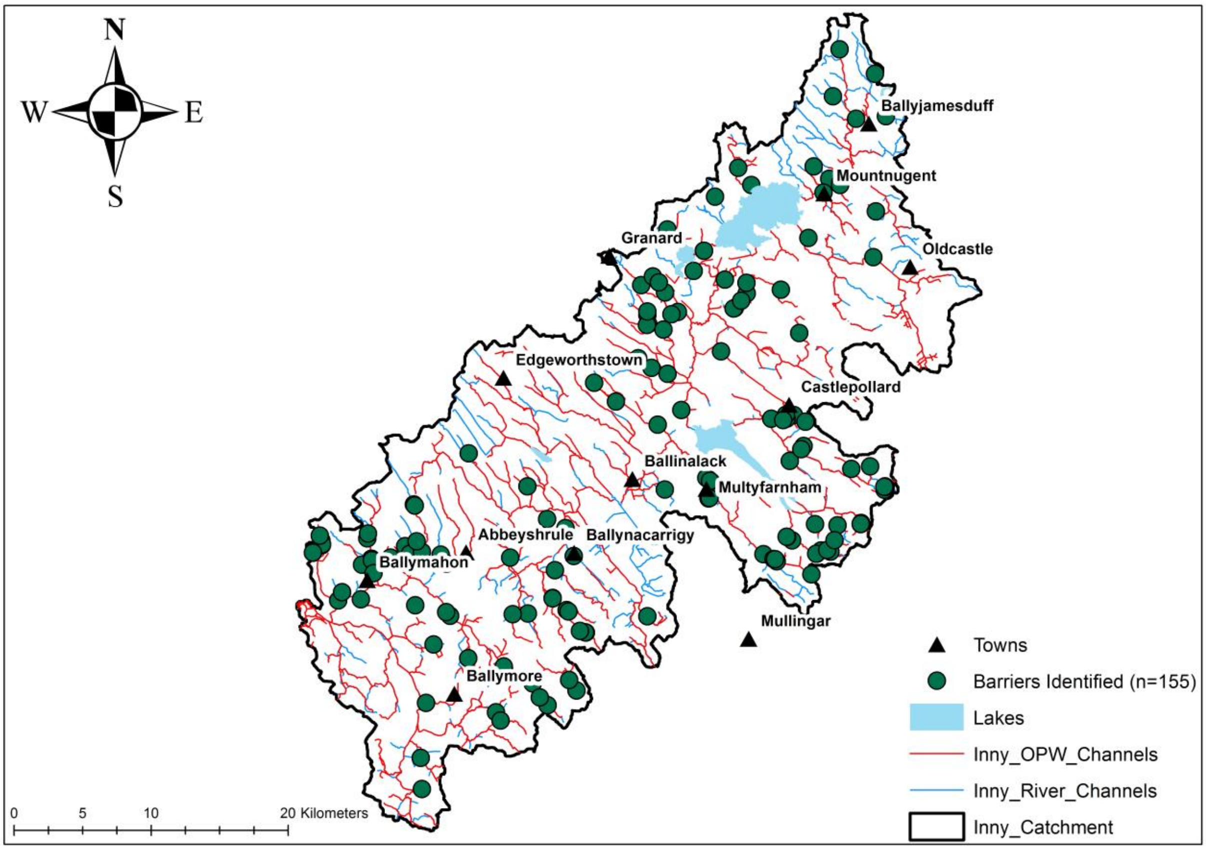


Figure 1.16. Map displaying locations of all barriers identified throughout the Inny Catchment (Green Circles (n=155)).

2 Specific Scientific Studies

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

2.1.1 Introduction

The objective is to quantify the effect of fencing as a 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 re-vegetate. The basic experimental design is a BACI (before, after, control, impact) style with the target channel (Stonyford tributary (C1/32/33)) monitored for five years. This section is reporting four years post fence instillation.

In the current study, changes in fish community composition have been documented along with the recovery of instream macrophytes and bed-forms. 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 channel maintenance 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-maintenance and their effect on descriptors of physical state within the channel. 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. The survey protocol was repeated in 2018.

2.1.2 Results

Fish community structure

1296 fish were captured measured and released in the five survey sites over the five years of this study. Brown trout (*Salmo trutta* L.) was the most abundant species, followed by three-spined stickleback (*Gasterosteus aculeatus* L.), roach (*Rutilus rutilus* 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 2.1.

Mean minimum density (no/m^2) with 95% confidence intervals for the four most abundant species is given in Figure 2.2. There have been significant changes (G = 0.643585, DF = 12, P = >0.05) in the frequency of the four most abundant species over the five sampling years. This is due to fluctuations in brown trout density and a reduction in lamprey and roach numbers.

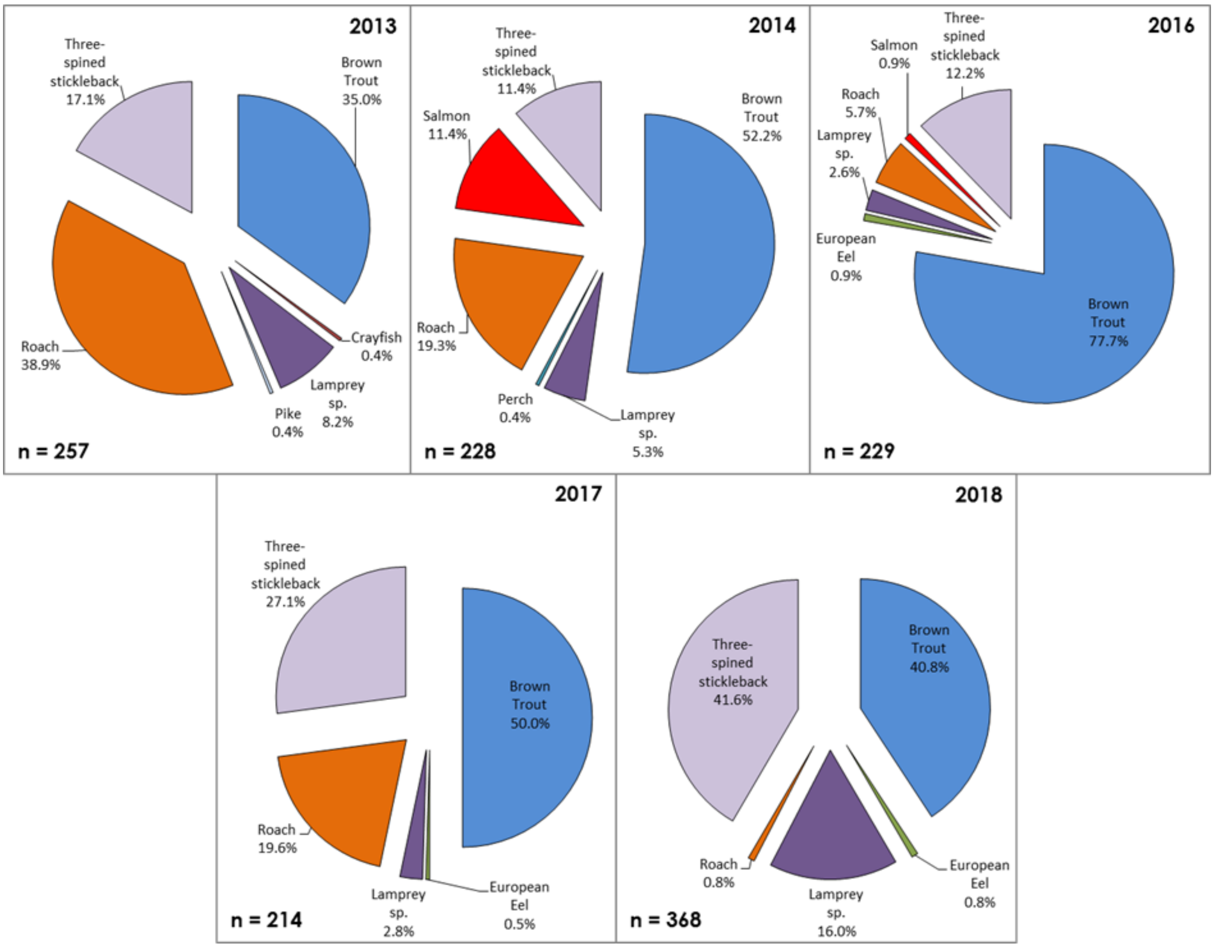


Figure 2.1. Composition of the fish community captured in the five Stonyford survey sites 2013, 2014, 2016 2017 and 2018.

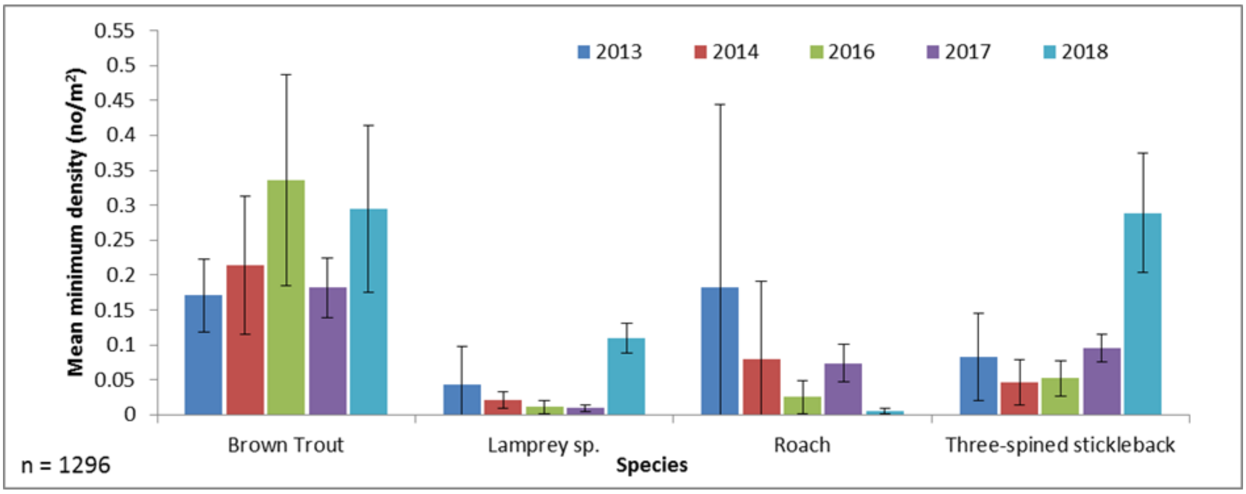


Figure 2.2. Mean minimum density (no/m^2) with 95% confidence intervals of the four most abundant fish species in the Stonyford River experimental sites 2013, 2014, 2016, 2017 and 2018.

Figure 2.3. Site 4 looking downstream in January 2018 (top) and July 2018 (bottom), showing extent of instream vegetation dieback during winter months and summer macrophyte growth.

Interaction between trout abundance and percentage vegetation cover over the five year sampling period is given in Figure 2.4. This demonstrates a bell shape curve response of trout numbers to vegetation cover. The highest trout densities were recorded in 2016 and 2018 when intermediate instream macrophyte cover was recorded. This suggests that maximum trout density may be associated with intermediate levels of instream vegetation cover (~45% - ~75%), a potential "green zone" of maximum trout density.

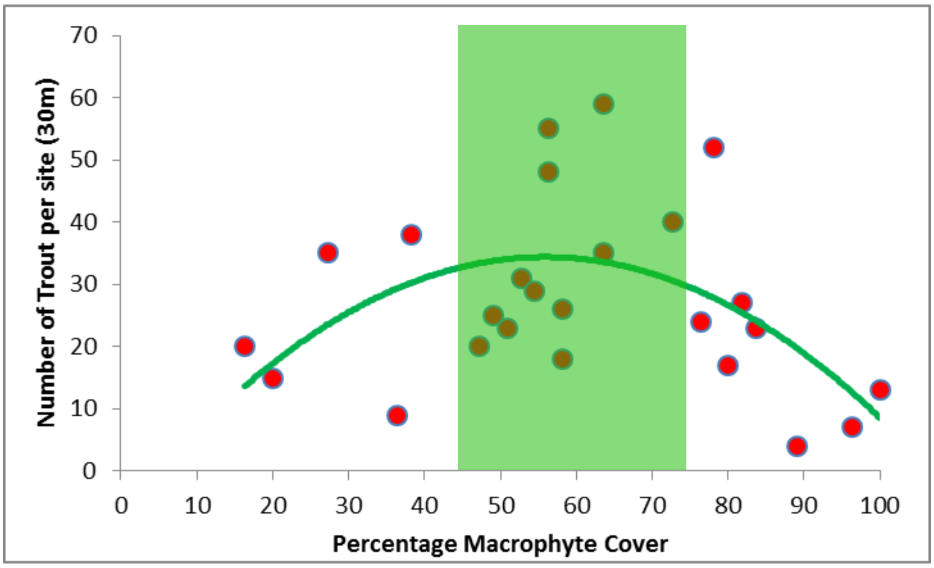


Figure 2.4.Interaction between brown trout numbers and percentage vegetation cover over the five year sampling period. The green box represents a hypothetical "green Zone" of maximum trout densities.

2.1.3 Discussion

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

Analysis of the fish community composition indicates that increased instream diversity led to increased brown trout habitat and therefore increased brown trout densities. Trout densities are responding to increased velocities driven by plant growth 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 growth of specific vegetation types choking the channel. The five 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 their densities.

2.2 Brosna Tributaries Temperature Experiment

2.2.1 Introduction

Climate change is expected to modify the thermal regime of Irish rivers. Increased water temperatures will affect all 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. 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 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 a particularly influential regulating factor in small to moderate sized channels (stream order 1-3) with its importance decreasing in larger channels. 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 and reduction of riparian canopy.

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 in maintenance. 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 and highlights the importance of channel shading by riparian vegetation.

2.2.2 Study Area

The current study builds on previous work undertaken within EREP, examining the relationship of tree cover to water temperature (O'Briain *et al.,* 2017) and is a continuation of thermal studies on three channels in the Brosna catchment, commenced in 2017. It considers the linkages of temperature and riparian tree cover over a two- year period (2017-2018). 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 groundwater-fed channel.

The Clodiagh River is surface water fed with heavy riparian tree cover, the Tullamore River had very little canopy cover and is surface water fed while the Tullamore Silver had low levels of canopy cover and is a groundwater-fed channel. In 2018, data capture on the Tullamore Silver River was curtailed, as the 2017 data set indicated that this groundwater-fed system showed limited response to solar heating.

Both the Tullamore Silver and the Tullamore are alkaline, moderately enriched channels with high conductivity, whereas the Clodiagh is moderately enriched but with lower conductivity. The 15 study sites in the three catchments (Figure 2.5) were initially chosen to represent the different river types, maintain equilateral distance between each site and give safe and easy access for thermal probe deployment and site surveying. A description of the study sites can be found in the 2017 EREP report.

