Owenriff Fish Population Rehabilitation Plan

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Inland Fisheries Ireland

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National Research Survey Programme

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Inland Fisheries Ireland, 3044 Lake Drive, Citywest Business Campus, Dublin 24.

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Cover photo: Letterfore River and Corrib adult trout

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Executive Summary

Many factors can limit fish production in streams, rivers and lakes, and identification of those present in a waterbody is required to determine the solutions to apply if remedial action is required. A recent catchment wide survey of the fish stocks at selected sites across the Owenriff catchment and surveys of two lakes (Loughs Bofin and Agraffard) identified that there has been a decline in the fish stocks in the Owenriff in recent years (IFI, 2018). As there are little or no major anthropogenic pressures in the catchment the report concluded that it is reasonabe to infer that the introduction of pike is the main factor causing the decline of brown trout and salmon in the Owenriff catchment (IFI, 2018). Pike were officially captured in the catchment for the first time in 2009, subsequent removal operations revealed that both juveniles and adults were present inferring that a breeding population had become established within the system sometime prior to that date.

There are two options available to IFI in relation to the Owenriff fish populations, i.e. inaction or implement a rehabilitation plan. If actions to control or eradicate pike in the Owenriff are not undertaken it is reasonable to infer that there will be an ongoing decline in ecological biodiversity in the catchment. Implementation of a rehabilitation plan for the fish stocks in the Owenriff catchment would be costly and would include numerous remedial measures and involve various stakeholders, but should be designed specifically for this catchment. The case for implementing a fisheries rehabilitation plan to protect the biodiversity and prevent further decline of fish stocks in the Owenriff catchment is endorsed by EU and national legislation and international guidelines, i.e. EU Water Framework Directive, EU Habitats Directive, Water Policy Regulations (S.I. 722 of 2003) and the Food and Agriculture Organization of the United Nations.

The purpose of the Owenriff rehabilitation plan is to develop a project that can be undertaken to promote the recovery of the brown trout (both resident and migratory Corrib) and salmon populations in both lakes and rivers and to prevent further decline.

It is important to select the appropriate actions and tools needed for the fisheries rehabilitation project in the Owenriff catchment. The tools selected to address declines in the fish stocks for the Owenriff catchment are; fisheries enhancement works in selected sub-catchments to favour brown trout and salmon, genetic restoration, removing the problem (pike control), reducing anthropogenic impacts in the catchment, public awareness, inter-agency coordination, climate change mitigation and other measures.

Monitoring and evaluation of rehabilitation works is essential for determining the effectiveness of measures aimed at improving habitat and increasing fish numbers and conditions (FAO, 2008). Monitoring a river or lake post-restoration allows the success of a programme to be assessed. It will also help identify which restoration methods work best for ongoing and future initiatives. The monitoring programme developed for the Owenriff is specific for this catchment and recommends; baseline, status and trend monitoring, habitat mapping, annual census of numbers of migratory brown trout and salmon, acoustic telemetry, pike diet and ecological studies and other programmes.

Risks in achieving timelines for the plan include; delays in receiving approval for the Natura Impact Statement, delays in securing permission from landowners and delays in HPRA approval for acoustic telemetry project.

1. Introduction

1.1 Lough Corrib and the Owenriff catchment

The Lough Corrib catchment is the largest and most important wild salmonid catchment in Ireland and Lough Corrib is considered the premier wild brown trout fishery in Ireland (Gargan *et al*., 2002). However over the past century anthropogenic pressures, such as urban growth, deleterious discharges, farming activities and introduction of alien species, have contributed to the alteration of the lake and river environments in the Lough Corrib catchment and the loss and/or fragmentation of suitable spawning and nursery areas for brown trout (IFI, 2013). These anthropogenic-mediated factors have changed both the abundance and ecology of local populations and have led to reduced brown trout productivity (IFI, 2013). As a consequence, the status and long-term sustainability of trout populations spawning in the rivers comprising Lough Corrib's catchment has been of concern for a number of years (IFI, 2013). In response to these pressures a significant economic investment was inputted into fisheries habitat enhancement programme in the Lough Corrib catchment in the late 1990s as part of the Tourist Angling Measure Programme (TAM) of the Operational Programme for tourism (part funded by the European Regional Development Fund) (Gargan *et al*., 2002). Pre- and post-fisheries enhancement monitoring programmes were also undertaken in some sub-catchments of the Corrib (Gargan *et al.*, 2002). Additionally Inland Fisheries Ireland (IFI) also commissioned a PhD and a collaborative research project in 2006 and 2012 respectively to examine the genetic diversity and structuring of brown trout from nine major rivers in the Corrib catchment (Massa-Gallucci *et al*., 2010; IFI, 2013).

The Owenriff catchment is located on the north-western end of the Lough Corrib catchment and the main Owenriff River drains into Lough Corrib Upper downstream of Oughterard, Co. Galway. It is regarded primarily as a good salmon river (Browne and Gallagher, 1980, 1981 and 1982) and gets a run of salmon which ascend the river from the end of May; with each successive flood more fish run the river (O' Reilly, 2002). The resident brown trout in the catchment are small (up to 0.34kg) in some of the lakes (O' Reilly, 1987). It gets a run of upstream migrating Lough Corrib brown trout in late summer (O' Reilly, 2002).

There was no investment in the Owenriff catchment as part of the aforementioned TAM programme and therefore no major fisheries enhancement works were carried out. Nevertheless a small amount of work was undertaken by IFI and angling groups; e.g. low level weirs were constructed in

the environs of Oughterard, fisheries enhancement work was carried out on a diverted stretch of river in the Letterfore and recently limited tree pruning was carried out in the Bunowen and Knockmoyle sub-catchments. Additionally, the Owenriff was one of the catchments included in the aforementioned genetic diversity projects (Massa Gallucci *et al*., 2010; IFI, 2013).

1.2 Is there a problem with wild brown trout and salmon population in the Owenriff catchment?

Many factors can limit fish production in streams, rivers and lakes, and identification of those present in a waterbody is required to determine the solutions to apply if remedial action is required. A recent catchment wide survey of the fish stocks at selected sites across the Owenriff catchment and surveys of two lakes (Loughs Bofin and Agraffard) identified that there has been a decline in the fish stocks in the Owenriff in recent years (IFI, 2018a). In general, minimum density estimates for brown trout and salmon were relatively poor at many of the river sites surveyed during 2017, and the proportion of 1+ and older brown trout were lower in 2017 than in 1997. Data analysis shows that the density of the majority of comparable life stages for both trout and salmon were lower in 2017 than those recorded for 1997. The only exception was at one site in the Derrylaura sub-catchment where the density of 1+ & older brown trout density was higher in 2017. Total brown trout density was significantly lower in 2017 than 1997 at five matched sites. In general, salmon were more prevalent across the catchment in 1997 than 2017. Brown trout abundances were poor in both lakes surveyed and significantly lower in comparison to other similar lakes within the Owenriff (Lettercraffroe) and in neighbouring catchments (Loughs Doo, Glencullin, Kylemore and Lettercraffroe) where pike are not present (IFI, 2018a).

One site on the main channel (Site 15) is a designated surveillance monitoring site for fish and its ecological fish status has deteriorated from Good in 2010 and 2015 to Moderate in 2017. Additionally, four river sites were assigned Good fish status; however the remaining 13 sites were assigned moderate or lower fish status (nine Moderate fish status, two sites Poor status and two sites Bad fish status). The two lakes surveyed (Lough Bofin and Agraffard) were assigned a fish ecological status of Poor and Bad respectively. In contrast, Lettercraffroe Lough (a lake within the catchment with no pike present) was assigned a status of Good in 2016. These failures were mainly due to the absence, lower than expected abundance or missing age classes of type specific indicator species (i.e. brown trout and salmon) (IFI, 2018a).

As there are little or no major anthropogenic pressures in the catchment to cause the decline in fish stocks it is reasonable to infer that the introduction of pike (their subsequent range expansion, impacts of competition for food and space and predation on resident and migratory fish) is the main factor causing the decline of brown trout and salmon in the Owenriff catchment. Research from Europe and North America supports this finding (IFI, 2018a).

1.2.1 Introduction of pike to the Owenriff catchment

Prior to 2009 there were no official records of pike (*Esox lucius*) being present in the Owenriff catchment upstream of the natural waterfall at Canrawer, Oughterard. There were anecdotal records suggesting that there were pike present in some lakes in the catchment in the 1990s but this was never confirmed by IFI staff and no pike were recorded in the electrofishing surveys of 1997 and 2007 (IFI unpublished data; WRBD, 2008). Gradients in excess of 6.6% (Spens *et al*., 2007) and 7% (Hein *et al*., 2011) have been shown to act as barriers to the natural dispersal of pike. The natural waterfall at Canrawer, Oughterard on the main channel of the Owenriff exceeds the published gradient threshold preventing natural colonisation of pike from the established population in Lough Corrib, as do the natural falls on the Clooshgereen and the Glashanasmearny both of which now have pike present in the lakes above these natural barriers (IFI, 2018a).

In 2009, pike were captured for the first time by Inland Fisheries Ireland (IFI) staff in two lakes in the catchment (Loughs Bofin and Agraffard) following reports from anglers of pike in the system. Efforts were made at that time by IFI staff to remove the pike from the system; however as the pike taken included juveniles as well as adults, it seemed likely that a breeding population had become established within the system sometime previous to then (IFI, 2018a).

1.2.2 Impacts of pike introductions- ecological

Pike are an apex (opportunistic, but predominantly piscivorous) predator (Craig, 2008) and can shape fish communities in waters where they occur (DeBates *et al*., 2003). The ability of pike to reduce or even extirpate resident fish species has been described across Europe (e.g. Hesthagen *et al*., 2015) and North America (Nicholson *et al*., 2015, Sepulveda *et al*., 2013, Patankar *et al.,* 2006) where pike have expanded outside of their native range. Such changes in fish community structure are a common feature in areas where pike are recent colonisers (Craig, 1996). Some research seems to indicate that salmonids cannot co-exist with pike (Spens and Ball, 2008) although lake morphology may facilitate coexistence in some (large/deep/cold) lakes (Hein *et al*., 2014). In Ireland, historical

reports of negative impacts on trout populations have been described in a number of previously isolated lakes and rivers (Went, 1957). In Lough Ross (Corrib catchment), for example, connectivity to a population of resident pike in Lough Corrib was created following the construction of a canal in the mid-1800s and resulted in a reported decline in brown trout stocks at that time (Went, 1957). This lake now supports a coarse fishery and stocks are dominated by cyprinids (Kelly *et al*., 2017).

1.2.3 Impacts of pike - Economic

Both brown trout and pike support substantial recreational angling fisheries in Ireland, where the estimated annual economic contribution has been valued at €148m and €105m respectively in 2014/2015 (IFI, 2015a & b). Pike are present in many large Irish lakes which contain trout, and pike management operations have been carried out in many of these fisheries for many decades (Fitzmaurice, 1983). In 2017, the costs associated with pike management operations in six lakes in the Western River Basin District were estimated to be in excess of €116,000 (Inland Fisheries Ireland, 2017). Currently, pike are not present in several prestigious brown trout and salmon fisheries and numerous small lakes in the northwest, west and southwest. The economic ramifications, if this were to happen, could be large. However, it is not currently possible to predict with certainty the associated economic ramifications in the event of any future pike introductions to these waters, and the estimation of direct removal costs is often uncertain (Jardine and Sanchirico, 2018). However, the preservation of fish stocks in these fisheries has an intrinsic economic value (Campbell and Hutchinson, 2007).

1.3 Options for rehabilitation of the fish community in the Owenriff catchment

There are two options available to IFI in relation to the Owenriff fish populations, i.e. inaction or implement a rehabilitation plan.

1.3.1 Consequences of Inaction

If actions to control or eradicate pike in the Owenriff are not undertaken it is reasonable to infer that there will be an ongoing decline in ecological biodiversity in the catchment. Brown trout, salmon and other species will continue to be impacted in the Owenriff. Salmonids are the intermediary host for freshwater pearl mussel (*Margaratifera margaratifera*) populations and therefore inaction could affect the recovery of this rare and endangered species

1.3.2 Implement a rehabilitation plan for the fish stocks in the catchment

Implementation of a rehabilitation plan for the fish stocks in the Owenriff catchment would be costly and should include numerous remedial measures and involve various stakeholders. The plan should be designed specifically for this catchment and involve such measures as a fisheries enhancement programme in degraded sections of the catchment, control of pike, genetic restoration, reduction of anthropogenic impacts, climate change mitigation, public awareness, etc. It should also involve a programme of effectiveness monitoring to review the success or otherwise of the plan.

1.4 Owenriff rehabilitation plan

1.4.1 What is rehabilitation?

The FAO (2008) define rehabilitation as the "restoration of functionality to a modified water course or waterbody where the pressures producing the modification have eased or ceased or where new technology can be introduced to reduce stresses" and Shields *et al*. (2003) define it as "the return of a degraded stream ecosystem to a close approximation of its remaining natural potential". These definitions do not imply that waterbodies (e.g. Owenriff) can or should be restored to a pre-industrial revolution state or a state pre-pike introduction. This can be impossible as rivers can naturally change over time and because of societal benefits (Dufour and Piegay, 2009). The measures employed can involve the alteration of physical processes of a modified river so that they are returned to a natural or semi-natural state (e.g. reintroduce diversity of depth, flow, substrate and riparian structure, reintroduce habitat complexity and longitudinal and lateral connectivity where necessary (FAO, 2008). Additionally, Addy *et al*. (2016) recommend that restoring water

quality and removing invasive species are equally important for the recovery of river habitat and biodiversity.

1.4.2 Case for implementing a fisheries rehabilitation plan in the Owenriff catchment (supporting legislation)

The case for implementing a fisheries rehabilitation plan to protect the biodiversity and prevent further decline in the Owenriff catchment is endorsed by EU and national legislation and international guidelines. The EU Water Framework Directive (2000/60/EEC) aims to enhance the natural character of waterbodies and sets out four core objectives (prevent deterioration, restore to good status, reduce chemical pollution and achieve protected areas objectives). Public bodies identified in the 2003 Water Policy Regulations (S.I. 722 of 2003) are required to exercise their functions in a manner which is consistent with and contributes to achieving the objectives of each River Basin Management Plan. River rehabilitation and restoration is also a measure promoted by the EU Habitats Directive (92/43/EEC). The Directive specifies a range of key river habitat types and species to conserve at a "favourable status" throughout their natural range. It forms the cornerstone of Europe's nature conservation policy along with the Birds Directive (2009/147/EC) and established the EU wide Natura 2000 network of protected areas to safeguard against potentially damaging developments. The wide network of National Heritage Areas (NHAs) (75 raised bogs, 73 blanket bogs and 630 proposed areas) also reinforces the need for efforts to safeguard biodiversity. The EC Floods Directive (2007/60/EC) also supports the restoration and maintenance of natural features to reduce flood risk (Addy *et al*., 2016).

Additionally, Food and Agriculture Organization of the United Nations (FAO) members (Ireland has been a member since 1946) have a responsibility to maintain aquatic ecosystems in a state consistent with the sustainability of fish stocks and the fisheries they support. Article 6.1 of the General Principles of the Code of Conduct for Responsible Fisheries requires that "states and users of living aquatic resources should conserve aquatic ecosystems. The right to fish carries with it the obligation to do so in a responsible manner so as to ensure effective conservation and management of the living aquatic resources" (FAO, 2008).

The Owenriff River is located within the Lough Corrib Special Area of Conservation (NPWS, 2015a). The SAC is selected for numerous habitats and species, in particular freshwater pearl mussel (*Margaratifera margaratifera*) and Atlantic salmon that are listed in Annex II of the Directive. In addition part of the catchment is situated within the Connemara Bog Complex SAC which has also

been selected for numerous habitats and species including Atlantic salmon (NPWS, 2015b). The status of Atlantic salmon has been classified as vulnerable in Ireland (King *et al*., 2011).

1.4.3 Purpose of the rehabilitation plan

The purpose of this plan is to develop a fisheries rehabilitation project that can be undertaken on the Owenriff catchment to promote the recovery of the brown trout (both resident and migratory Corrib) and salmon populations in both lakes and rivers. This report plan does not provide detailed drawings for identified projects as these will be developed as individual projects under the "plan umbrella" when funding is secured. It will also be used to guide the long-term development of the Owenriff catchment. The plan provides a description of the various rehabilitation tools recommended (including preliminary fisheries enhancement plans for the catchment based on fish stock surveys in summer 2017 and field investigations (walk over habitat assessment surveys) in December 2017) and a monitoring and assessment programme.

Monitoring and evaluation of rehabilitation works is essential for determining the effectiveness of measures aimed at improving habitat and increasing fish numbers and conditions (FAO, 2008). Unfortunately, few projects are monitored or evaluated properly and little adequate information exists on the effectiveness of most rehabilitation techniques. A properly designed and implemented monitoring and evaluation programme is a necessary and critical component of any rehabilitation project and should be incorporated into initial project design (FAO, 2008). A detailed effectiveness monitoring programme is presented in section 3.

1.4 Main objectives of the rehabilitation plan:

The principal objectives of the plan are to:

- Protect biodiversity
- Rebuild the brown trout and salmon population
- Prevent further decline of fish stocks in the Owenriff catchment.
- Improve habitat for all life stages of brown trout and salmon
- Improve survival rates of brown trout and salmon by reducing/mitigating against the impact of the introduced pike (see separate stock management plan for the Owenriff (IFI, 2018b))
- Improve the opportunity for adult fish to reach their spawning habitats (by understanding predator prey interactions at various bottlenecks in the catchment).

2. Applying the correct tools to rehabilitate the brown trout and salmon populations in the Owenriff catchment

It is important to select the appropriate actions and tools needed for the fisheries rehabilitation project in the Owenriff catchment. As there are little or no major anthropogenic pressures in the catchment, a recent report on the fish stocks in the catchment concluded that it is reasonable to infer that the introduction of pike is the main factor causing the decline of brown trout and salmon in the Owenriff catchment (IFI, 2018). Therefore, the tools described below have been chosen to address this by improving habitat in degraded sections of river, improve survival rates of brown trout and salmon, reduce pike abundance and increase public awareness of the impacts of the introductions of species not indigenous to an area.