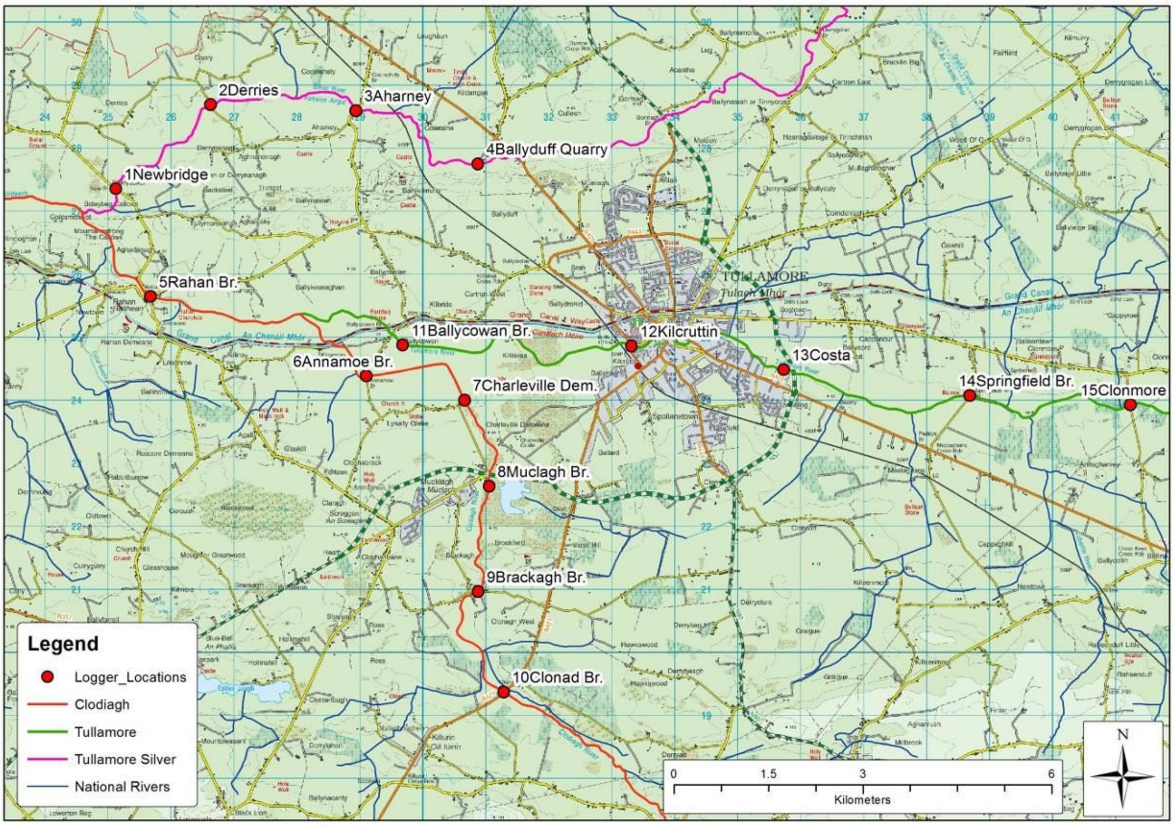


Figure 2.5. Deployment location and site name of temperature loggers in the Tullamore Silver, Tullamore and Clodiagh Rivers, Brosna Catchment in 2017. Sites 2, 3, 4 and 5 were dropped for 2018.

2.2.3 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).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.

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 2.5.) in summer (June to August) in 2017 and 2018. 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.

2.2.4 Results

Observed mean maximum daily temperatures in June ranged among sites from 15.1°C to 17.2°C in 2017 and 15.4°C to 18.1°C in 2018. June mean temperature range varied from 13.1°C to 15.1°C °C in 2017 and 14.4 to 16.6°C in 2018. Sites with low tree cover experienced greater temperature maxima than sites with higher tree cover.

The realised upper thermal threshold for brown trout (>18.7°C) is the temperature which dictates the observed summer distribution brown trout. Above 18.7°C, trout migrate out of an area to find thermal refuges. The upper temperature limit for brown trout growth (>19.1°C) is the threshold at which brown trout cease to grow. Water temperatures exceeded the realised upper thermal threshold for brown trout (>18.7°C) and the upper temperature limit for brown trout growth (>19.1°C) in both the Tullamore and Clodiagh Rivers but not in the Tullamore Silver in both 2017 and 2018 (Figure 2.6).

The effect of canopy cover on the number of 30-minute periods per month when water temperature exceeded 19.1°C, in summer 2017 and 2018 is given in Figure 2.7. Separating the 2017-2018 summer months into hot (>18.7°C) and cool (<18.7°C) periods, the thermal responses of the Tullamore and Clodiagh rivers to solar heating are different (slope of the line). In the Tullamore River the effect of canopy cover appears to respond proportionally between the hot and cool periods (slope of the regression lines is similar), the cooling response due to tree cover remaining similar between the two temperature regimes. In the Clodiagh River, increasing canopy cover has no effect during cool periods as the canopy cover is extensive (>40%). The flat liner regression line for "Clodiagh cool" (Figure 2.7) is probably the river temperature responding to ambient air temperature. For the "Clodiagh hot" data canopy cover does have an effect, with increasing cover reducing the periods when water temperatures exceed 19.1°C. The "Clodiagh hot" regression line in Figure 2.7 would indicate that as ambient air temperature exceeds >18.7°C canopy cover becomes increasingly important.

However the overall trend is the greater the percentage canopy cover the lower the number of 30 minute periods per month water temperature exceeded 19.1°C. 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.

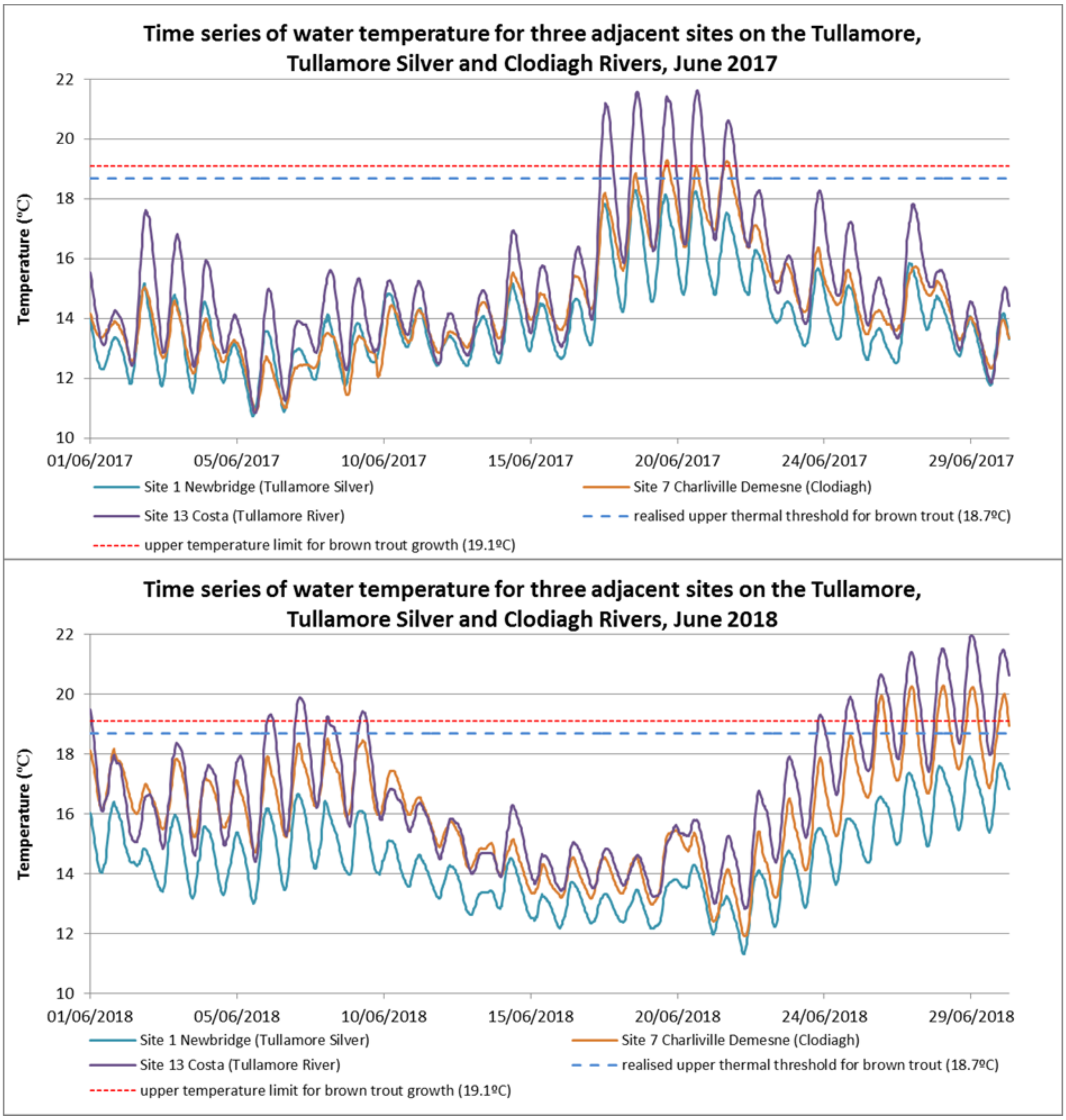


Figure 2.6. Water temperature recorded from three adjacent sites on the Tullamore, Tullamore Silver and Clodiagh Rivers in June 2017. The dashed blue line shows the realised upper thermal threshold for brown trout (*Salmo trutta*) distribution. The dashed red line shows the upper temperature limit for brown trout growth.

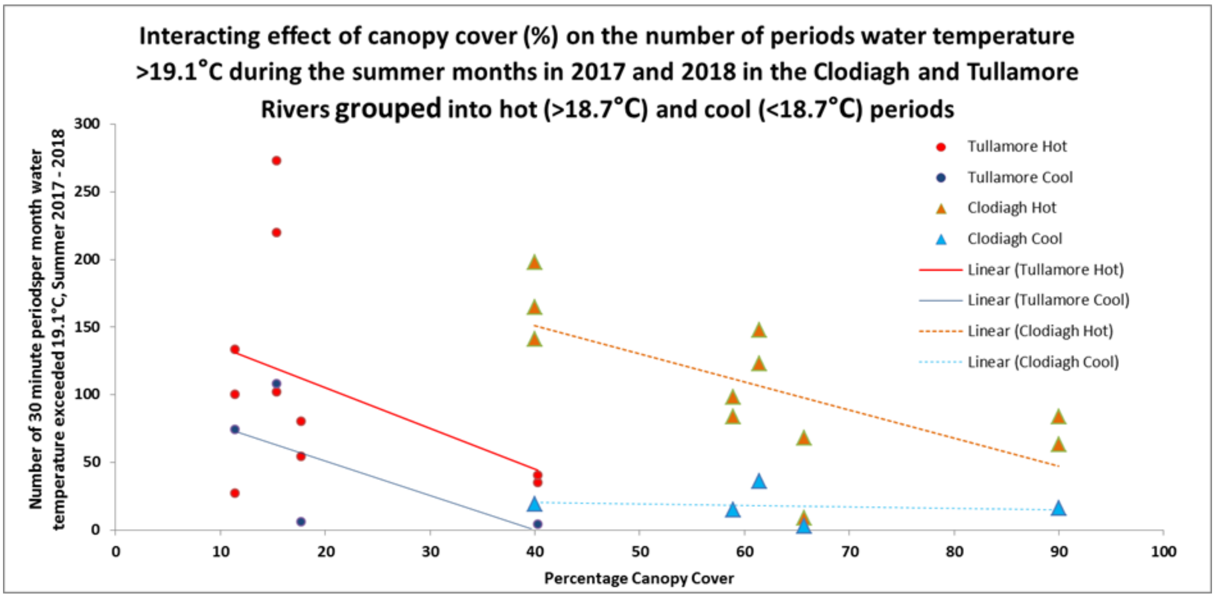


Figure 2.7. The effect of percentage canopy cover on the number of 30 minute periods per month water temperature exceeded 19.1°C, in summer 2017 and 2018 in the Clodiagh and Tullamore Rivers.

2.2.5 Discussion

Water temperature >18.7°C is the realized upper thermal threshold for brown trout distribution. Above this temperature brown trout have been shown to disperse seeking cold water refuge. The water temperature in the Tullamore Silver did not exceed 18.7°C in June 2017 or 2018, primarily due to groundwater springs buffering river water temperatures. The effect of canopy cover on the number of periods (30mins) when water temperature exceeded 19.1°C in the Tullamore and Clodiagh River in the summer of 2017 and 2018 given in Figure 2.7, shows that increasing canopy cover reduced the number of periods when water temperature exceeds 19.1°C.

The Tullamore and Clodiagh rivers differ in both percentage tree cover, depth regime and instream plant cover. Being so physically and ecologically different, it is evident that heat transfer mechanisms for these two channels are also different. The Tullamore is heated through direct thermal heating (sunshine) as it is has predominantly deep water with the river bed out of direct sunlight while the Clodiagh is heated through both direct thermal heating and thermal conduction as it is both wide and shallow and the water and bed can be heated. However on the Clodiagh the high percentage canopy cover protects the channel from direct solar heating and in most cases elevated river water temperatures may be reflecting ambient air temperature.

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

2.2.6 Management implications for drained rivers 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 adequate buffering against increase in water temperature
- The OPW maintenance strategies in regard to tree management require 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 and IFI shared EREP study, has a role in regard to conservation and protection of tree cover, particularly young trees, from grazing by livestock.
- 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 (thermal refuge habitat). This strategy can be implemented using Topic 10 in the OPW’s Environmental Guidance on channel maintenance. The digging strategy has been proven 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’).

3 Long-term Monitoring Repeat Studies

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 such as the fish survey of the Blackwater catchment in Monaghan (1980-81) conducted prior to commencement of arterial drainage. 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). This update process was continued in 2018 with repeat surveying on the R. Camoge in the Maigue CDS and on the Attymass stream in the Moy CDS. Repeat surveying of cross-sections on the Dungolman, commenced in 2017, were completed during 2018.

3.1 Long Term Study I: River Camoge (C1/25 Maigue CDS)

The Camoge River is one of the largest sub-catchments in the Maigue system. It rises in the area of east Limerick – south-west Tipperary and flows in a westerly direction to enter the Maigue near Croom. It is essentially a lowland meandering river although localised areas of elevated gradient do occur, particularly downstream of Glenogra. As an arterially drained river it is highly channelized, being widened and deepened to increase its capacity for flow volumes. The initial fisheries and habitat study undertaken as part of the Environmental Drainage Maintenance (EDM) Programme took place from 1998-2001. During this period the Camoge was scheduled for maintenance. This operation was to be a ‘first maintenance’ subsequent to the initial arterial drainage of the 1970s.

A considerable degree of re-naturalisation had occurred in the river since the initial drainage operation, despite the modified nature of the channel. Issues of particular concern to engineers in 1998, in terms of impact on conveyance, were the growth of trees along the channel cross-section and the degree of localised deposition forming berms or lateral shoals. It was envisaged that the maintenance operation would have a severe impact on the river corridor habitat and a series of locations were selected for fisheries surveys. The areas chosen for investigation were all lowland locations or 'corcas' areas – a local term for extensive flat areas of landscape adjoining the river.

The sites of initial investigation were:

- Chg. 272 – 262 at Herbertstown
- Chg. 254 – 212 Herbertstown corcas (Cloghansoun Bridge – Longford Bridge)
- Chg. 174 – 158 between Grange and Glenogra Bridges

The Camoge study examined the impact of a major "first maintenance operation" commenced in 1998 – the maintenance being the first return to the river by OPW following the arterial drainage scheme. Monitoring had collected data prior to impact in 1998 and for subsequent years to 2001 relating to the fish community, tree cover, channel width-depth-velocity profiles and cross-sections. Three zones were examined in the 1998-2001 period and two of these were re-examined in 2018. The series of representative cross-sections surveyed in the earlier study were re-surveyed in 2018.

The fish community was examined using electric fishing methods to stun, collect and process fish before returning them to the water. Use of a mark-recapture technique permitted the fish community to be examined over long segments of channel. Fishing proceeded in a downstream direction and all fish captured in a specific area were processed for species, length and weight. All target species e.g. brown trout, pike, were then 'marked' i.e. clipped in the apex of the tail fin area. This enabled these fish to be distinguishable in the 'recapture' fishing some days later. In this way a series of continuous fishing's were undertaken in the various zones, providing an overall picture of the fish community over a larger area of channel.

The fish and physical surveys were undertaken prior to commencement of maintenance and in the year following maintenance. The aim of the study undertaken in 2018 was to re-survey a number of the fishing areas and to repeat levelling surveys of cross-sections.