The following tools have been selected to address declines in the fish stocks for the Owenriff catchment:

- Fisheries enhancement works in selected sub-catchments to favour brown trout and salmon.
- Genetic restoration
- Removing the problem (pike control) -
- Reducing anthropogenic impacts in the catchment
- Public awareness
- Interagency coordination
- Climate change mitigation
- Other measures

2.1 Preliminary Fisheries Enhancement Plan

2.1.1 Introduction

Many river systems throughout Ireland, and indeed globally, have been subjected to anthropogenic pressures to varying degrees since the industrial revolution and earlier which in many cases has led to deleterious impacts on habitat to the detriment of the local fish community, in particular salmonids (Hendry *et al*., 2003). Poor land management practices in Ireland in particular those relating to agriculture and land drainage schemes have resulted in a decline in riverine habitat in many areas. The main tool employed by fishery biologists globally in relation to habitat degradation is known by such terms as habitat enhancement/rehabilitation or restoration. Ultimately works involve instream development or riparian management on the affected channel sections.

The Owenriff catchment is no exception. Issues that have occurred across the Owenriff catchment over the past century include:

- Channelization (parts of the Owenriff were drained during the Lough Corrib drainage programme in the 1950's by the Office of Public Works (OPW))
- Forestry (including spraying of fertiliser, clear felling and associated nutrient release)
- Habitat degradation
- Tunnelling
- Damage to riparian zones
- Land management practices (including over-grazing and local land drainage)
- Introduction of pike (and roach to one lake)

Many of the problems listed above are localised and occur in discrete areas of the catchment and individually are not considered a serious threat to the whole Owenriff system. Nevertheless, a preliminary fisheries enhancement plan has been drafted to help alleviate some of the issues and help restore the ecological aspects of the Owenriff riverine system including salmonids, freshwater pearl mussel and riparian zones. Riverine fish populations are strongly influenced by physical habitat parameters which can be used to predict their distribution and abundance (Maddock, 1999; Roper *et al*., 2002; Whitacre *et al*., 2007; Harding *et al*., 2009). Therefore, if channel hydromorphology and habitat conditions are improved fish should recolonize providing water quality and other pressures are not an issue.

Selecting the appropriate restoration techniques requires clear restoration goals with specific objectives, an understanding of the disrupted processes and desired habitat conditions, and an understanding of which restoration techniques can achieve these objectives (Roni and Beechie, 2013). If you can identify what the problems are, the reasons for them and locations of the problem, it should be possible to compile a restoration plan that will help address most of the issues and allow a river to function naturally again.

2.1.2 Habitat assessment methods

A preliminary habitat assessment survey was carried out along sections of 12 tributaries and a section of the main channel in Oughterard in early December 2017 (Fig.1 and Table 1). Salmonid habitat assessment requires detail on a number of key physical river attributes (instream and riparian). Such features and riverine processes that should be considered when undertaking a salmonid habitat mapping exercise include the following:

- Channel morphology and flow types
- Channel vegetation
- Substrate diversity and condition
- Barriers to continuity
- Bank structure and stability
- Bank and bank top vegetation
- Riparian land cover & landuse

While some of this information is available through geographical information systems (GIS), aerial photography and online sources (e.g. GSI, EPA, NPWS, OSI), 'ground-truthing' which involves "walk-over surveys" of a number of different river types is also required.

Data collected during these habitat assessment walk-over surveys included information on habitat type (riffle/glide/pool), bed material, channel flow, instream vegetation, land-use, riparian cover, spawning / nursery potential, water quality issues, enhancement potential and access to site. The walk-over surveys also provided an opportunity to put together a photographic catalogue of sections walked.

Table 1. Summary of tributary channels walked and distance covered in the Owenriff catchment, December 2017

Tributary Name	Section walked (m)
Sruffaunboy	1,900
Derrygauna	1,000
Glashanasmearany	700
Letterfore	3,200
Derryerglinna	500
Knockmoyle (Leam)	1,000
Glengawbeg	500
Derreighter	530
Derradda	1,500
Rusheeny / Clooshgereen	1,500
Bunowen	2,500
Derrylaura	1,200
Owenriff Main Channel	1,000

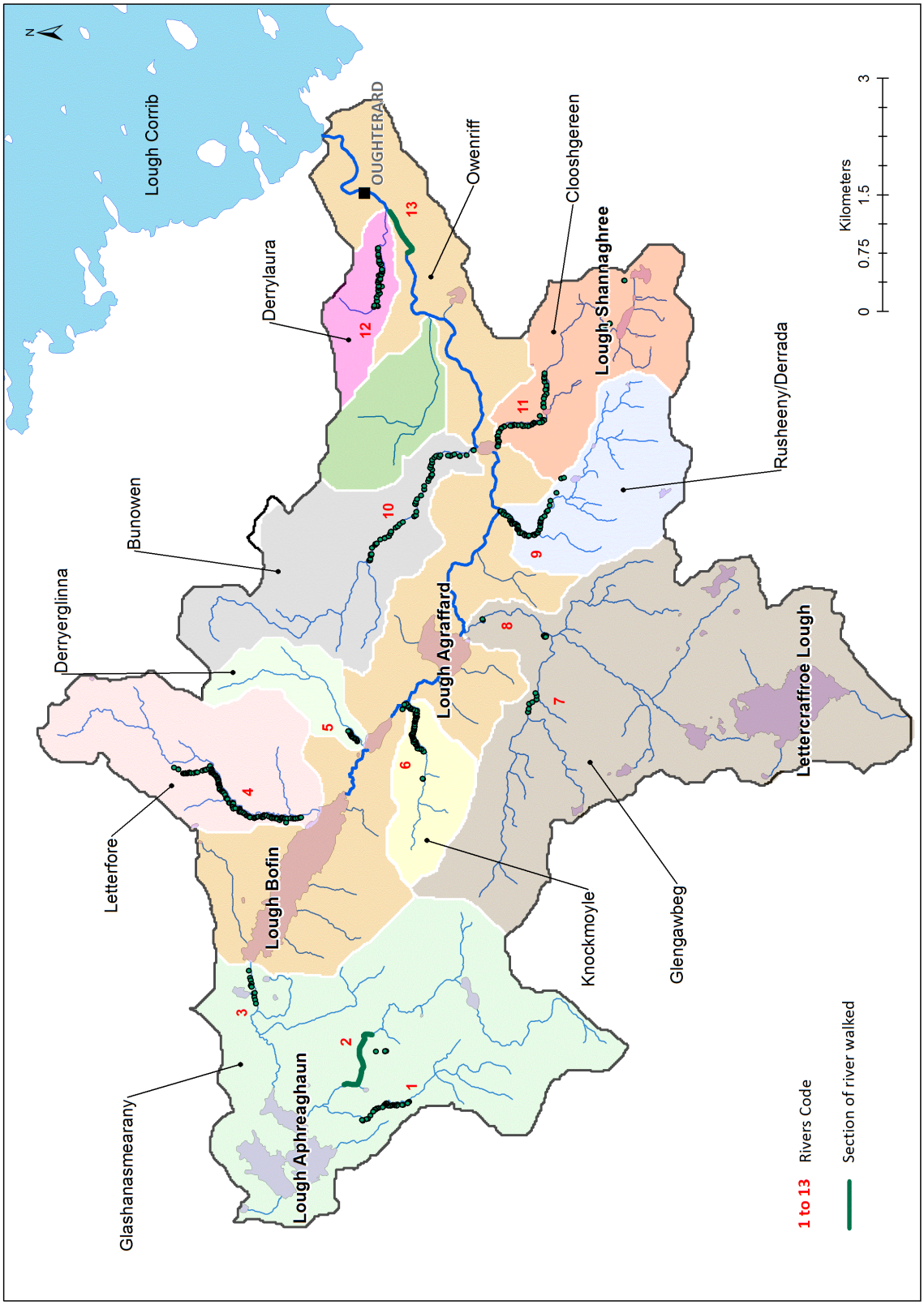

Figure 1. River sections reviewed during habitat assessment walk-over surveys, Owenriff 2017

2.1.3 Fisheries enhancement options and habitat assessment walk-over findings on the Owenriff catchment

There were no significant issues recorded and most issues were localised. However, the issues encountered across the Owenriff catchment during the habitat assessment walk over survey in late 2017 were; excessive riparian cover, lack of riparian cover, lack of suitably sized spawning gravels, bank erosion, paucity of instream features, some minor water quality issues, some siltation problems and lack of fencing.

However, it should be noted that the entire Owenriff riverine system was not fully assessed, during the preliminary habitat assessment walkover survey in December 2017 survey. While the channels walked represent a good range of channel type and forms present within the catchment, further and more detailed habitat assessment walkovers in 2018 may identify additional problems. Detailed information on each channel assessed is summarised in Appendix 1. Additionally a summary of the works recommended for the Owenriff main channel downstream of Canrawer waterfall (from a walk-over inspection undertaken in April 2016) is available in Appendix 2.

1. <u>Riparian Zone Management (selective pruning and some planting)</u>

Riparian zones play a critical and integrated role in the proper functioning of riverine channels (Gregory *et al*., 1991; O'Grady & Duff, 2000). Efforts to restore riparian vegetation and processes usually have multifaceted objectives such as increasing shade and reducing stream temperature, reducing erosion and stabilising stream banks, improving water quality through filtration of fine sediment, nutrients or pollutants from agriculture and providing cover (Roni and Beechie, 2013). Management options that promote and allow for the development of a good riparian zone include planting of native tree and scrub species, removal / pruning of excessive vegetation cover, fencing and the creation of buffer zones.