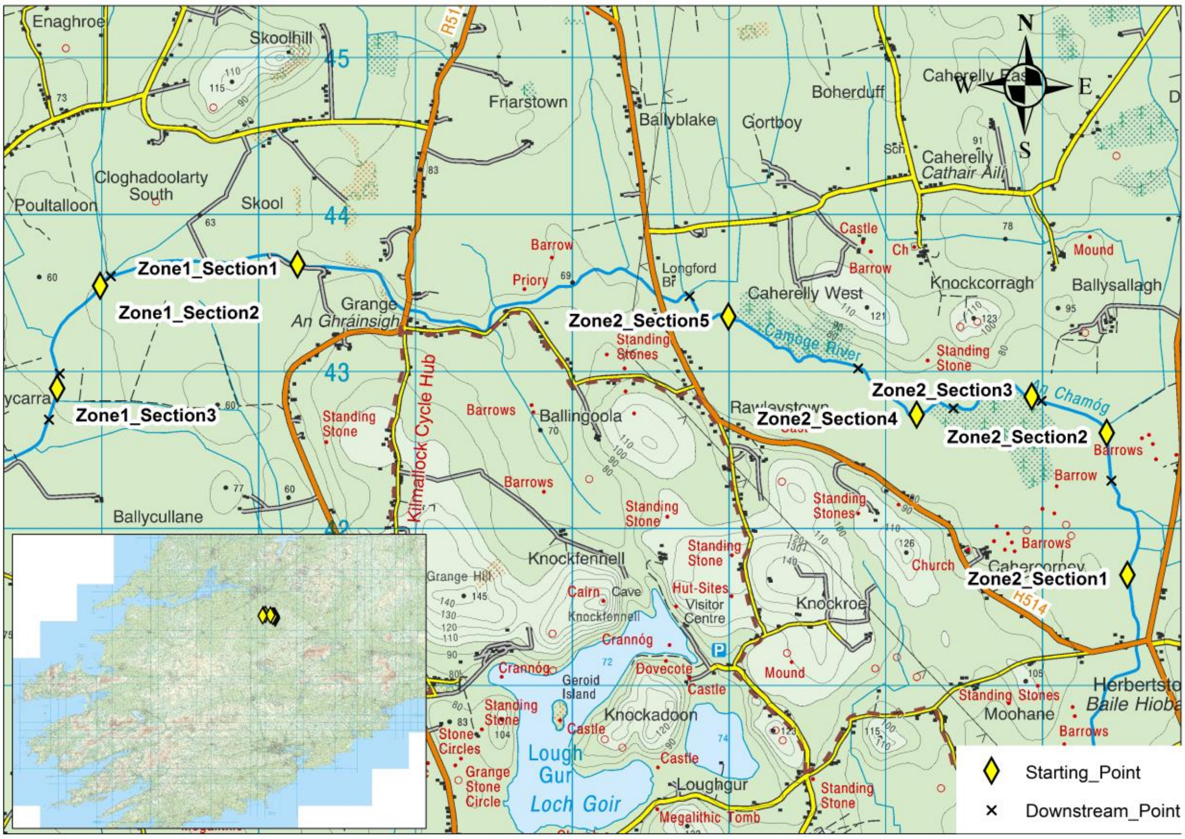


Figure 3.1. Camoge Sites Fished in 2018. (Yellow Diamond indicating starting point and the x indicating end point for boat for each stretch)

3.1.1 Fish Community Composition in the River Camoge

Brown trout was the predominant species encountered in the 2018 electric fishing surveys, undertaken in May-June. Small numbers of 'young-of-the-year' or '0-group trout' were recorded. A number of trout size or age groups were evident (Figure 3.2 and Figure 3.3) with a modal peak of younger trout at 14cm. A smaller number of fish in the 20 – 30cm range were recorded in addition to individual trout up to 54cm. Fish in excess of 25cm are generally considered to be of angling size and the larger fish here were indicative of habitat size and extent that can support such larger fish.

In addition to brown trout, the most prominent fish species were Atlantic salmon and pike. The salmon recorded had traversed from the Shannon estuary into the Maigue catchment and then into the Camoge *on route* to spawning water upstream. Salmon spawn in the late autumn – winter period so the fish encountered during this survey would be waiting for several months, availing of the extensive areas of deeper water in the river.

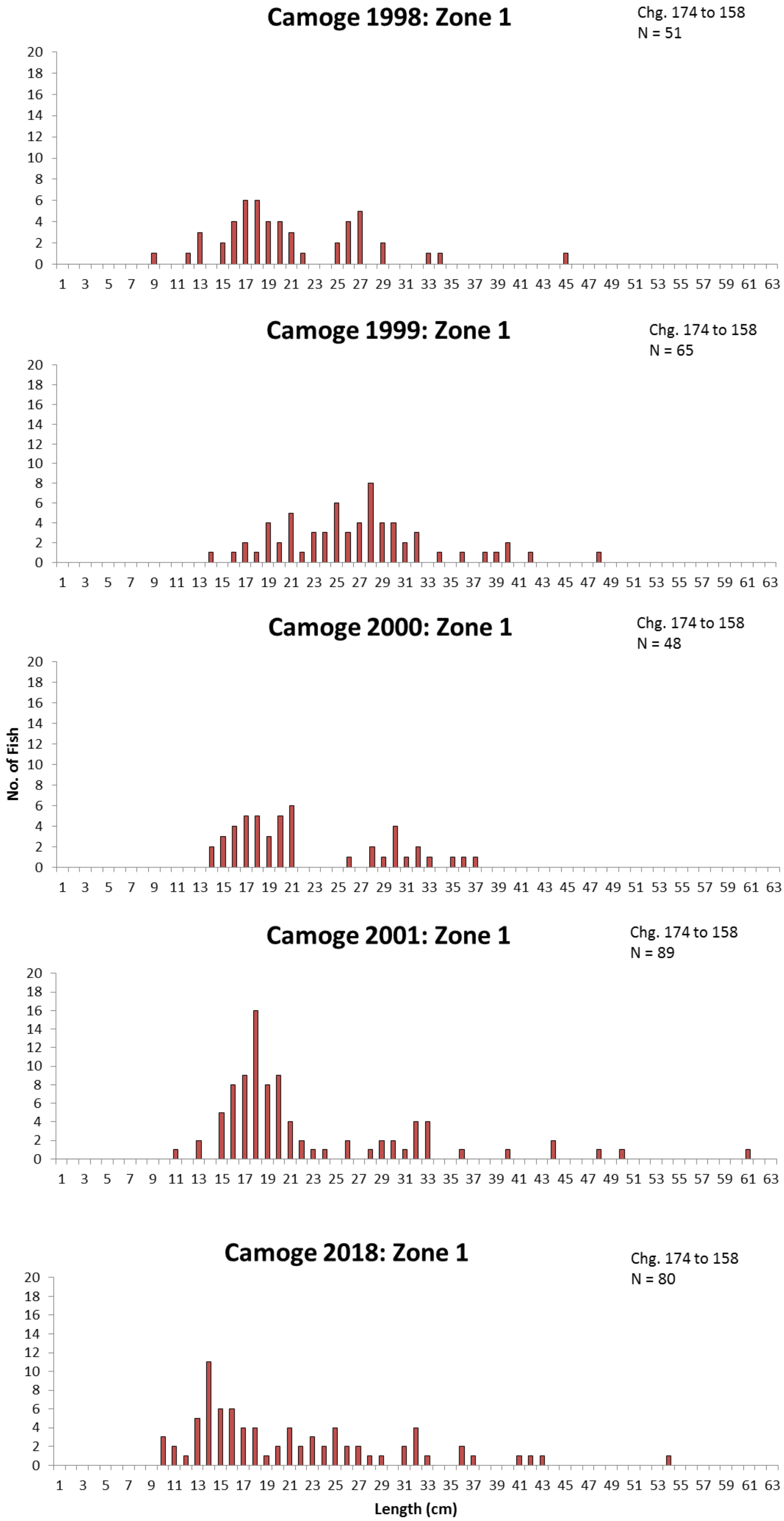


Figure 3.2. Length frequency of Brown Trout captured within Zone One (Grange-Glenogra) for each year the surveyed (1998, '99, '00, 2001 and 2018).

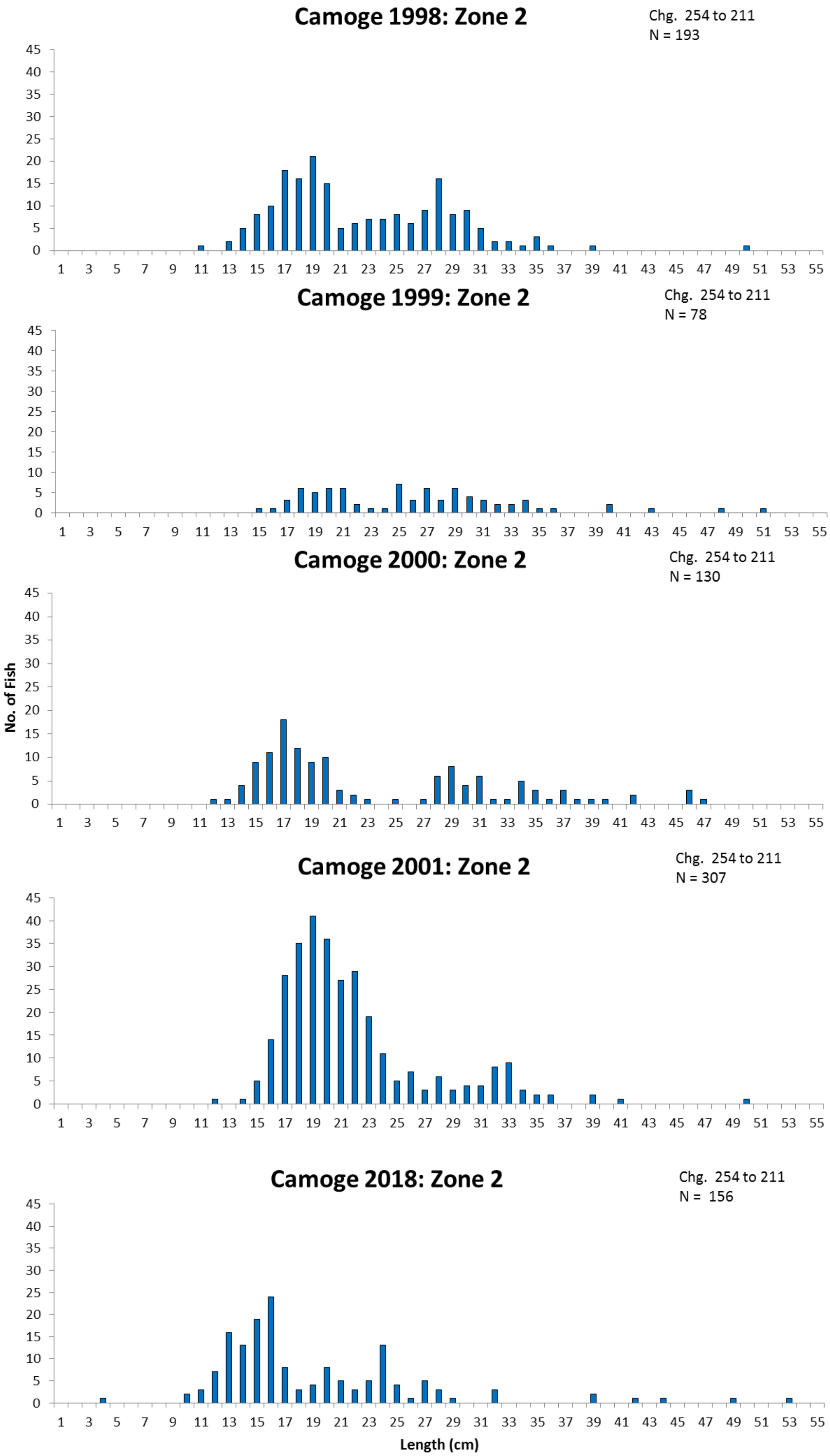


Figure 3.3. Length frequency of Brown Trout captured within Zone Two (Cloghansoun – Longford Br.) for each year surveyed (1998, '99, '00, 2001 and 2018).

Biomass and density of brown trout:

The biomass of brown trout varied widely between years and between sites within zones (Figure 3.4). The overall values in the Grange-Glenogra zone (Zone 1) were notably lower than those recorded in the Herbertstown – Longford bridge area (Zone 2).

Population density data (Figure 3.5) broadly reflected the biomass data. Reduced numbers of brown trout were recorded in several sites in the year following maintenance i.e. between 1998 and 1999. However, density values rose in subsequent years to mirror the pre-maintenance values. The density values recorded in 2018 were in the same range as the pre-maintenance values of 1998. The majority of the sites did not prove technically problematic to survey, apart from the site at chg. 224-231/50. This latter site lacked clearly defined up- and downstream ends, such as instream shallows that would cause moving fish to turn and be captured. This may account for the very low density values recorded here in 3 of the 5 years of surveying.

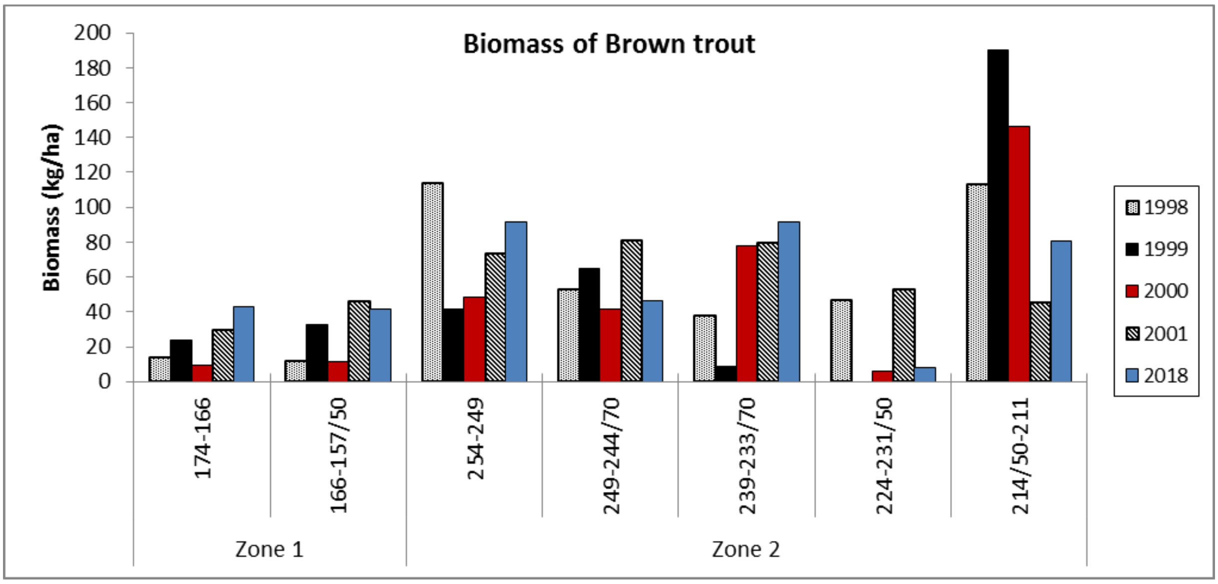


Figure 3.4. Biomass (kg/ha) of Brown trout from Camoge River zones 1 & 2 (1998/99/00/01 and 2018).

Population structure of brown trout:

The size range or length frequency distribution of brown trout over the period of sampling (1998 – 2018) is presented separately for the two survey areas – Zone 1 and Zone 2 – fished in 2018. Trout numbers were low in Zone I in all years and, based on the modal peaks and scale reading, the population in 1998 prior to maintenance was composed primarily of two - (17-18cm mode) and 3-year old (25cm mode) trout (Figure 3.2). The population structure shifted in 1999 with a predominance of 3-year old fish but showed a reverse trend in 2000. These shifts may be influenced by the overall impact of channel maintenance. The loss of more complex and stabilised niche habitat was observed due to drainage works. This in turn created a more simplified habitat better suited to younger fish rather than older fish. The structure in 2001 broadly mirrored that in 2018 with larger numbers of younger, 2-year old fish and a range of larger sized trout including individual fish in excess of 40cm.

The pattern of population structure in Zone 2 was broadly similar to that in Zone 1 but the trout numbers were generally larger (Figure 3.3). There was a pronounced reduction in trout numbers in 1999 (the year of maintenance); although the fish survey was undertaken in all years prior to any maintenance work in that sector in that year. The peak of 2-year old fish in 2001 mirrored that of Zone 1. As with Zone 1, occasional large brown trout, in excess of 40cm were recorded in all years.

Sample sizes were small in each zone, in the majority of years. Experience of surveys in similar channels would have expected a higher population of brown trout, given the depth of water available for larger fish and the extensive cover available both in the channel bed and in the channel margins. There was no evidence of a long-term adverse impact of the actual maintenance work of 1998-2000, the time span taken for maintenance work to traverse the two Zones.