Many river systems that have been subject to an OPW drainage scheme will have undergone significant changes in its riparian zone. After drainage the vegetation that forms the new riparian zone will in most cases not be the same especially in terms of species and to a lesser extent location. Routine drainage maintenance is not frequent along the OPW drained Owenriff channels which has led to many sections becoming overgrown and tunnelled. This limits light penetration to the river bed which impacts on river productivity in terms of flora and fauna of the channel. While a certain

level of riparian cover is critical to a healthy river system too much is often a problem. It can be addressed through a selective pruning and thinning programme. Examples of this issue within the Owenriff catchment are presented in Plate 1.

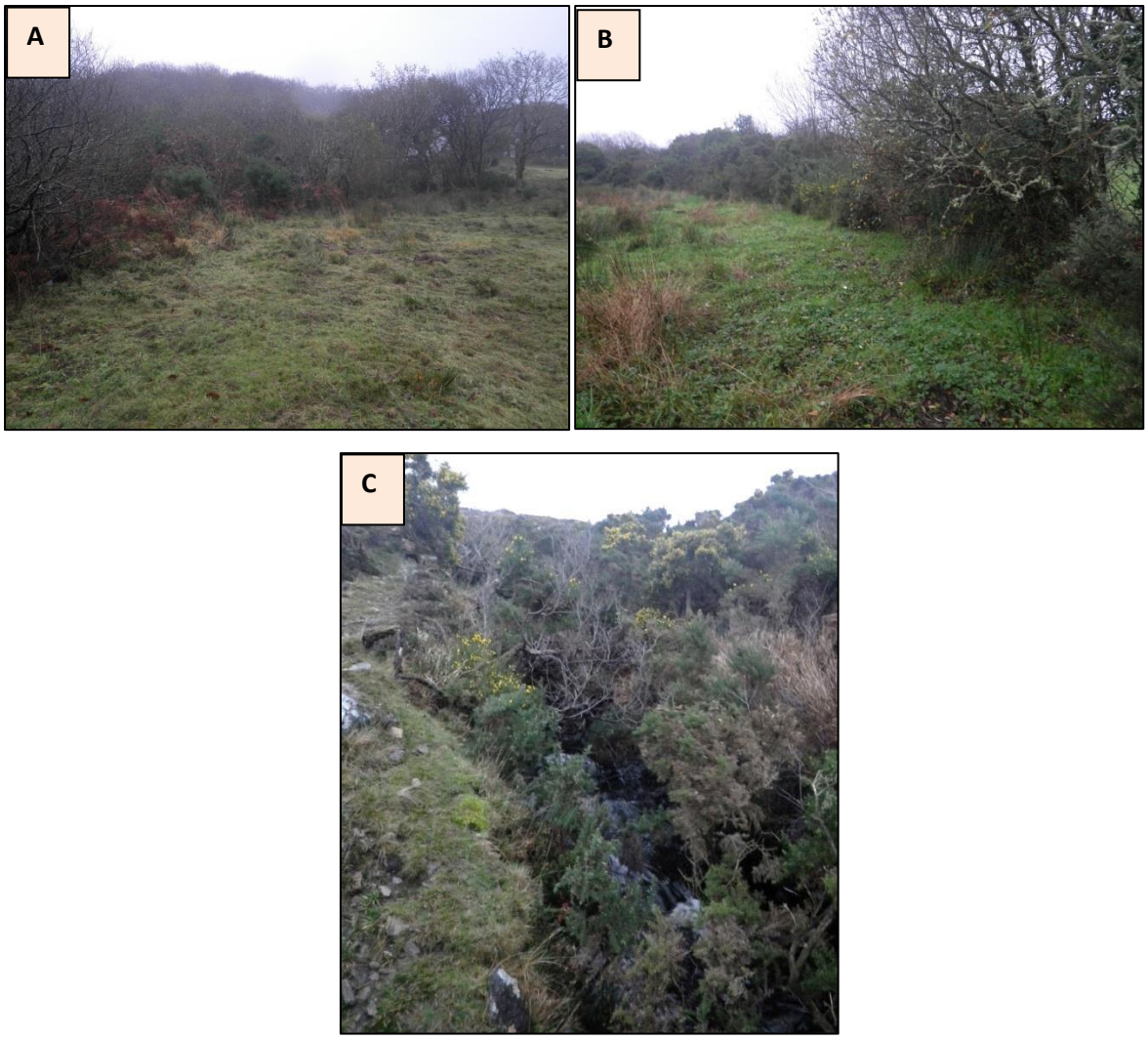

Plate 1. Examples of excessive bank cover in the Owenriff catchment; A) Bunowen R., B) Derrylaura R. and C) Derryerglinna R.

Equally the absence of riparian cover is also an issue. Riparian cover helps regulate stream temperature, provides shade and cover for fish, reduces erosion, stabilises stream banks and improves water quality through filtration of fine sediment, nutrients or pollutants from agriculture (Roni and Beechie, 2013). Examples of this issue within the Owenriff catchment are presented in Plate 2.

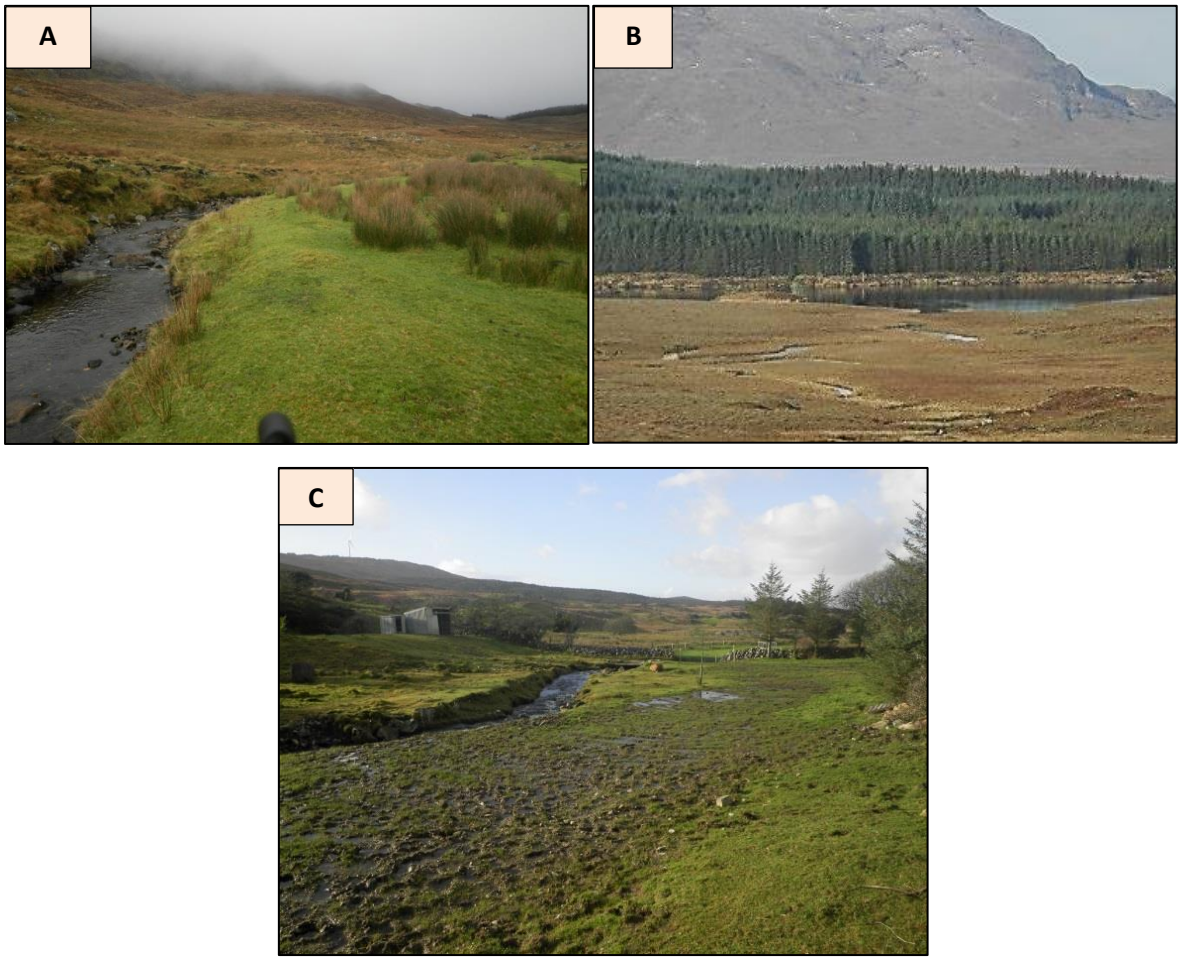

Plate 2. Examples of absence of riparian cover and no fencing in the Owenriff catchment; A) Bunowen R., B) Sruffaunboy R. and Clooshgereen R.

2. Bank Stabilisation / Protection

A certain level of bank erosion is part of the natural process in rivers (Leopold, 1994). When this bank erosion goes beyond natural then it can becomes an issue. Restoration techniques to reduce bank erosion can either take the form of soft or hard engineering, depending on the level and severity of the problem. Soft engineering techniques (using timber and other natural materials) are more beneficial in enhancing and improving river habitat while hard engineering works (most often stone and concrete) are more commonly used to protect property and infrastructure in high energy channels (Roni and Beechie, 2013).

Bank slippage and trampling caused by farm stock having access to river banks were also noted around the catchment (Plate 3).

Plate 3. Bank slippage in the Owenriff catchment, A) Knockmoyle R. and B) Derrylaura R.

Bank erosion and instability is a problem where it occurs beyond what would be considered natural levels of erosion. This typically occurs in rivers which have undergone some level of habitat degradation/modification (Plate 4).

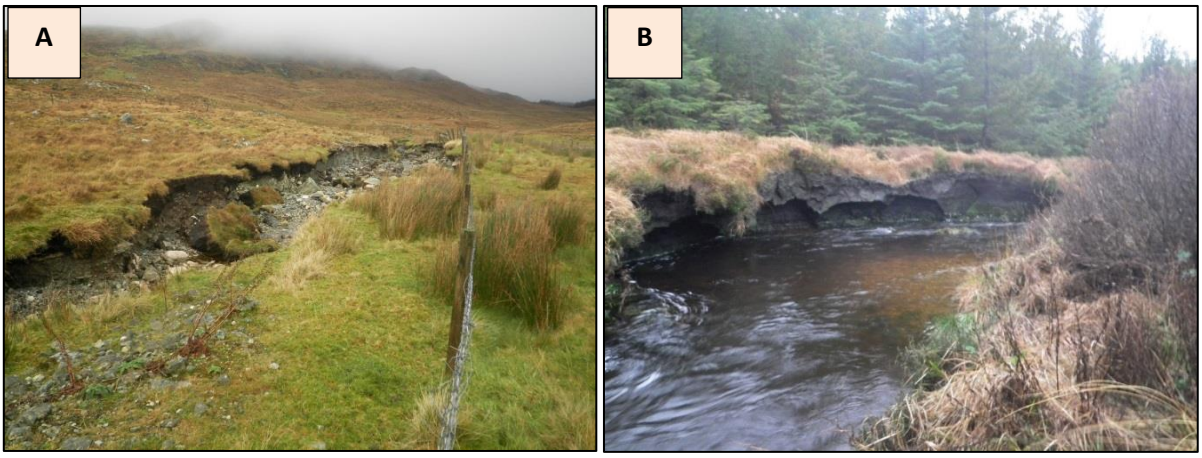

Plate 4. Bank instability in the Owenriff catchment, A) Letterfore R. and B) Derreighter R.

3. Instream structures

Where a river has been altered through direct human activities and instream habitat has been lost or degraded, the need for direct intervention in the form of improving or creating new habitats may be required (O'Grady and Duff, 2000; Roni and Beechie, 2013). Instream modifications can be used to great effect to improve instream habitat for all life stages of salmonids (Hendry *et al*., 2003). Common habitat enhancement techniques include a wide range of options, and selecting and designing the most appropriate habitat improvement techniques requires knowledge of the impacted river and its processes. In general, most commonly implemented instream structures include the restoration of the riffle/glide/pool sequence as appropriate, reforming lateral scour pools, the addition of spawning gravels and providing a natural level of instream diversity in both a physical and ecological sense (O'Grady and Duff, 2000). Retaining features such as low level weirs and deflectors designed to increase stream turbulence and direct flow to promote habitat diversity are good examples of this.

The type of physical impacts observed around the Owenriff catchment included alterations to rivers due mainly to land drainage (OPW and local) and landuse (farming practices). Rivers affected often have less in-channel biodiversity (such as channel sinuosity, riffle/glide/pool sequences, recruitment of spawning gravels, alterations to channel flow). Measures used to alleviate these type of typical impacts are many and choosing which to use will often depend on the individual river, access to the channel, available materials and resources. In the case of the Owenriff system the main instream recommendations include addition of salmonid spawning gravels, improving channel sinuosity through alternating deflectors and the provision of weir/pool/gravel units. Examples of channels where instream work programmes would be of benefit are presented in Plate 5.

Plate 5. Examples of rivers in the Owenriff catchment where instream development would be of benefit, A) Bunowen R., B) Derrylaura R. and C) Clooshgereen R.

4. Connectivity

The connectivity of a river and its habitat is important for maintaining the movement of water, sediment, organic matter, nutrients and the movement of fish and other biota (Vannote *et al*., 1980; Fullerton *et al*., 2010). Three main types of connectivity exist and can be impacted by anthropogenic alteration – longitudinal, lateral and vertical. Longitudinal refers to the upstream-downstream connectivity. Lateral most often refers to the connection of a river to its floodplain and riparian area. Vertical connectivity is concerned with the area of the river covering top to bottom (from the top of the bank to the river bed) (Roni and Beechie, 2013).

All significant barriers to fish migration observed in the catchment were natural and should not be interfered with. A number of man-made obstructions / impediments were noted during the habitat assessment walk-over surveys including ford crossings, culverts, bridge aprons and instream structures (e.g. Plate 6). These should be removed unless they are acting as a barrier for pike dispersal.

Plate 6. Examples of man-made barriers in the Owenriff catchment, A) ford crossing on the Bunowen and B) instream structure in the Derrylaura R.

Limitations / Issues

Much of the Owenriff catchment lies within two SAC's (NPWS, 2017). The implementation of any enhancement programme requires consultation with NPWS and all other stakeholders including landowners. Many of the rivers within the system are remote with very limited access and difficult terrain to cross and so may preclude them from undergoing enhancement works as the cost benefit analysis may not justify such works. The success of any enhancement programmes is also reliant on good water quality which falls outside the remit of enhancement programmes.

How to implement

A number of agencies and NGO's have an interest in the Owenriff catchment and any enhancement programmes considered should be reviewed with all relevant stakeholders prior to implementation. The setting up of a 'working group' represented by the main stakeholders should be considered (see also section 2.6). All enhancement plans would be reviewed by this group and feedback provided on

such plans. Other such agencies include NPWS, OPW, Forest Service, EPA and Galway County Council.

Rivers which would benefit most from enhancement programmes (not in order of priority);

- Clooshgereen
- Derrylaura
- Bunowen
- Letterfore
- Knockmoyle (Leam)
- Main channel in Oughterard

Other rivers have access issues and do not have serious habitat degradation. Most rivers throughout the catchment, however, would benefit from the addition of salmonid spawning gravels in discrete sections.

Further work

The habitat assessment surveys carried out in December 2017 only included a sub-section of the main tributaries to the Owenriff. Further work is required to complete a comprehensive habitat assessment for the entire catchment. This would allow detailed fisheries enhancement plans to be drawn up where necessary.

2.2 Genetic Restoration of fish populations in the Owenriff catchment

If suitable conditions have been restored in a river, brown trout and salmon should recolonize a rehabilitated section or stretch of river naturally; however it cannot be assumed that this will always occur. Desired species must be present somewhere in the connected river/stream system, and have good access to the rehabilitated section (FAO, 2008); therefore genetic restoration should be considered as part of the Owenriff fish population rehabilitation plan. If necessary, the first stage in this process would be to determine the genetic diversity of brown trout in the catchment. Restoration of biota (i.e. the augmentation or re-establishment of extirpated populations or communities) is becoming increasingly common as freshwater populations are reduced through habitat loss and degradation, species introductions and overfishing (e.g. Smith, 2009; Clewell and Aronson, 2007). Restoration typically involves the supplementation of populations with translocated stock or seed from wild populations or from hatcheries (Ryman and Laikre, 1991).

2.2.1 Brown trout genetic diversity in the Corrib catchment

Inland Fisheries Ireland commissioned a Ph.D. project and a collaborative research project, with Queens University Belfast (QUB), to examine the genetic diversity and structuring of brown trout from nine major rivers in the Corrib catchment (Massa-Gallucci *et al*., 2010; IFI, 2013). This work has shown that there are three distinct genetic groups of brown trout in the Corrib catchment: Group 1 represented by samples from the Owenriff, Drimneen, Bealanabrack, Cornamona and Cong rivers, Group 2 represented by samples from the Grange, Abbert, Annacourta, Black and Cross rivers and Group 3 is represented by “ferox” trout. In 2012 it was calculated that group 1 contributed 59% of trout to the mixed non-ferox lake trout, while group 2 contributed 41%. Based on the QUB study (IFI, 2013) it was found that the Owenriff catchment was a significant contributor to the Lough Corrib lake brown trout mixed population (approximately 15%) after the Abbert (23%), Grange (21%) and Cornamona/Bealnabrack (19%) catchments. Previous studies have shown that the Owenriff catchment contribution to the adult stock in the lake varies temporally (2006 – 12.64%, 2007 – 5.77%) (Massa-Gallucci *et al*., 2010).

A review of the brown trout genetic data available for the Owenriff catchment was undertaken by Queens University in December 2017 and early January 2018 (Prodohl, QUB, pers. comm.). This revealed that the numbers of samples for the Owenriff catchment, analysed as part of the larger Corrib project, were too few to make any conclusive recommendations about future restoration plans. Therefore, it is recommended that additional genetic material for brown trout be collected as

part of the IFI baseline monitoring programme in 2018 and analysed to examine genetic diversity prior to any genetic restoration works being implemented.