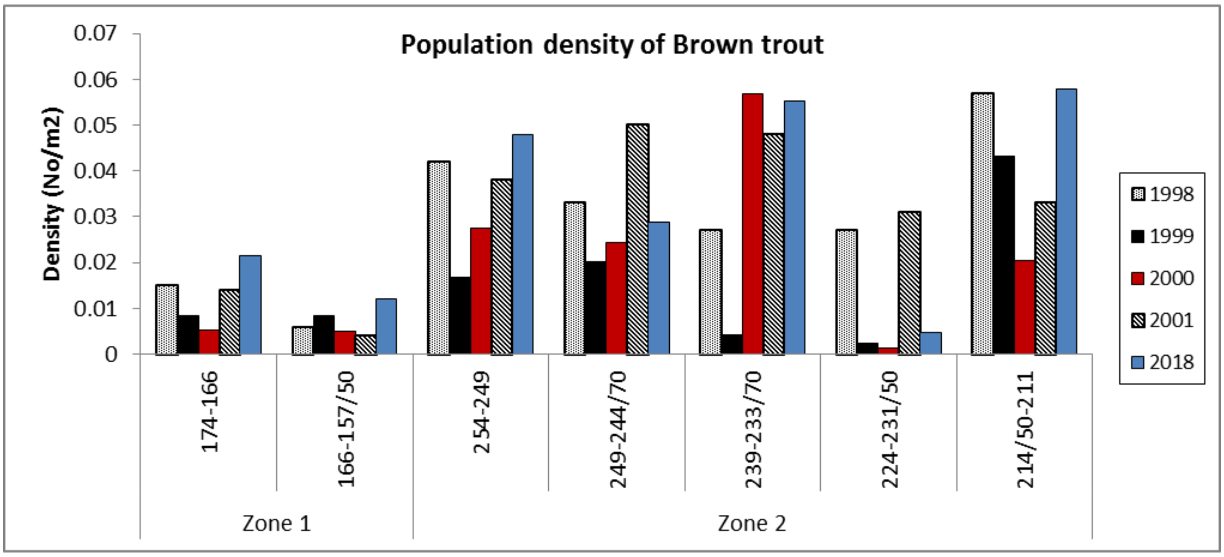


Figure 3.5. Population density (No./m^2) of Brown trout from Camoge River zones 1 & 2 (1998/99/00/01 and 2018).

3.1.2 Survey of channel cross-sections

A series of 8 cross-sections were surveyed in 1999 prior to any maintenance work and these were re-surveyed in 2018. The cross-sections lay in the area of channel between Longford Bridge and Herbertstown, from chainage 228 up to chainage 268, a distance of approximately 3.6km (Zone 2 of the fish survey). The data was analysed using the RIVERmorph ™ software to generate graphics of cross-sections as well as summary data. No fixed O.D. reference points or markers were established initially, so replication of the cross-sections was dependant on matching of photographs from the initial levelling survey.

Comparison of critical dimensions - cross-sectional area, wetted perimeter and hydraulic radius - indicated very small differences between the pre-maintenance dimensions and the 2018 data, measured 19 years later (Table 2). The majority of dimensions were smaller in the 1999 survey compared to the 2018, as might be expected. The mean values, over 8 cross-sections, for 1999 data as a proportion of 2018 dimensions were close to unity, with small deviation values. In two of the cross-sections the pre-maintenance area was notably smaller than the 2018 area, 77% at chainage 240 and 80% at 244.

The graphics generated in RIVERmorphTM illustrated the pattern shown by the calculated dimensions, with loss of some features and a smoothing out of others but with an overall reasonable 'fit' of the 2018 images on their corresponding pre-maintenance images (Figure 3.6). The graphic for chainage 228 showed a closeness of fit on the left bank area with a degree of smoothing and a reduction in the lateral berm area on the right bank. Some degree of deepening of the centre of the channel was also evident (Figure 3.7). The composite graphic for chainage 232 showed an even closer fit, with a small degree of bed deepening in the channel centre and some smoothing along both bank slope areas.

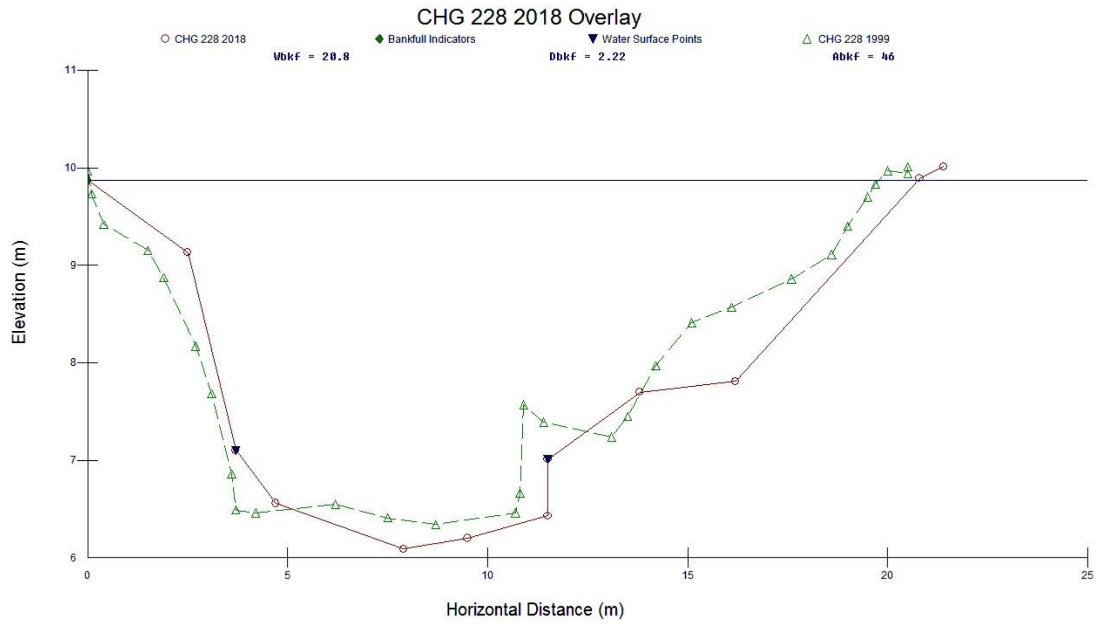
The most evident changes in the cross-sections were the visual ones. Comparison of paired images showed little change in landscape features adjacent to chainage 228. However, an extensive tree growth in the adjoining riparian areas had taken place at chainage 232 where the 2018 cross-section data collection just fitted between gaps in the now-developed tree line.

A reference to the Manning's equation $Q = 1/n. A.R^{2/3}. S^{1/2}$

(Q= quantity of water through the cross-section; n = Mannings roughness element; A = cross-sectional area; R = hydraulic radius; S = slope) and the two levelling surveys points to any difference, in terms of 'Q', residing with the Manning's n or roughness element, given that the measurements of A and of R were largely unchanged between 1998 and 2018. The extent of tree growth in some, only, of the cross-sections, would point to an increased 'n' value and a potential impact on 'Q' (see below – Figure 3.7 and Figure 3.8).

Table 2. River Camoge (C1/25 Maigue) cross-section dimensions from pre-maintenance (1999) and 2018. Mean and Standard Deviation based on averaging of the 8 measured sections.

Year	CHG	Bankfull Width (m)	Pre/ Post	Cross-sectional Area (sq. m)	Pre/ Post	Wetted perimeter	Pre/ Post	Hydraulic Radius (m)	Pre/ Post
1999	224	17.41	0.867	37.45	0.908	20.47	0.928	1.83	0.979
2018		20.08		41.26		22.07		1.87	
1999	228	20.5	0.987	45.13	0.98	23.82	1.021	1.89	0.959
2018		20.76		46.04		23.34		1.97	
1999	232	23.71	0.845	55.17	1.023	26.31	0.877	2.1	1.167
2018		28.06		53.91		29.99		1.8	
1999	236	29.45	1.062	71.26	1.16	32.07	1.036	2.22	1.121
2018		27.74		61.45		30.97		1.98	
1999	240	21.4	0.909	47.36	0.772	24.34	0.91	1.95	0.852
2018		23.55		61.35		26.76		2.29	
1999	244	21.52	0.922	49.34	0.804	23.94	0.947	2.06	0.848
2018		23.35		61.4		25.27		2.43	
1999	264	18	0.994	38.38	1.097	20.15	1.011	1.91	1.085
2018		18.1		35		19.93		1.76	
1999	268	21.96	1.044	58.3	1.101	25.87	1.106	2.25	0.996
2018		21.04		52.93		23.4		2.26	
Mean			**0.954**		**0.981**		**0.979**		**1.001**
SD			**0.08**		**0.142**		**0.076**		**0.118**



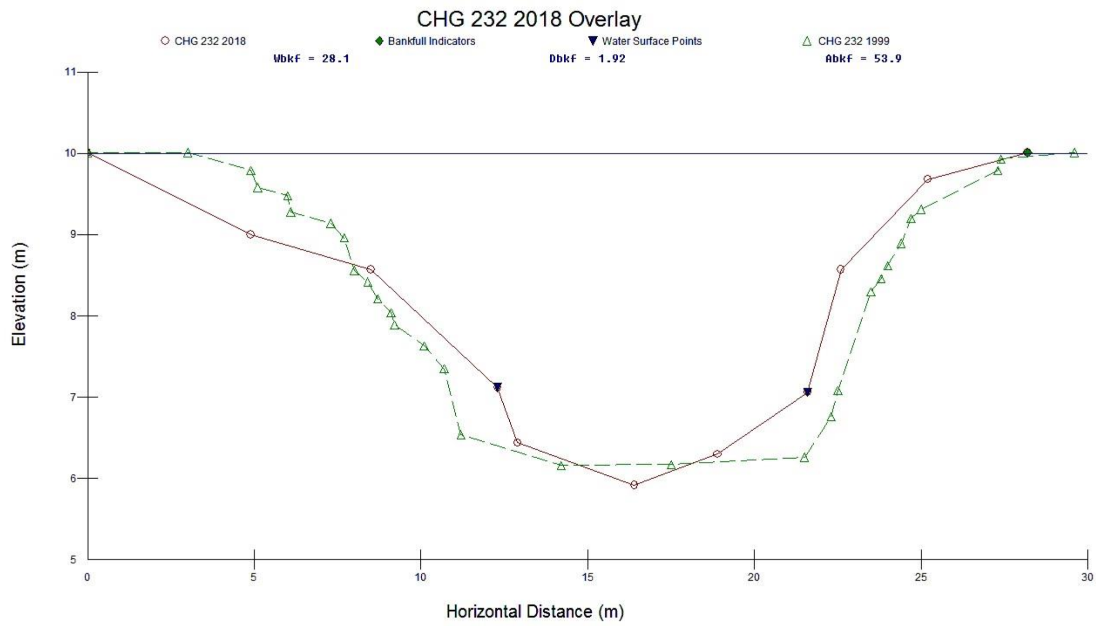


Figure 3.6. Comparison of cross-sections from 1999 (pre-maintenance – green line) and 2018 (black line) for chainage 228 (top) and 232 (bottom). See photographs below.

Figure 3.7. Photos from cross sections taken at chainage 228 from 1999 (top) and 2018 (bottom).

Figure 3.8. Photos from cross sections taken at chainage 232 from 1999 (top) and 2018 (bottom).

3.1.3 Conclusion

The long time lag between the initial monitoring of pre- and post-maintenance impact and the survey of 2018 could have allowed for substantial changes to the river corridor in the case of a dynamic river. The Camoge is, in the areas surveyed, a lowland meandering-type channel subject to arterial drainage. There was localised evidence of changes in cross-sectional form, as evidenced by bank slippages, lateral berm development and siltation facilitating instream vegetation growth. The most prominent evidence of change was in tree growth and collapse of trees into the cross-section. This was localised but significant in one or two cases. The limited change in channel geometry dimensions over the period 1999 – 2018 is indicated in the RIVERmorph TM analysis.

The fish community, dominated by brown trout, had not undergone any substantial changes over the period 1999 – 2018. As stated above, it would be expected that a channel of the size of the Camoge would be carrying a larger population of brown trout, including a larger number of angling-sized fish.

The fish and cross-sectional data indicate a long-term stability in this system, following a major channel maintenance operation in the period 1998-2000.

3.2 Long Term Study II: River Attymass

3.2.1 Introduction

The Attymass River flows south west draining from Ballymore Lough towards Carrowkeribly Lough where the river becomes the Bunnafinglas River before discharging directly into the River Moy between Foxford and Ballina. The river has a main stem length of 8km. The channel has a degree of tree cover, equating to linear deciduous woodland, running along much of its length, particularly in the study area.

This river, although relatively small, plays an important role for diadromous fish species, with Atlantic salmon using this river for spawning as the riverbed supports good spawning gravels.

Channel Maintenance

The river is part of the OPW's Moy Drainage Scheme. In regard to maintenance, this channel has a high gradient throughout and was not subjected to radical silt removal. A limited degree of tree management/thinning and minor gravel removal was undertaken in 2004. A pre and post works monitoring programme was undertaken at that time. A series of 10 sites were originally examined and 8 of these were re-surveyed in 2018 (Figure 3.9).

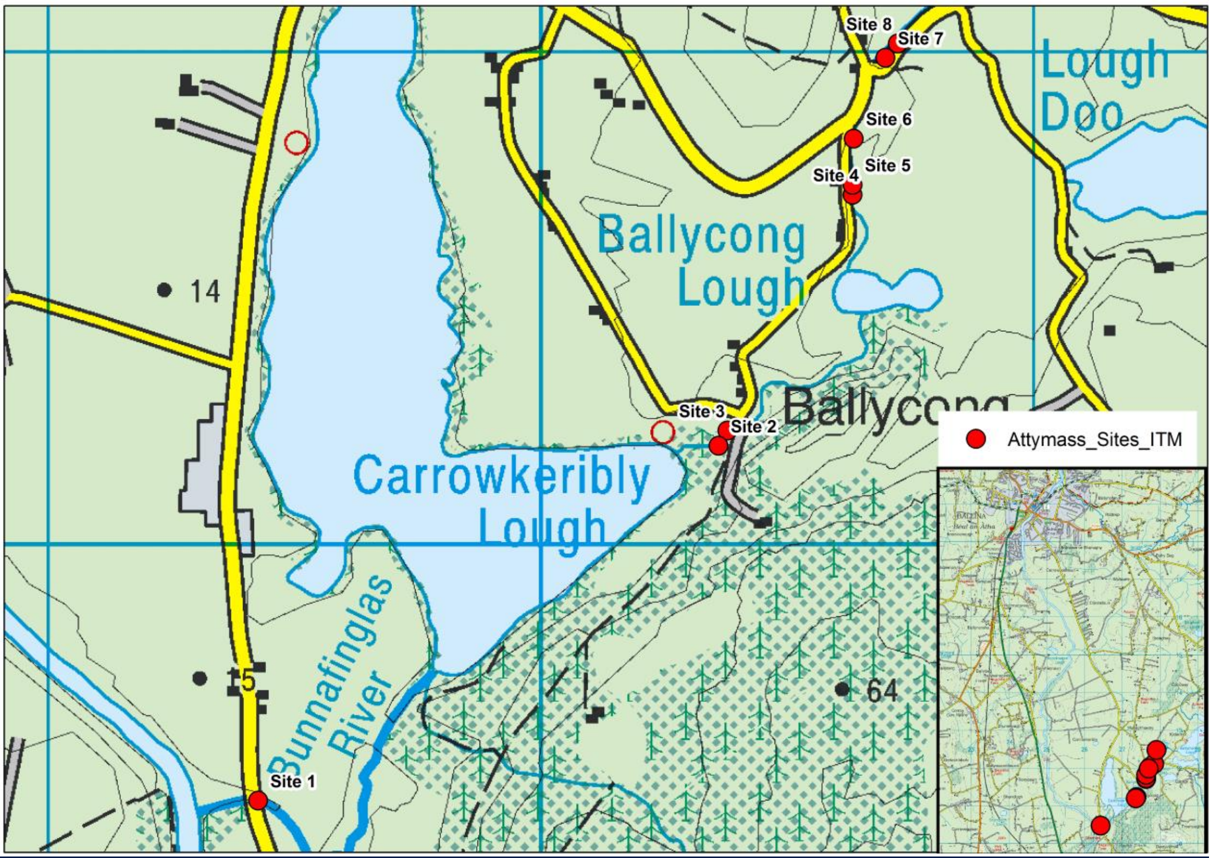


Figure 3.9. Map displaying location of sites relative to Ballina Co. Mayo, fished during the Attymass Surveys in 2000, 2002, 2004, 2005, 2006 and 2018.