2.2.2 Steps recommended for genetic restoration

1. Collect new genetic material across the Owenriff catchment (lakes and rivers) in summer 2018 as part of IFIs baseline monitoring programme in the catchment. Separate samples should be taken upstream and downstream of natural barriers (approximately 1000 to 1500 samples required in total).
2. Analyse the samples and define genetic structuring in the catchment (external laboratory)
3. Ensure that restored populations persist over time (sufficient numbers of founders are established and if necessary supplement with additional introductions (temporal sampling)
4. Consider and assess the viability of a supportive breeding programme using IFIs conservation hatchery in Roscrea, Co.Tipperary, if other measures are not successful.
5. A last resort measure would be to stock unfed fry from a neighbouring catchment (e.g. Drimneen). Supplementing salmonid populations by stocking is a widely used method to improve catch or to rehabilitate populations but should only be considered if habitat enhancement and other measures are not successful.

2.3 Removing the problem (controlling pike)

Controlling invasive plant and animal species is very challenging and complete eradication is often impossible. However, control measures can improve native biodiversity and reduce the detrimental physical effect of certain species (Addy *et al*., 2016). A separate stock management plan has been prepared for 2018 to reduce the impact of pike in the catchment which involves electrofishing and gillnetting (IFI, 2018b). Fyke nets will also be used during 2018 (IFI, 2018b). Numerous methods for controlling pike populations have been considered by the Fish and Wildlife Agencies in the U.S. for river and lake habitats (e.g. Southcentral Alaska Northern Pike Control Committee, 2010), but IFI have found gillnetting and electrofishing to be the most effective methods in controlling pike populations in designated rivers and lakes in Ireland (e.g. Fitzmaurice, 1983). From 2019 the annual stock management programme in the Owenriff catchment will be aligned closely with this rehabilitation plan and the research outputs from the effectiveness monitoring programme will guide the process.

2.4 Reducing anthropogenic impacts in the catchment

IFI environmental staff will target and address any water quality issues identified during walkover surveys. There will also be on-going consultation with the EPA, Local Authorities, NPWS, Forest Service, etc. It is recommended that the Owenriff be included in the national priority catchments for Water Framework Directive purposes.

2.5 Public awareness campaign

It is recommended that a public awareness campaign be implemented to inform the public about the consequences of illegal pike (and other species such as roach) introductions, to both prevent further illegal introductions and gain public support for control actions.

A biosecurity plan for the catchment should also be drawn up to prevent any more introductions of pike or other species. Information fliers and signs should be designed and could be issued to local businesses and information signs erected at the main access points to lakes and rivers. Additionally, IFI protection activities should be increased in the catchment and new technology such as digital surveillance cameras could be employed. A web page should also be designed and provide regular updates along with social media and other methods.

<u>Aims of the campaign:</u>

- Prevent further introduction of invasive non-indigenous fish to the catchment - inform the public about the economic dangers associated with introductions of species such as pike and other species beyond its range (illegal, detrimental, etc.)
- Detect, monitor, contain and reduce invasive non-indigenous with minimal environmental impacts
- Educate the public about the importance of preventing introductions
- Disseminate research findings

2.6 Interagency Coordination

An Owenriff Working Group was set up in 2006 to review the causes of a substantial loss of freshwater pearl mussel in the catchment. It is recommended that this working group be reinstated for this important site for the freshwater pearl mussel and brown trout and salmon populations, and to provide increased coordination and communication among relevant state agencies and other

stakeholders. It is important that IFI provide leadership, direction and oversight of the proposed fish population rehabilitation plan for the catchment. The main objectives of the group would be to develop common goals, develop agreements, keep public information consistent based on sound science and that it should complement other work in the catchment (e.g. freshwater pearl mussel monitoring, etc.)

2.7 Climate change mitigation

Climate change is happening and it's being observed on all continents and oceans (DCCAE, 2018). Changes in Ireland's climate are in line with global trends. It is predicted that mean annual temperatures will increase, that there will be decreases in mean annual spring and summer precipitation and that heavy rainfall events will increase in winter and autumn (DCCAE, 2018). Climate change is expected to have significant impacts on the geographical range and phenology (i.e. the timing of life-cycle events) of native species. Projected shifts in climate, temperature and precipitation may result in the increased occurrence of invasive species and competitive pressures for Ireland's native species (DCCAE, 2018). Rivers and lakes are highly sensitive to altered temperatures and precipitation regimes and therefore vulnerable to the effects of climate change (Addy *et al*., 2016). Potential effects of climate change include more frequent extreme floods that could affect physical habitat stability as well as water quality (Whitehead *et al*., 2009; Orr, 2010) and cause dispersal of species into areas where they were previously not indigenous (e.g. Chu *et al*., 2005; Hein *et al*., 2014). The effects alter habitat, species abundance, composition and distribution (Clews *et al*., 2010) and the connectivity between water bodies (Durance and Ormerod, 2007). Reduced summer rainfall and increased evaporation may put stress on river and wetland communities and fish (Addy *et al*., 2016).

The National Adaptation Framework (NAF) envisages an integrated approach, involving all stakeholders at all institutional levels to ensure adaptation measures are taken across different sectors and levels of government to manage and reduce Ireland's vulnerability to the negative impacts of climate change (DCCAE, 2018). Following the launch of the NAF in January 2018, a number of government departments will be required to prepare sectoral adaptation plans in relation to an area under their remit. In advance of this it is recommended that this rehabilitation plan build in climate change measures for fish into the project to assess and monitor risk, assess adaptations, and identify mitigation measures.

2.7.1 Climate change research in the Owenriff catchment

The Owenriff catchment will be included as part of IFI's "Irish Fish in Rivers Temperature Monitoring Network" (IFRTMN) to identify areas vulnerable to climate change and thermal refuges for salmonids. Areas to benefit from tree planting and other measures could be identified. The main aims of the IFRTMN are to develop models to understand and predict river temperatures across Ireland, to produce vulnerability maps to show where rivers are vulnerable and hottest and will change the most under climate change and where trees can protect rivers, and provide information on changing river temperatures. Pilot projects have already been initiated by IFI in eastern catchments in the Broadmeadow, Ward and Devlin and the Vartry, Dodder and Dargle rivers.

The project will involve installing continuous temperature loggers at multiple sites (rivers and lakes) across the Owenriff catchment. Installation of weather stations could also be considered as part of the programme.

2.8 Other measures

- A temporary ban on angling in the catchment could be considered
- A temporary restriction on issuing section 59 to the Oughterard hatchery should also be considered – to allow the fish to run up into the catchment naturally and increase recruitment.
- Strengthen fisheries legislation to help combat illegal translocation of non-indigenous fish species into new areas (e.g. polluter pays principle).
- Reducing habitat suitable for pike, e.g. aquatic vegetation removal or restrict access to spawning grounds using enclosures around known spawning areas. Habitat mapping of pike spawning areas would be required in the case of both of these suggestions.

3. Effectiveness Monitoring Programme

Monitoring and evaluation of rehabilitation works is essential for determining the effectiveness of measures aimed at improving habitat and increasing fish numbers and conditions (FAO, 2008). The evaluation of rehabilitation activities is concerned with determining the physical and biological effectiveness of individual of various rehabilitation actions (FAO, 2008). Monitoring and maintaining a river or lake post-restoration allows the success of a programme to be assessed. It will also help identify which restoration methods work best for on-going and future initiatives.

The monitoring and maintenance programme developed for the Owenriff is specific for this catchment and is outlined below – a detailed plan (number and locations of sites, schedules, etc.) will be produced prior to any surveys.

3.1 Baseline monitoring

A baseline catchment wide study for all fish stocks was undertaken at river sites in 1997. Additionally a catchment wide assessment of juvenile salmon fry distribution was carried out in 2007. In 2017 a further baseline survey was undertaken to assess the current status of the fish stocks in the catchment at selected rivers sites in the catchment. Two lakes were also surveyed during 2017 and Lettercraffroe Lough is surveyed triennially as part of IFI's WFD fish monitoring programme (IFI, 2018). It is recommended that a more detailed survey be undertaken in the catchment in 2018, this will include:

a. Rivers – A more detailed survey of the entire catchment (repeat 1997 sites and include sites upstream and downstream of natural barriers) is recommended for the 2018 sampling season to provide a complete picture of the status of all fish stocks, understand extent of the range expansion of pike and to collect genetic samples. Additionally, a catchment wide survey for juvenile salmon should be undertaken at the 2007 sites to put into context the level of salmon escapement and spawning and distribution throughout the catchment.
b. Lakes – Assess the status of the fish stocks in the most upstream and downstream lakes in the catchment – Loughaphreaghaun, Lough Ateeann (Leadmine), Loch an Droichid, Lough Shannaghree in 2018.

3.2 Status and trend monitoring

a. Rivers - It is recommended that a detailed catchment wide survey is carried out annually for a period of at least five years, before, during and after any proposed works. The objective will be to monitor any change in fish populations.

b. Lakes – All five lakes should be included in a triennial monitoring programme alongside IFIs WFD surveillance monitoring assessment of Lettercraffroe Lough. Lakes in neighbouring catchments will also continue to be surveyed as part of IFIs WFD surveillance fish monitoring programme.

3.3 Habitat mapping

A detailed pike spawning habitat mapping programme should be carried out in all lakes and rivers, particularly where pike are known to be present. This could be carried out by using unmanned aerial vehicles (UAVs or drones) to acquire high quality aerial images and habitat assessment walk-over surveys. Various methods have been developed for habitat assessment using UAVs (e.g. Casado *et al*., 2015; Wilms and Whitworth, 2017; Woodget *et al*., 2017). A spawning habitat suitability index assessment could then be carried out to describe the percentage of waterbody/catchment that provides pike spawning habitat and rearing areas for YOY (e.g. Inskip, 1982). Mapping of critical summer thermal refuges of brown trout and salmon could also be carried out in the catchment using a thermal imaging camera mounted on a UAV (e.g. Wilms *et al*., 2017).

3.4 Annual census of numbers of migratory brown trout and salmon on the Owenriff River

This would involve the installation of a fish counter on the Owenriff main channel downstream of the Canrawer waterfall in Oughterard. The aim of the work would be to assess the changes in the annual upstream run of adult brown trout and salmon during the progamme.

3.5 Acoustic telemetry

It is recommended that an acoustic telemetry programme be initiated in the catchment to assess predator prey interactions, identify bottlenecks, analyse movement of fish, including pike, e.g. evaluation of pike movements through dispersal pathway analyses (e.g. Jepsen *et al*. 2000; Aarestrup *et al*., 2003). Novel acoustic tags have been developed that can track fish with a unique function, i.e. the ability to detect predation in the wild, and could be considered for this project. The extent of predation and its role in brown trout and salmon declines has yet to be entirely

understood, in part due to the difficulty of detecting predation in the wild. These novel tags contain a digestible fuse which dissolves when it comes into contact with enzymes in the predatory fish's stomach (Fishbio, 2017).

Preliminary plan and recommendations:

- Acoustic listening stations to be placed in four zones in the catchment
- Fish capture methods will include downstream and upstream traps (mobile traps or fixed traps)
- Fish to be tagged are:
    1. Predator: pike (40 pike, 10 in each zone)
    2. Prey: (20 tags per prey category) a) Adult salmon u/s migrants, b) Adult brown trout u/s migrants, c) Salmon smolt d/s migrants and d) Lough Corrib brown trout 'smolts' d/s migrants (or simply trout from the natal streams hitting a lake as we wouldn't necessarily know the destination of these fish and e) Resident trout in the lakes

3.6 Pike diet and ecology

Examine the seasonal diet of pike in the catchment to assess any change pre- and post-works using the euthanized pike taken during the stock management programme and other samples. A range of abiotic parameters are required to be recorded, regular visits by IFI R&D staff should take place and training provided to IFI staff involved in the pike stock management programme to record environmental parameters.

3.7 Other monitoring programmes

As the Owenriff was identified as one of the main brown trout spawning tributaries in the Lough Corrib catchment during the genetic research programmes (IFI, 2013) it is important that a survey of the fish stocks in Lough Corrib be carried out in 2018, 2021 and 2024 to update information on the contribution of the Owenriff catchment to the brown trout lake stock, assess temporal variation and evaluate the impact on lake stocks.

4. Summary of tools to rehabilitate brown trout and salmon populations and effectiveness monitoring in the Owenriff catchment

The estimated costs for the above proposals are outlined below in Table 4.1. The costs include a project manager to oversee the project (both the tools and effectiveness monitoring) and two temporary staff for a minimum of 3 years, to assist with implementation of rehabilitation tools and effectiveness monitoring.

Table 4.1: Estimated costs for the fish rehabilitation plan on the Owenriff catchment (Year 1)

Project management and staffing		**Costs**
	Project manager	€50,000
	Research officer	€36,000
	Technician	€33,000
Tools to correct the problem	**Measures**	**Costs**
Fisheries enhancement works	Natura impact statement	€10,000
	Detailed walkover and habitat assessment surveys, detailed plan compilation (pre-works)	€5,000
	Fisheries enhancement (OPW drained sections) – detailed plan required	To be costed
	Fisheries enhancement (non-OPW drained sections) – detailed plan required	To be costed
Genetic restoration	Define genetic structuring of brown trout in the catchment	€50,000
Pike control	See separate stock management plan (IFI, 2017)	€60,000
Reducing anthropogenic impacts	IFI environmental staff	Core IFI work
Public awareness	IFI to hold briefing sessions with stakeholders, website, printing and design costs	€10,000
Interagency coordination	Set up Owenriff coordination group as per 2006 (quarterly meetings)	€5,000
Climate change mitigation	Instream and lake temperature monitoring to identify thermal refuges of salmonids and habitat mapping	€30,000
Other measures	Temporary ban on angling in the catchment Temporary restriction on issuing section 59 to the Oughterard hatchery – let the fish run up into the catchment? Strengthen fisheries legislation to increase fines for illegal translocation and introduction of non-indigenous fish into an area	Core IFI work
Effectiveness monitoring		**Costs**
Baseline	River surveys (T&S, fuel, etc)	€7,000
	Lake surveys (T&S, fuel, etc)	€5,000
Trend status	Habitat mapping (purchase of drone or external company, thermal camera and associated software) (T&S, fuel, etc.)	€12,000
	Annual census of u/s migrating adult salmon and trout (fish counter) (Vaki counter, grates and structure) (or use one of IFIs existing)	€50,000
	Acoustic telemetry (high resolution)	€86,398
	Pike diet and ecology	€15,000
	Other monitoring e.g. Lough Corrib survey	€6,000

Total approximate costs for year 1 of the project, including capital items: €470,398. This figure excludes fisheries enhancement works as detailed plans are required prior to costing. Estimated costs reduce to approximately €217,500 (year 2), €211,000 (year 3), €102,500 (year 4) and €92,000 (year 5).

5. Obstacles/Delays/Risks

- Natura Impact Statement (NIS) – this is required prior to any instream or riparian work in the Owenriff catchment. Prior to implementation, all measures will be assessed for their effectiveness and potential negative impacts on freshwater mussels or other species or habitats of high conservation value and a NIS compiled. Approval delays for the NIS could cause interruption in timelines of the project plan.
- Securing permission from landowners to carry out works could also affect timelines
- Delays in HPRA approval for acoustic telemetry project could delay the plan

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Appendix 1: Individual Sub-catchment Notes

1. Glashanamearany sub-catchment

This sub-catchment is located in the north west of the Owenriff system and flows into Lough Bofin (Fig. 1). Three separate tributary channels were included in the habitat assessment walk-over surveys for the Glashanamearany sub-catchment. Details for each are presented below (Table A1, A2 and A3) and photographically in Plates 7, 8 and 9.

Table A1: Sruffaunboy Tributary habitat assessment (1)

	Habitat description
Channel type:	Within the lower gradient sections long moderate depth glides with short riffle type runs. Higher gradient sections were bedrock and boulder strewn with riffle and pools.
Range of widths:	0.5 to 3.5m
Substrate type:	Mixed have 2 distinct types either soft peaty sediment with limited gravels present or bedrock with mixed boulder, cobble and some large gravels.
Instream vegetation:	A lot of algae present.
Riparian Cover:	No trees or scrub cover – only bog mosses/grasses and rushes.
Salmonid channel type:	Lower reaches more suited to trout but mid to upper more suited to salmon. In either case, this channel would be classed as a spawning and nursery tributary.
Channel form:	Appears natural and undisturbed.
Landuse/ Land cover:	Peat bog.
	Problems identified
Fencing:	None (though only small numbers of sheep seen).
Artificial Barriers:	Several partial falls and most likely a number of complete further upstream.
Drained:	No
Issues:	Pike found in pool along this section.
Access:	Very difficult, no driving access route.
	Recommendations
Enhancement Recommendations:	Possible addition of gravels but access to this river is extremely difficult and would not get a lorry or machine in here

Plate 7. Examples of Sruffaunboy river habitat

Table A2: Derrygauna Tributary habitat assessment (2)

	Habitat description
Channel type:	Within the lower gradient sections long moderate depth glides with short riffle type runs. Higher gradient sections were bedrock and boulder strewn with riffle and pools.
Range of widths:	1 to 4m
Substrate type:	Mixed have 2 distinct types either soft peaty sediment with limited gravels present or bedrock with mixed boulder, cobble and some large gravels.
Instream vegetation:	A lot of algae present and some floating vegetation
Riparian Cover:	Trees or scrub cover almost absent – only bog mosses/grasses & rushes.
Salmonid channel type:	Lower reaches more suited to trout but mid to upper more suited to salmon. In either case this channel would be classed as a spawning and nursery tributary.
Channel form:	Appears natural and undisturbed.
Landuse/ Land cover:	Peat bog
	Problems identified
Fencing:	Not present.
Artificial Barriers:	None
Drained:	No
Issues:	Pike found in this section.
Access:	Very difficult, no driving access route.
	Recommendations
Enhancement Recommendations:	Possible addition of gravels and loosen/rake all existing gravels but access to this river is extremely difficult and would not get a lorry or machine in here.