3.2.2 Survey Works

Physical Measurements

The channel's physical attributes (depth, width) and canopy cover were recorded at 5 metre intervals in each of the study sites from 2000 onwards. Canopy cover was recorded using a concave spherical densitometer. A large woody habitat survey was completed at each of the 8 fishing sites for 2018 only, using the Large Woody Debris Index (LWDI) (Harman *et al.,* 2017).

The Index defines woody debris/material as a dead piece of wood that is at least 10cm in diameter and at least one metre long. Although this index was developed for remote wilderness streams, it is adaptable and proven to assess Large Woody Debris (LWD) as a function-based parameter of geomorphology in impacted and restored streams such as arterially-drained rivers. This index requires additional information which in turn provides a link between structural assessment and function.

In the LWDI, each piece of LWD is classified under one of the 7 variables, whilst classification of a debris dam (DD) consists of 5 variables. Each of the variables is scored from 1-5, relative to the importance of each piece of woody material within the channel. Some of the factors considered during the classification of each woody fragment include; length/bankfull width, diameter, location, type and stability (Harman *et al.,* 2017). Higher LWDI Scores indicate that the woody structures within the channel have a greater influence on channel form and features.

Depletion Fishing

The fish population survey was carried out using the same protocol as previous years, which was bank-based depletion fishing's, utilizing two passes, using stop nets both at upstream and downstream ends of each fishing site. The fish captured were counted, measured and retained after each pass, being returned once the section was fished and nets removed. Over all of the survey years, species encountered in order of decreasing abundance were Brown trout, salmon, eel, perch, minnow, pike, stoneloach, roach and three-spined stickleback.

3.2.3 Results

Fish Community

From the first survey in 2000 up to 2018 the river contains a fish community dominated by 0+ and 1+ brown trout and 0+ and 1+ salmon (Figure 3.12 and Figure 3.13). Individual trout of 19 – 20cm length have been taken in most years on the survey. The size of the channel and the range of depths are those typically associated with these size and age groups of salmon and trout. Capturing both age classes within this riverine system indicates that there is recruitment each year for both salmon and brown trout.

The percentage brown trout length frequency remained very consistent over the period of study, with both 0+ and 1+ fish represented in each year (Figure 3.10). The total number of trout captured in 2018 was very low compared to all previous years. This may be a consequence of slightly elevated water levels and velocities in 2018, with the water levels falling following previous flooding. Increase in water levels may encourage fish movement to other areas for refuge, and this may have well been the case. The various lakes within the Attymass system could act as buffer zones or refuge areas during increased water levels.

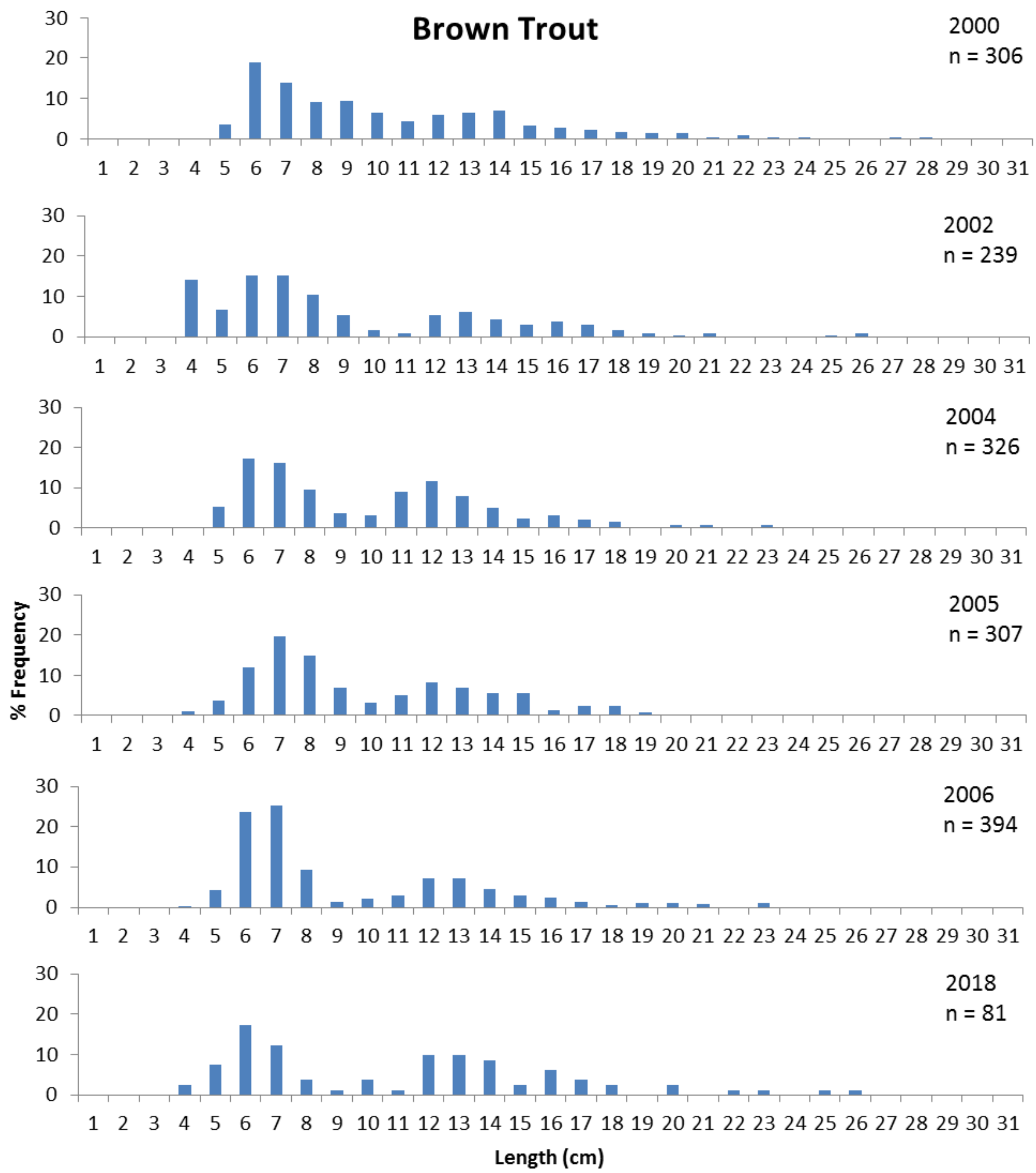


Figure 3.10. Percentage length frequency distribution of brown trout captured in all of the eight survey sites for each year.

The percentage salmon length frequency showed a substantial degree of variation over the study period (Figure 3.11). Both 0+ and 1+ salmon were present in all years but the proportions varied widely, with some years dominated by 0+ fish and some by 1+ fish. Juvenile salmon numbers in 2018 were not as depleted as the juvenile trout and total numbers were similar to the 2006 survey.

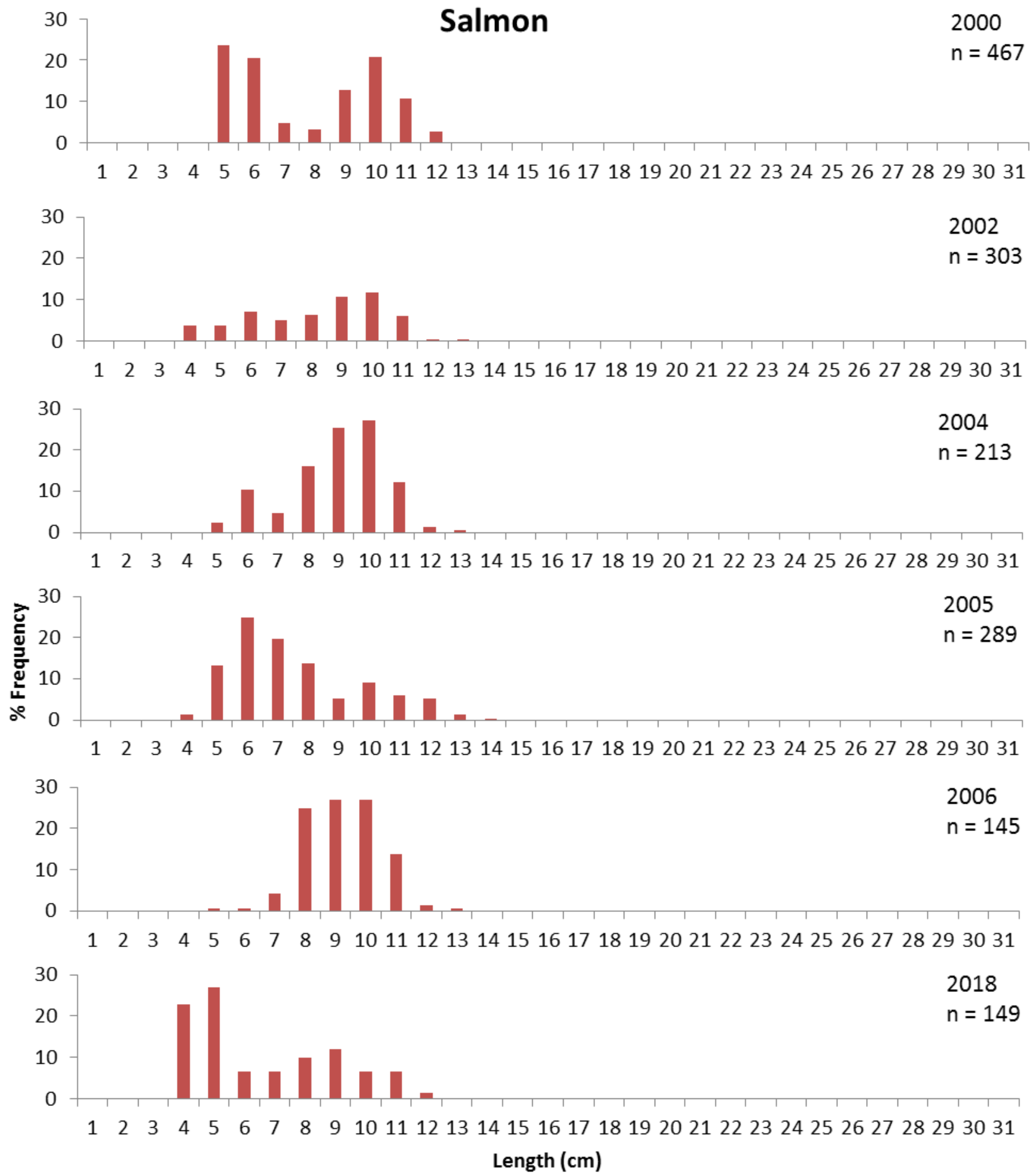


Figure 3.11. Percentage length frequency distribution of salmon captured in all of the eight survey sites for each year.

Fish Densities: The age groups (0+ and 1+) of the two dominant fish species (salmon and trout) showed a wide variation in density across the 8 survey sites in 2018 (Figure 3.12 and Figure 3.13). Density values of 1 fish/m2 would be considered typical for 0-group salmon and brown trout in appropriate habitat types in Irish rivers in late summer-autumn. This density level was achieved by both species in Site 4, only. The other sites tended to show a predominance of one species or the other. Density values for both species were low in the adjoining Sites 7 and 8. 0+ salmon occurred in seven of the eight sites and high density values were recorded in Sites 4, 5 and 6.

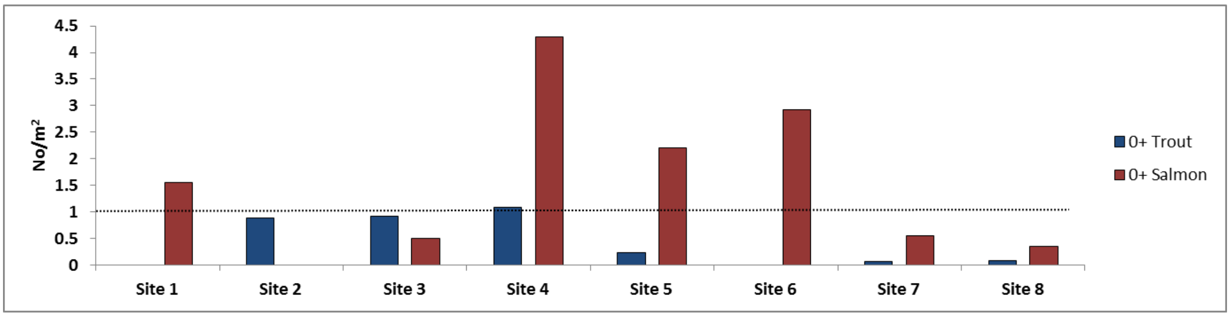


Figure 3.12. Density of 0+ salmon and 0+ brown trout at eight sites in the Attymass Stream, September 2018. (Dotted line is the 1 fish/m^2 density level that may be anticipated at this time of year.)

The larger, 1+ age group of trout and salmon was represented at the majority of sites, brown trout at all locations and salmon missing from two sites. Based on observations from other Irish streams, the density values for 1+ fish at the late summer - autumn time of year might be typically 0.1 fish/m^2 or higher. Using this criterion the two species, where present, occurred at or above this baseline. The trout 1+ density values were generally higher than the 1+ salmon and exceeded the 0.1 density level at seven of the eight sites.

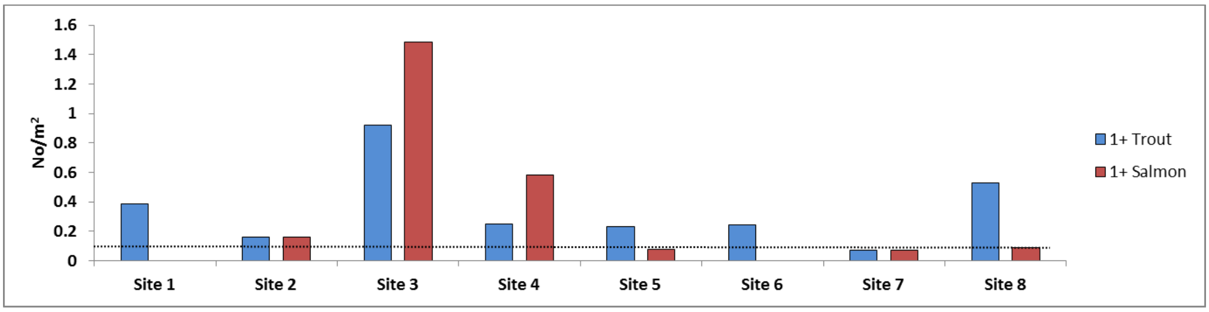


Figure 3.13. Density of 1+ salmon and 1+ brown trout at eight sites in the Attymass Stream, September 2018. (Dotted line is the 0.1 fish/m^2 density level that may be anticipated at this time of year.)

Physical Habitat

Tree canopy cover: Channel maintenance, which consisted of tree management, was completed on the Attymass in 2004. Tree management works, consisting of removing some tree cover, removal of branches overhanging the channel etc., was undertaken in Sites 2, 3 and sites 6, 7 and 8. Sites 1 (open channel), 4 (full canopy, untreated) and 5 (open channel, untreated) were not treated. This cutting impact is evident in the 2005 survey data of canopy cover (Figure 3.14) as is the recovery of the tree canopy subsequently, as percentage canopy cover in all sites – open and closed - continued to increase over the entire survey period. Site 3 showed reduced recovery since maintenance in 2004, and since visiting this site it is obvious that the trees were completely removed from the left bank and have not grown back. Site 4 shows a high percentage canopy cover for all the years as maintenance in this site in 2004 was minimal.

Factors other than maintenance, which influence canopy cover in these sites, are the natural cycle of trees, particularly with alder trees. Trees dying off and falling into the channel reduce canopy cover in some sections. The fallen tree is then not providing any cover for the water body, but now has the ability to create large woody habitat (LWH) within the riverine corridor. The addition of LWH into the channel has the potential to significantly enhance the ecological potential and support gravel accumulation, depth variations, greater flow diversity, improved hydraulic regime and therefore support higher trout densities.

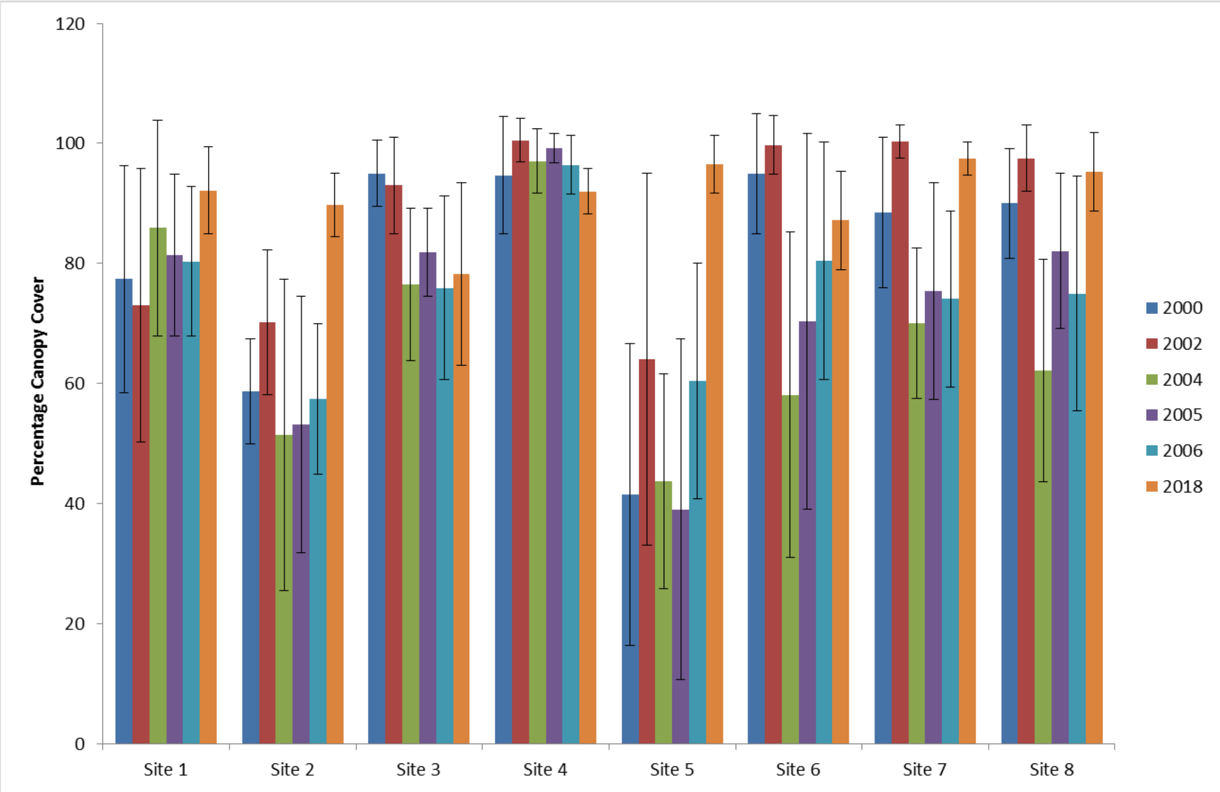


Figure 3.14. Showing percentage canopy cover and their standard deviations for all sites on the Attymass River 2000 to 2018.

Water depth as cover: The percentage of each site where water depths were greater than 0.39m, which is the typical depth threshold for supporting 1+ brown trout and salmon were reduced in all sites (1-8) in 2005 (Figure 3.15). This may be a consequence of low water levels generally at the time of survey but may also be partly a consequence of the maintenance works in 2004 with tree thinning and removal of woody blockages/habitat during maintenance. Woody habitat located in the channel encourages scouring and the development of pools, along with the ponding of water upstream of the structures increasing water depths within the channel. In 2005 the water levels for the complete survey were low with an average depth of 0.17m for all sites compared to 0.23m for 2018.

Sites 7 and 8 were the deeper sites from the survey in 2018 and showed the highest percentage of deeper water over the study period. These sites had a lower gradient and were more glide-like in character compared to the remaining six downstream sites where minimal depths reached above this threshold. In sections of a river with higher gradient, the water passes very quickly with water levels dropping rapidly following any high flood flow event. It would be expected that erosion and scouring would occur in such a gravel bed channel with relatively high gradient and, in such conditions, that deeper pool areas would be created in addition to shallow areas.

This is not the case in the Attymass and there is a general absence of well-delineated pools. This absence is manifest in the limited extent of relatively deep water (>0.4.m) available for trout and salmon (Figure 3.15)

The overall gradient would suggest a riffle-pool sequence of depths in the channel bed and this absence may be due to the original arterial drainage excavation which may have widened the original channel and created a more uniform longitudinal profile. This requires to be checked on the original scheme drawings. Despite the possibility of such an impact at excavation stage it might have been expected that the channel would have "re-structured" itself to a greater degree given the potential for high volume discharge, available gradient and availability of gravels and alluvial material in the bed and banks of the channel.

The three largest fish (23cm – 26cm) caught during the 2018 survey were captured in sites 6, 7 and 8 – the sites with a larger percentage of depths >0.39m recorded in 2018 - potentially due to the presence of deeper glide areas.

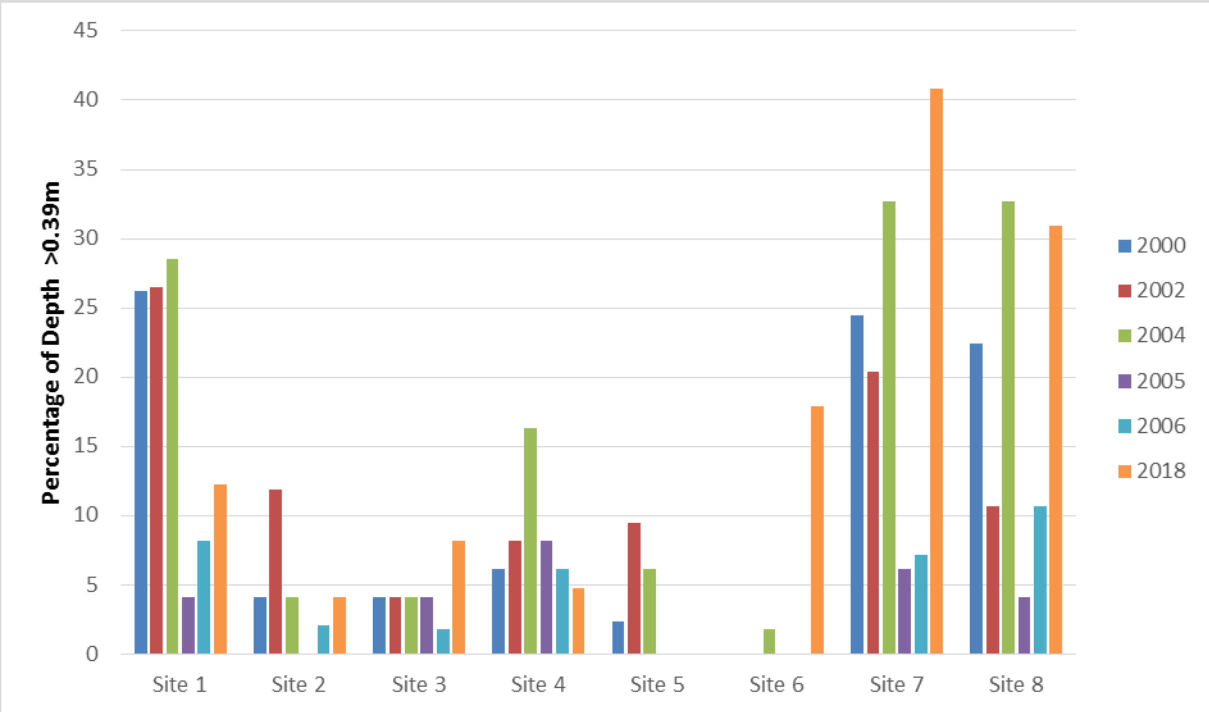


Figure 3.15. Displaying percentage of depth >0.39m for each site on the Attymass River from 2000 – 2018.

The relationship between fish population density and structures and the physical habitat variables in any river is very complex and will vary from site to site and even within-site depending on prevailing conditions. In the Attymass study the water depth and canopy cover have been monitored along with the salmon and trout population data.

For the 2018 data set scatter plots were examined separately for 0+ and for 1+ trout with canopy cover, large woody habitat and with water depth variables. No pattern was evident for any variable vs. 0+ trout density. The pattern for 1+ trout vs. canopy cover had a regression value of >0.5 suggesting some linkage between cover and 1+ fish (Figure 3.16). No such patterns were recorded for water depth vs. 1+ brown trout density when plotted against percentage water depth in excess of 0.4m (Figure 3.17). No patterns were recorded for either fish species of 1+ when plotted against LWDI score for each 100m stretch (Figure 3.18). However sample size was small.

The value of being able to undertake long-term studies, such as the Attymass, lies in the extended data set collected and the potential for it being robust enough to examine and test for any scenarios or trends. The current data set points to a strong degree of ‘stability’ in the brown trout population structure over time, with a greater degree of fluctuation in the salmon population. The data also point to the increasing level of deciduous tree canopy and apparent absence of any shade inhibition on fish production.

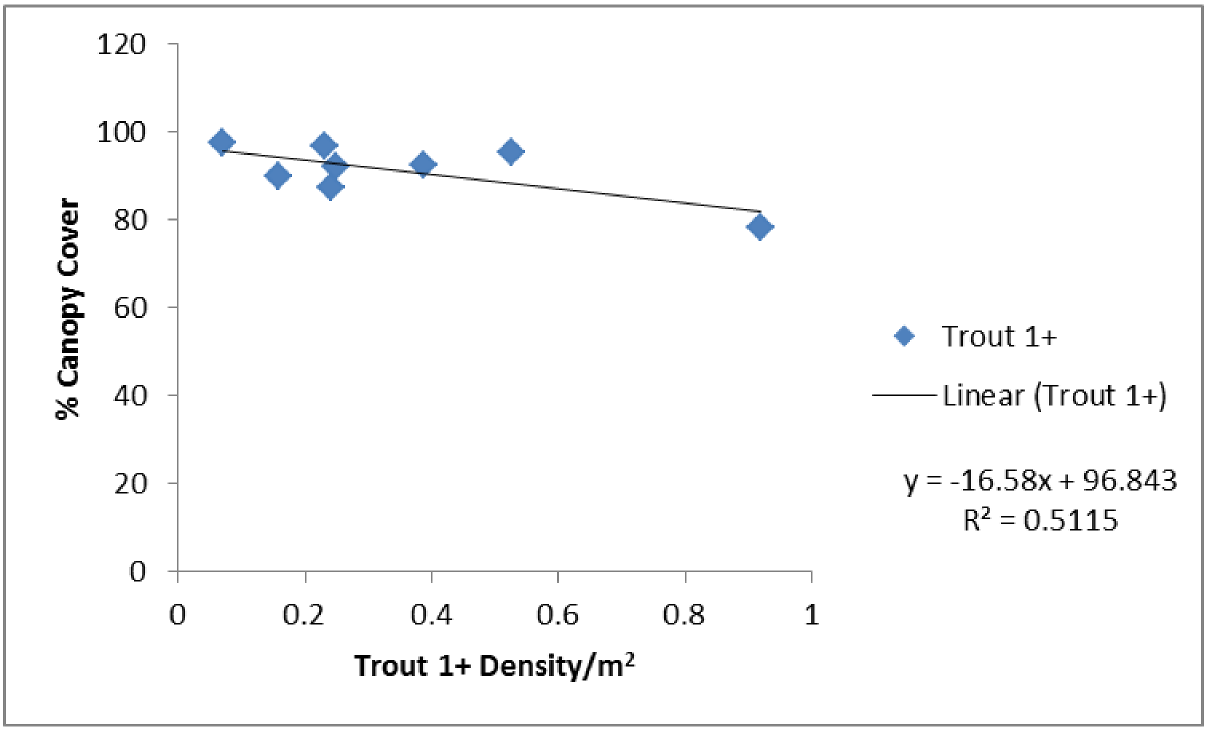


Figure 3.16. 1+ Trout Density/m2 plotted against % Canopy Cover for each of the 8 sites surveyed in 2018

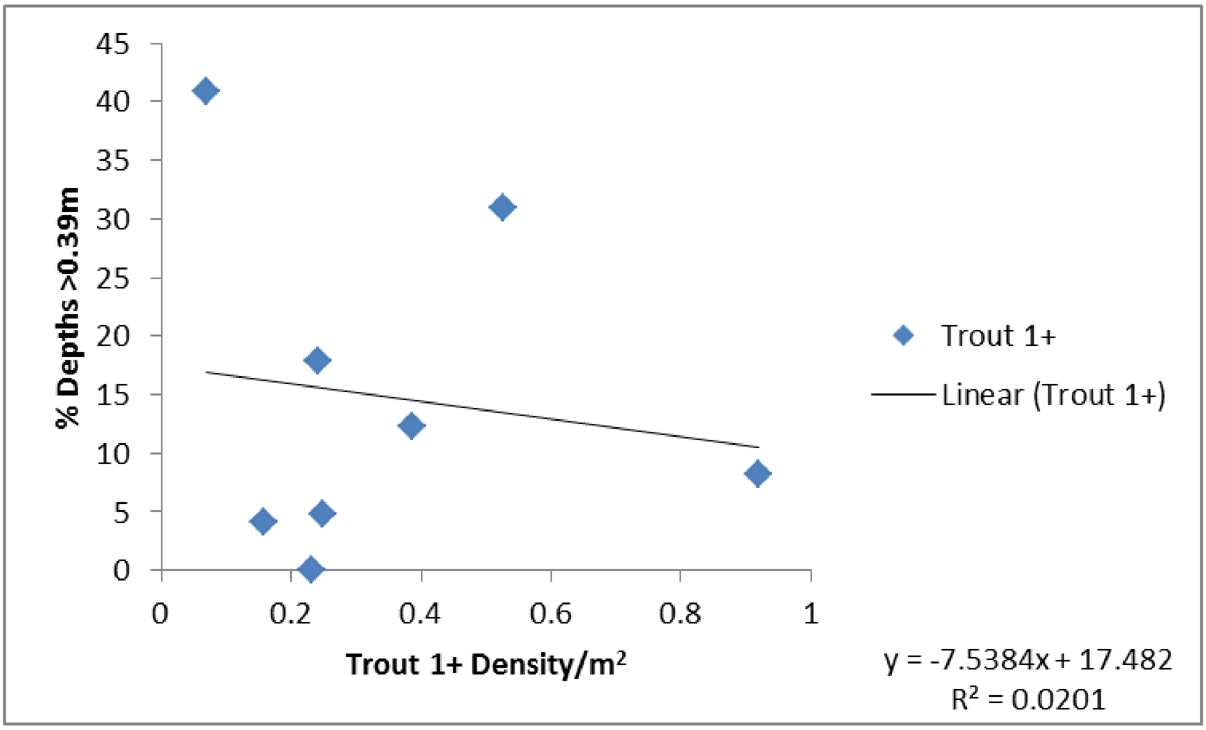


Figure 3.17. 1+ Trout Density/m2 plotted against % of Depths >0.39m for each of the 8 sites surveyed in 2018

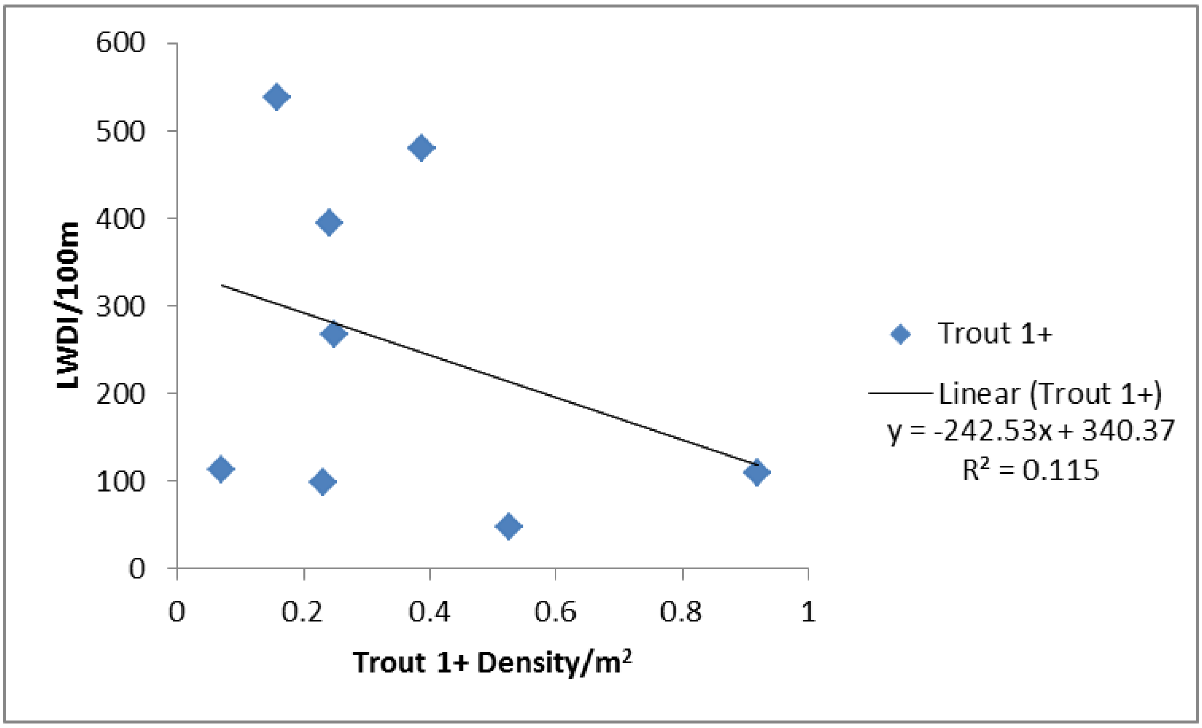


Figure 3.18. 1+ Trout Density/m2 plotted against Large Woody Debris Index Score/100m stretch for each of the 8 sites surveyed in 2018.

Woody Habitat: From Figure 3.19. It is clear that sites 1 and 2, in ascending order, contained larger amounts of functional woody habitat within the riverine system. The woody fragments recorded in these sites were predominantly located in zones 1 (below water surface) and zones 2 (above water surface). Woody material located within these zones in river systems can contribute to improved channel morphology, influence the flow, scouring pools and backwaters (Máčka *et al.,* 2017). These processes create a diversity of habitats within the channel, and in turn support a range of species. Conversely sites 5 and 8 generated the lowest scores as small amounts of woody habitat were recorded at these sites.

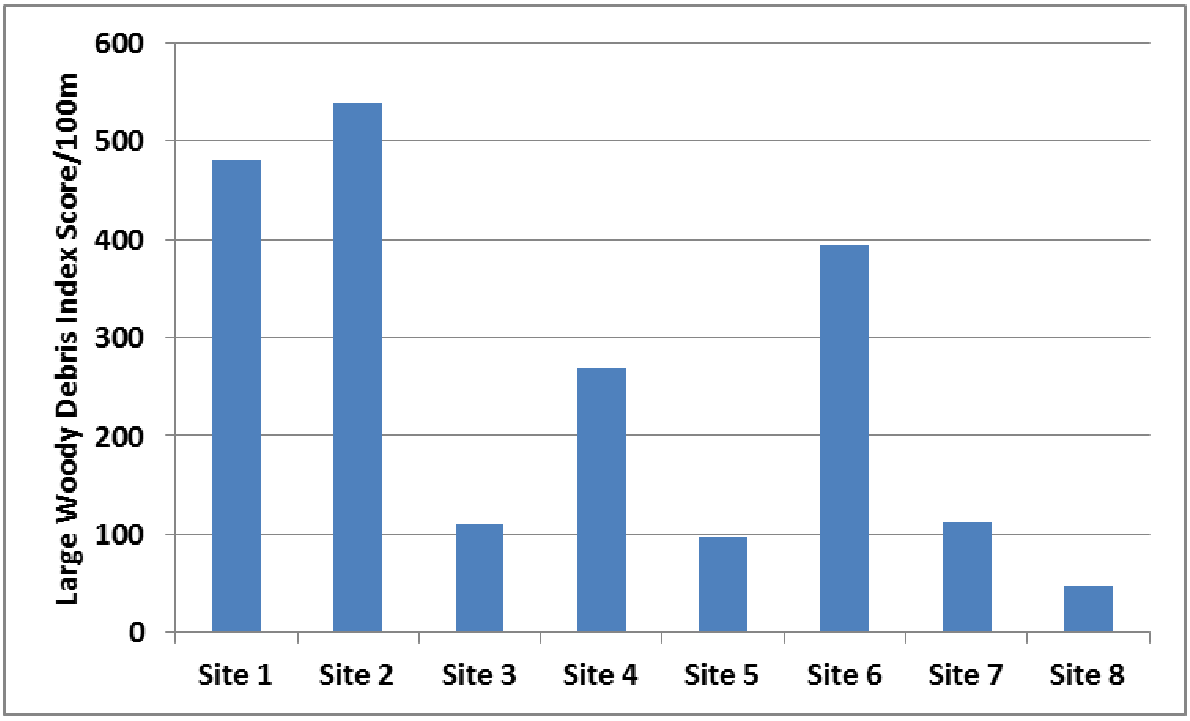


Figure 3.19. LWDI Scores for each site assessed on the Attymass River.

4 Survey of gravel traps

The OPW installed a limited number of gravel/sand traps as part of the engineering design in some of its arterial drainage schemes. The aim of this work package is to examine these traps and their impact on fish passage, as well as a possible role in impeding sediment transport and deposition in downstream areas of the river. Under WFD, these structures may adversely impact on river conditions as they impede natural downstream sediment transport and may also impact on the movement 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.

4.1 Progress in 2018

The OPW provided a geo-referenced list of structures to IFI in 2018; the list included some locations previously unknown to IFI. The Clodiagh structure, immediately downstream of Clonaslee in the Brosna catchment, was previously surveyed for fish passage in 2017. This structure was examined in more detail in 2018 in conjunction with Dr. Jonathan Turner of UCD School of Geography, who undertook a survey of bed levels downstream of the trap to investigate possible trap impacts via reduced gravel transport and associated bed incision. The results of this initial topographic survey showed between 0.2m and 1.4m of channel incision (below the 1947 bed level) had occurred downstream of the trap, and up to 1m of bed aggradation was recorded in the sediment trap itself. The superimposition of a pseudo riffle/pool profile has occurred since engineering stopped, with the deeper pools in this stretch now incising into glacial clay-rich sediments. Subsequent work will require extending the bed level surveys further downstream, together with assessment of channel bed sediment composition through a targeted ‘pebble counting’ study of riffle sequences. It is envisaged that the EREP team will continue this pilot study with UCD during 2019.

Two structures were examined with the OPW in January 2019 in the Nenagh River CDS (Figure 4.1 and Figure 4.2). These, in addition to remaining structures on the OPW listing, will require site visits and detailed surveying for fish passage in 2019.

Figure 4.1. Gravel trap on the main stem of the Nenagh River.

Figure 4.2. Gravel trap on the Ollatrim River, in the Nenagh catchment.

5 Re-meandering Programme

Following completion of a desk study in 2017, a series of old meanders were identified that had been cut off or by-passed during arterial drainage works. These had not been incorporated into the adjacent pattern of field management and cultivation. Such meanders may have potential to be re-connected to the current main channel at certain river stage levels and this is an underlying aim of this study.

A series of these sites were examined, via initial inspection or more detailed investigation, during summer 2018 and in January 2019 as follows (See Figure 5.1):

- 1x site on R. Camoge (Maigue CDS) – levelling survey – photo record
- 1x site on R. Deel main stem (Moy CDS) – levelling survey – photo record
- 3x sites on R. Moy main stem - inspection – levelling survey – photo record
- 3x sites on the Ollatrim River (Nenagh CDS) - initial inspection with OPW

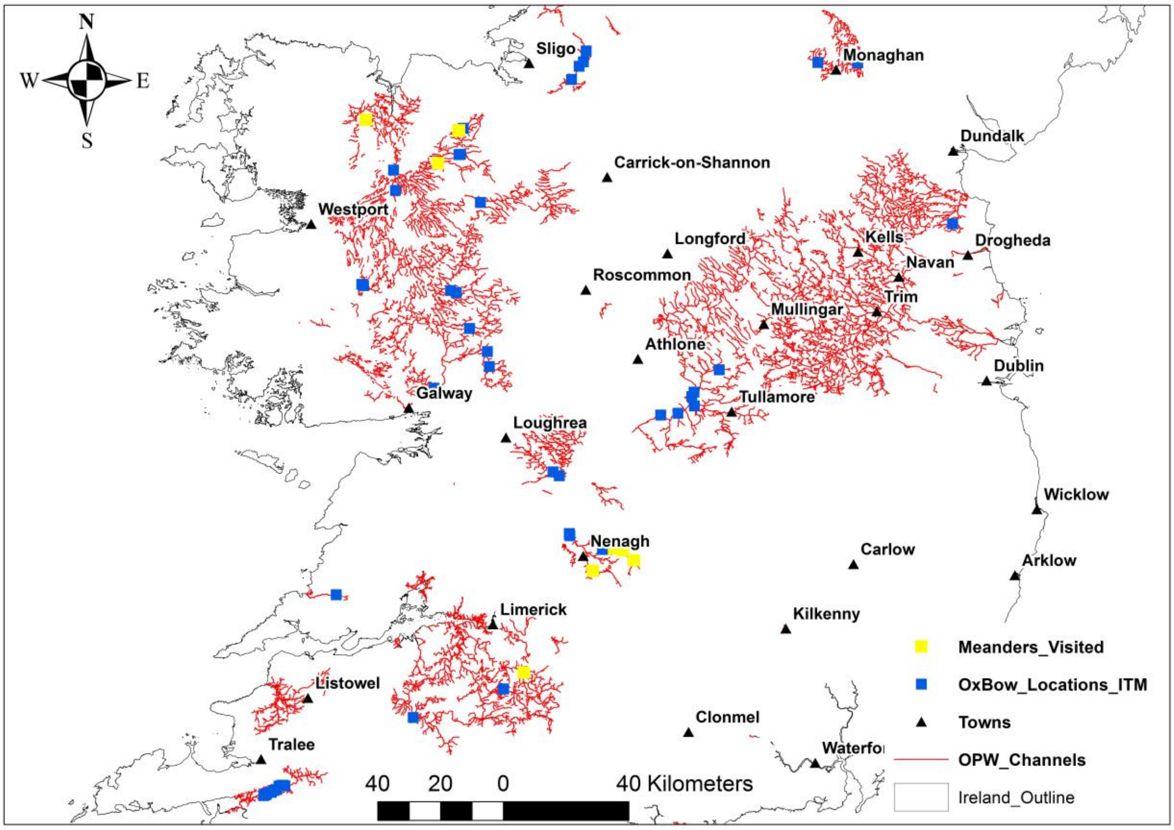


Figure 5.1. Map displaying potential sites in selected OPW schemes during the pilot desk study (Blue Squares) and sites visited in 2018 (Yellow Squares)

The GIS layer created by IFI has been passed to OPW and enquiries are currently underway by OPW at a local level to explore the possibilities of re-connection at to-be determined flow or stage levels of the adjoining parent channel.

5.1 Progress in 2018

Old meander sites identified from the desk study were visited in the catchments of the Maigue (1 site), Moy (4 sites) and Nenagh (3 sites).

5.1.1 Camoge meander (Maigue):

The old meander on the Camoge differed from all of the others insofar as it did not present with an extensive ribbon of tree cover along the meander itself (Figure 5.2), it was possible to undertake a simple levelling survey along the course of the full meander and this included the upstream and downstream levels of the current river bed.

The 'longitudinal section' (Figure 5.3) showed the extent to which the current river bed lies below that of the old meander and the extent of excavation that could be selected, depending on the frequency of re-wetting that was desired. The old meander here showed no evidence of surface water inflow from any source. The channel was clearly delineated from the surrounding land on both banks and the channel was lined with *Phalaris* grass vegetation, with smaller amounts of other soft vegetation. The *Phalaris* is commonly found along the margins and bank slopes of rivers.

Figure 5.2. Photos taken in the meander in Herbetstown within the Maigue Catchment (Bottom Right Corner is the Aerial Imagery from ArcMap).

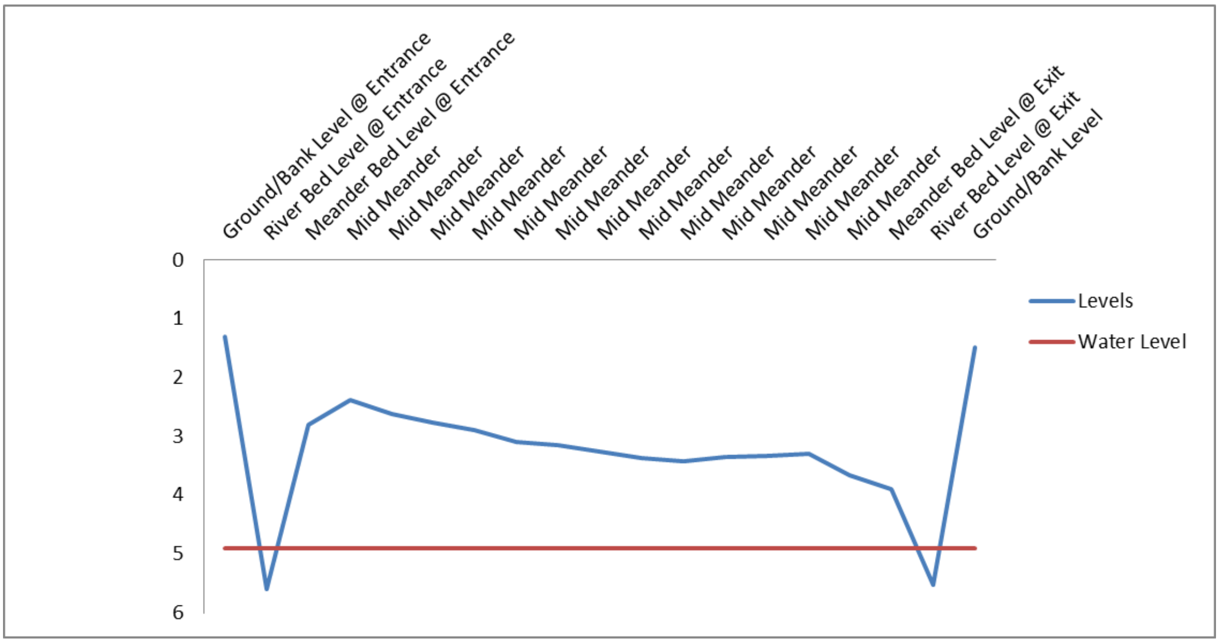


Figure 5.3. Longitudianal profile of the old meander obtained during the site visit in Herbetstown (Camoge C1/25 Maigue CDS)

5.1.2 Deel meander (Moy):

The large meander on the River Deel, in the Moy catchment, (See Figure 5.4) was completely separated at its upstream end from the current river channel with complete masking on current river bank at the location where the meander adjoined. This meander had a substantial cross-sectional area (Figure 5.5) and it showed a range of wetland habitat types with some extensive areas of permanently-wetted open-water habitat, some large wood and wet woodland-type habitat, along with extensive growth of tall emergent vegetation characteristic of habitat adjoining wetted areas (Figure 5.6.)

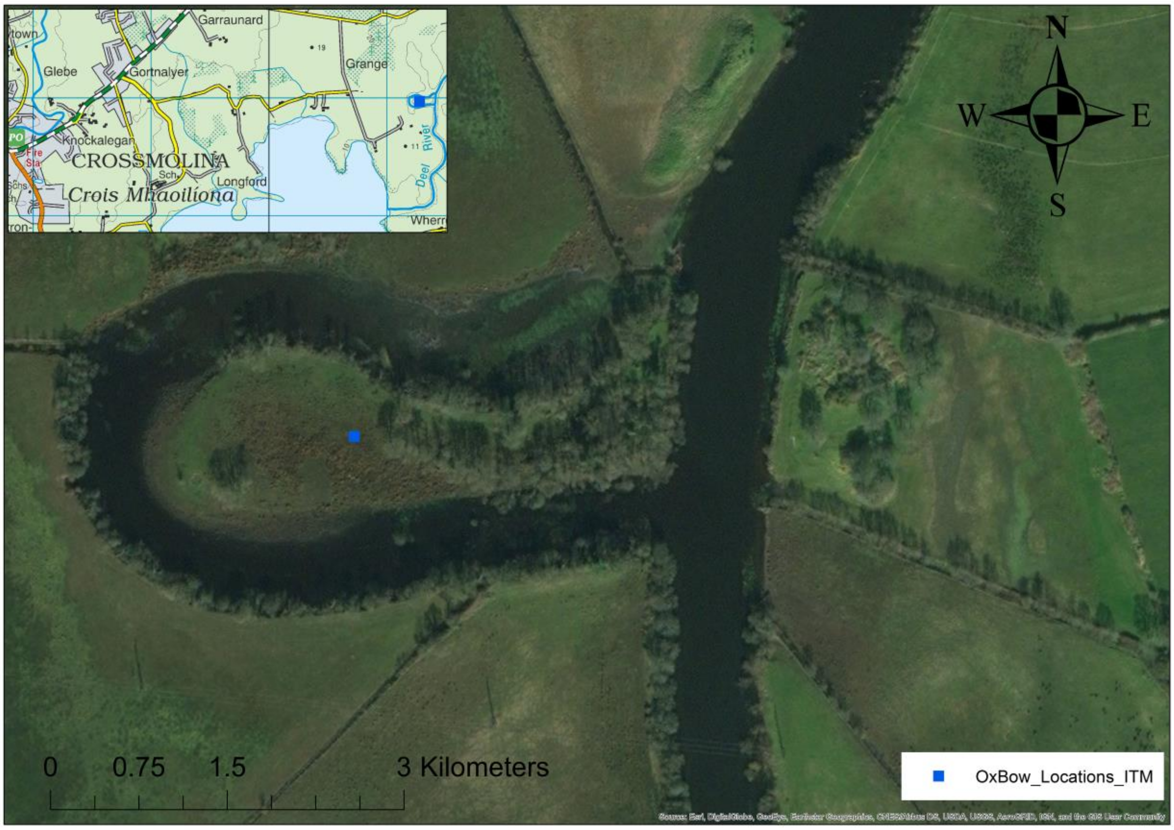


Figure 5.4. Aerial Image of the Deel Meander from the desk study; along with its location in relation to Crossmolina, Co. Mayo.

The downstream end of this meander had an evident outflow channel, of small dimensions, to the main river. This meander loop was clearly in use by the landowner, with evidence of grazing in the central area, dry access near the upstream end and fencing along parts of the bank top area separating the wetted areas and bank slope from the grazed area.

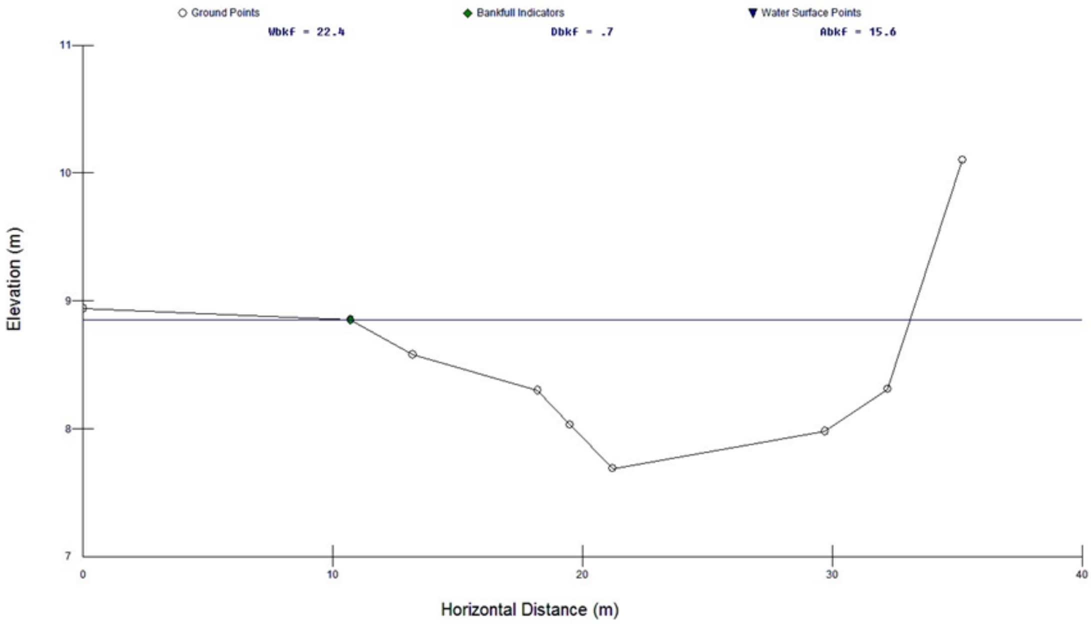


Figure 5.5. Channel dimensions at location of cross-section levelling.

Figure 5.6. Diversity of habitat types present within the Deel meander examined.

5.1.3 Upper Moy (main stem) meanders:

The meanders examined on the upper reaches of the main River Moy were of smaller size, had substantial tree cover along the full meander line and received a small inflow of water from side channels discharging into the old channel. These meanders formed a mosaic of habitat types of varying wetness, from wet woodland patches to swampy ground with tall emergent vegetation to dryer areas with species of *Equisetum* and of trees (Figure 5.7).

Figure 5.7. Diversity of habitat present within old meanders on R. Moy main stem.

5.1.4 Nenagh – Ollatrim meanders:

The meanders viewed in the Nenagh system were overgrown along the bank full line with mature tree cover and they variously contained areas of standing water and more terrestrial niches.

The majority of all sites viewed had their downstream end at an OD level closer to the existing river compared to their upstream end. The difference in bed levels varied from one location to another (Figure 5.8). Each location was unique in regard to its ecological character and feasibility for re-wetting.

Any programme to develop re-connectivity would require, in all of the areas examined and in all sites from the desk study (Figure 5.1)

- Landowners goodwill and agreement
- Establishing in each case an agreed level of wetting and the frequency of wetting (confer with IFI and with NPWS)
- Establishing a permanent and manageable ‘facility’ to permit flowing water to enter the meander - with options such as an open channel flow scenario in completely ‘wilderness’ sites or box culvert opening in sites to permit landowner access to the dry ground inside the meander island
- An ecological survey prior to re-connection to compile an inventory of habitat niches and of species

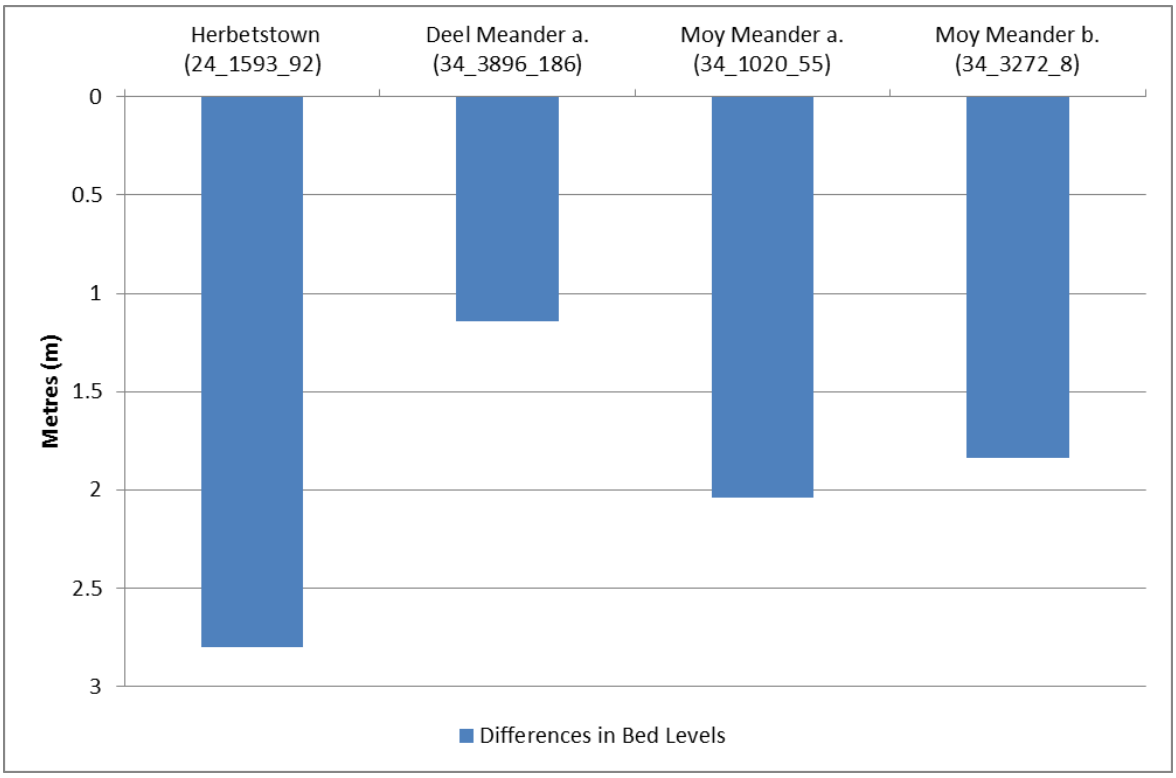


Figure 5.8. Stage or vertical height (m) differences between existing river bed level adjacent to meanders and bed level in meander. 0 on x axis is the current bed levels of each meander.

6 Synergies with other IFI studies

Many of IFI's fish studies within specific projects and programmes 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 2018 the IFI Habitats team undertook catchment-wide surveys on larval lamprey status in the Moy and Nore catchments. The former is an OPW catchment drainage scheme with on-going maintenance in channels annually. Thus the data generated in the Moy lamprey study is of relevance and value to the OPW and, in line with agreements with the OPW's Environment Section, this data will be made available digitally to the OPW for adding to its GIS layer of environmental items.

In addition to 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 2018, the index sites on the Feale main stem were examined as were those on the Clodiagh (C8/1 Brosna) and the Moy main stem (C1).

There are 3 programmes conducted by IFI which have a close synergy and linkages to the overall EREP umbrella, and they are as follows:

- National Barriers Programme (2018 – 2021) funded by the Dept. of Housing. IFI is tasked with a series of actions by 2021 including development of protocols for barrier assessment, data collection on barriers in catchments, development of mitigation proposals and prioritisation processes for addressing barrier issues in the third cycle of the WFD. The barrier surveying will be undertaken on a wide scale, as IFI resources permit. Information gleaned in EREP surveying in OPW catchments will be available to the OPW. Likewise, the information compiled in specific barrier surveys in particular OPW drainage schemes within the EREP study (using the same survey protocol) will merge into the National Barriers database of structures.

- IFI's Habitats Directive Fish programme, whereby IFI undertakes surveillance and monitoring in respect of Annex II fish species of the Directive, is assessing 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 (COs) for species in catchments and the degree to which the COs are being achieved. The outcomes are relevant to the 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. Fish passability was assessed using SNIFFER at locations in the Deel (Moy CDS) and in the Boyle River (Boyle CDS) during 2018.

- The INTERREG Catchment CARE project (2017-2022) is tasked with examining and bringing forward measures to improve the ecological quality of waters in three cross-border catchments. These include the Blackwater (Monaghan / Ulster). IFI is a partner in the project and has a hydromorphologist working in the Blackwater in Northern Ireland (NI) and Republic of Ireland (ROI). Selected channels were assessed and strategies developed in order to improve their hydromorphology, along with their ecological status under WFD. Both the OPW (ROI) and Dept. for Infrastructure (DFI) (formerly Rivers Agency (NI)) are vital components in this project within the Blackwater, given that the catchment is arterially drained. IFI personnel in the Catchment CARE project are working with the EREP team and with the OPW in regard to examining channels and appropriate measures within the Monaghan Blackwater CDS – the aspirations of the Catchment CARE project mirroring those of EREP.

7 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 combined 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. This contributed to the signing of an agreement by OPW and IFI in 2018, undertaking to continue with applied scientific studies and experimental investigations in OPW-managed catchments in a context guided by key EU Directives – the Water Framework Directive, the Habitats Directive and the Floods Directive.

The 5-year commitment by OPW and IFI allows for planning in regard to agreed studies and investigations in a scenario where resources of time and manpower can lead to positive outcomes. The WFD and its emphasis on (a) ecological quality and on (b) hydromorphology underpin 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

In the context of the agreed 5-year programme the EREP project team in IFI has developed an outline plan of work to cover the period of 2019 – 2022. The structure includes continued knowledge accumulation and sharing on fish and habitat in a WFD-focussed framework – with a catchment-wide survey planned for the Deel in 2019.

In 2017, IFI was tasked by the Dept. of Housing, Planning and Local Government with producing a series of deliverables in regard to barriers within rivers impeding 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 relative to the immediate downstream river bed, causing 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 date 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 long-term studies, revisiting channels where specific investigations were undertaken, returned to the River Tullamore Silver in 2016. This process has been continued in the interim and it is planned that several of the sites where intensive Capital Works were undertaken in EREP in the 2008 – 2010 period will be incorporated up to 2022, with a review of the Enfield Blackwater study planned for 2019.

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 (Table 3).

Table 3. Five year plan for the Environmental River Enhancement Programme

ACTION	2018	2019	2020	2021	2022
FPI Study (Fish,Habitat,Barriers)	Upper Inny	Deel	Kells Blackwater (Boyne)	Lung (Boyle CDS)	Brosna I: (Source - Clara)
Long term report studies I: Capital Works		Enfield Blackwater (Boyne) (2009 - 2010)	Robe at Sheepwash Bridge (Corrib - Mask) (2008 - 2010)	Dee at Hem Bridge (Glyde - Dee) (2008 - 2010)	Morningstar (Maigue) (2009 - 2010)
Long term report studies II: Maintenance impacts	Attymass (Moy)	Cloonlavis (Moy)	Deel (1998 - 2000)	Lung (2001 - 2007)	Moynalty (1996 - 2001)
	Camoge (Maigue)	Eignagh (Moy)			
Feasibility studies for river enhancement		Boyne tributaries (x4)			
Specific Investigations					
Climate change / thermal studies in drained chennels	Brosna tribs	Tullamore River / Tulamore Silver	To Be Selected		
	(Tree cover)	Sparganium Tall Emergent Vegetation Year 1	Sparganium Tall Emergent Vegetation Year 2	Water Celery/Cress vegetation Year 1	Water Celery/Cress vegetation Year 2
Tree mgmt./ trees and riparian cover	Attymass; Atherlow (Control)	Deel desk study; Eignagh	Kells BW desk study	Lung desk study	Brosna I (Source - Clara) : desk study
Impact of channel modifications (long X; cross X) and relevence of Topic 10 in 10-step guidence	Camoge (Maigue)	Cloonlavis; Cloonshire; Tullamore Silver; Enfield Blackwater	Clodaigh; Eignagh		Moynalty (1996 - 2001)
Crayfish studies	FPI Inny	FPI; Tullamore River repeat survey	FPI; Robe repeat survey	FPI	FPI
Lamprey studies	FPI Inny	FPI	FPI	FPI	FPI
Synergies with other studies					
Habitats Directive (Lamprey) -	Upper Inny	Deel	Kells Blackwater (Boyne)	Lung (Boyle CDS)	Brosna I: (Source - Clara)
IFI National Barrier Programme -	Upper Inny	Deel	Kells Blackwater (Boyne)	Lung (Boyle CDS)	
INTERREG Catchment CARE -		Monaghan - Blackwater	Monaghan - Blackwater	Monaghan - Blackwater	Monaghan - Blackwater

8 References

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