Plate 8. Examples of Derrygauna river habitat

Table A3: Glashanasmearany Tributary habitat assessment (3)

	Habitat description
Channel type:	Mostly deeper water with long glide like sections broken up with short slightly higher gradient riffle type sections. Limited defined pool areas.
Range of widths:	1.5 to 5m
Substrate type:	Mostly soft peat bed material, very limited cobbles and gravels seen in section walked. Though river upstream of natural falls is reported to have more stony bed material present.
Instream vegetation:	In the deeper slow flowing glide section moderate amounts of instream vegetation noted, potamogetons etc.
Riparian Cover:	No trees or scrub cover – only bog mosses/grasses & rushes.
Salmonid channel type:	Salmonids would migrate through this channel but more so to reach spawning grounds upstream. Might function for trout nursery and hold some older trout. The type of waters present here would also suit pike.
Channel form:	Appears natural and undisturbed. Resembles a lowland meandering channel but on a smaller scale.
Landuse/ Land cover:	Peat bog, rough grazing (RHB) and forestry (LHB).
	Problems identified
Fencing:	None seen.
Barriers:	Natural falls upstream of here, not a complete salmonid barrier not sure about for pike.
Drained:	No.
Issues:	Pike possible in channel as are in pond on LHB Loughanaduff and in upper lake Loughaphreaghaun.
Access:	Access to lower reaches yes through private road but after that very restricted.
	Recommendations
Enhancement Recommendations:	None – would need to assess river upstream of falls.

Plate 9. Examples of Glashanasmearany river habitat

2. Letterfore sub-catchment

This Owenriff sub-catchment drains into Lough Bofin along the eastern shore (Fig. 1). The habitat assessment survey was carried out on the main channel for approximately 2.2km. Details are presented below (Table A4) and photographically in Plate 10.

Table A4: Letterfore Tributary habitat assessment (4)

	Habitat description
Channel type:	High gradient channel riffle/pool type channel with limited shallow glide like sections present. Several small cascades and bedrock outcrops.
Range of widths:	2 to 4m
Substrate type:	Boulder strewn, with abundant cobble, moderate gravel and bedrock.
Instream vegetation:	Limited, some mosses on boulders and very limited instream vegetation.
Riparian Cover:	Abundant in places, absent along 'new' channel but thereafter good cover - gorse and other scrub, willow, alder. Possibly too much in places.
Salmonid channel type:	The high gradient and larger gravel sizes observed suggest this channel is more suited to salmon than trout. Spawning potential extends right up to the upper reaches while nursery waters would be more within the lower reaches where deeper sections were observed.
Channel form:	Modified in mid reaches though thereafter more natural in form however the impacts of the extremely high energy diverted channel has impact on river below that section.
Landuse/ Land cover:	Rough grazing, peat bog, forestry and agriculture within lower reaches.
	Problems identified
Fencing:	Yes, not continuous but common enough along both banks, and if not fences then heavy riparian cover present.
Artificial Barriers:	Minor, 1 road bridge, 2 land bridges and 1 ford crossing.
Drained:	Section of channel diverted down a small channel drain to alleviate flooding issues by landowner at least 20 years plus.
Issues:	Bank erosion, excessive riparian cover in places,
Access:	Lower reaches may have restricted access due to woodland cover.
	Recommendations
Enhancement Recommendations:	A section of the river has undergone some fisheries development work a number of years ago but requires further bank stabilisation, and instream development work. Selective pruning also recommended. Loosening of all gravels present and possible addition in areas where have cascading bedrock areas.

Plate 10. Examples of Letterfore river habitat

Derryerglinna Sub-catchment

The Derryerglinna tributary drains into the northeast corner of Lough Adrehid (Fig. 1). The habitat assessment survey was carried out on a section of the lower main channel only. Details are presented below (Table A5) and photographically in Plate 11.

Table A5: Derryerglinna Tributary habitat assessment (5)

	Habitat description
Channel type:	More typically riffle/pool, glide like sections not really evident.
Range of widths:	On average 2 to 3m.
Substrate type:	Mostly small cobble some gravels and finer bed material (silt/peat). Bedrock and boulders dominant the high gradient sections.
Instream vegetation:	Algae.
Riparian Cover:	Excessive in places, gorse and heavy scrub vegetation noted.
Salmonid channel type:	Probably best suited to trout more so than salmon. Some spawning opportunities but limited nursery waters. Number of natural falls on the channel would limited access to salmon, may even be a complete barrier, need to investigate further.
Channel form:	Moderate gradient in lower reaches around bridge but relatively high gradient after that.
Landuse/ Land cover:	Rough grazing lower reaches peat bog and forestry upper reaches.
	Problems identified
Fencing:	Sparse, lower section only.
Artificial Barriers:	Minor – 1 road bridge culvert.
Drained:	No
Issues:	Forestry, excess algae, land heavily trodden by horses.
Access:	To lower and upper reaches yes, middle section slightly more difficult.
	Recommendations
Enhancement Recommendations:	Possibly fencing in lower reaches and addition of spawning gravels, some light pruning

Plate 11. Examples of Derryerglinna river habitat

Knockmoyle (Leam) Sub-catchment

This sub-catchment drains into the Owenriff main channel (west side) between Lough Agraffard and Lough Adrehid (Fig. 1). The mid to lower section of the main channel was included in the habitat assessment survey. Details are presented below (Table A6) and photographically in Plate 12.

Table A6: Knockmoyle Tributary habitat assessment (6)

	Habitat description
Channel type:	Moderate gradient, with a few noted higher gradient break points where bedrock outcrops occur. Riffle glide pool sequences noted but not regular. Long extended riffle like sections and shallow glides more dominant.
Range of widths:	1.5 to 2m
Substrate type:	Cobble and gravel most common with occasional boulders and bedrock. Finer materials also present (silt and peat).
Instream vegetation:	Moderate levels – mostly moss and submerged instream.
Riparian Cover:	Gorse and heavy scrub with moderate tree cover. Excessive in places
Salmonid channel type:	Gradient and bed materials more suited to trout spawning with nursery waters less available until lower sections.
Channel form:	Some natural features noted channel sinuosity evident in places, though appears to have had had some localised reprofiling.
Landuse/ Land cover:	Rough grazing and farming.
	Problems identified
Fencing:	In places.
Artificial Barriers:	Minor, 1 road bridge .
Drained:	May have had some localised land drainage in past.
Issues:	Heavily bank trampling noted .
Access:	Should be ok, but need to consult with landowners well in advance.
	Recommendations
Enhancement Recommendations:	This channel has had some tree and riparian vegetation pruning as part of a fishery enhancement programme within the last year. Other recommendations include continued selective pruning, some fencing and addition of spawning gravels. Also has potential for some instream development work, such as paired deflectors, pools and gravel shoals.

Plate 12. Examples of Knockmoyle river habitat

Glengawbeg Sub-catchment

The Glengawbeg is a large sub-catchment which drains into the Owenriff main channel and Lough Agraffard outflow (Fig. 1). It has a number of lakes within its sub-catchment the largest of which is Lettercraffroe Lough, located at the top of the system. There is an impassable natural waterfall on the main channel around Derreighter. A short section on both the main channel and its most significant tributary the Derreighter were included in the habitat assessment survey. Details for each are presented below (Tables A7 and A8) and photographically in Plates 13 and 14.

Table A7: Derreighter Tributary habitat assessment (7)

	Habitat description
Channel type:	Relatively high gradient channel with reasonable riffle and glide like sections, difficult to fully assess in high water conditions.
Range of widths:	2 to 4.5m
Substrate type:	Difficult to fully assess with high water levels, though appears to have a good stony bed with some bedrock and occasional boulders.
Instream vegetation:	Not noted.
Riparian Cover:	Very limited.
Salmonid channel type:	Would be more suited to salmon than trout – due to higher gradients noted, has good potential for spawning and nursery.
Channel form:	High gradient fast flowing in upper to middle reaches, lower reaches more moderate grade and meandering.
Landuse/ Land cover:	Forestry and peat bog.
	Problems identified
Fencing:	Sparse
Artificial Barriers:	Minor, 1 road bridge.
Drained:	No
Issues:	Forestry and some bank erosion noted.
Access:	May be difficult with forestry and uneven bog surface, very difficult to even walk along.
	Recommendations
Enhancement Recommendations:	Some bank stabilisation may be required where have peat banks as the level of peat input from bank collapse may be an issue. Potentially would require additional spawning gravels. Could consider some riparian cover in open sections.

Plate 13. Examples of Derreighter river habitat

Table A8: Glengawbeg Tributary habitat assessment (8)

	Habitat description
Channel type:	Low grade for first couple of hundred meters upstream of lake after that gradient increases and fluctuates between moderate and high. Several natural falls on the main channel, one of which is impassable to salmonids and pike. Is a high energy riffle pool type channel.
Range of widths:	4 to 10m
Substrate type:	Large cobble and boulder strewn dominate, some gravels and bedrock outcrops.
Instream vegetation:	Limited, some mosses and in slower flowing sections some submerged vegetation.
Riparian Cover:	Limited to bog grasses and rushes, limited scrub in places. Forestry is set back from river.
Salmonid channel type:	In high gradient sections more likely suited to salmon, up to impassable falls. Some trout in lower grade stretches.
Channel form:	Appears natural and undisturbed.
Landuse/ Land cover:	Forestry and peat bog.
	Problems identified
Fencing:	Sparse
Artificial Barriers:	Minor – 1 private road bridge.
Drained:	No
Issues:	Forestry.
Access:	Difficult due to forestry.
	Recommendations
Enhancement Recommendations:	Fencing where appropriate, very limited bank stabilisation, possible addition of spawning gravels.

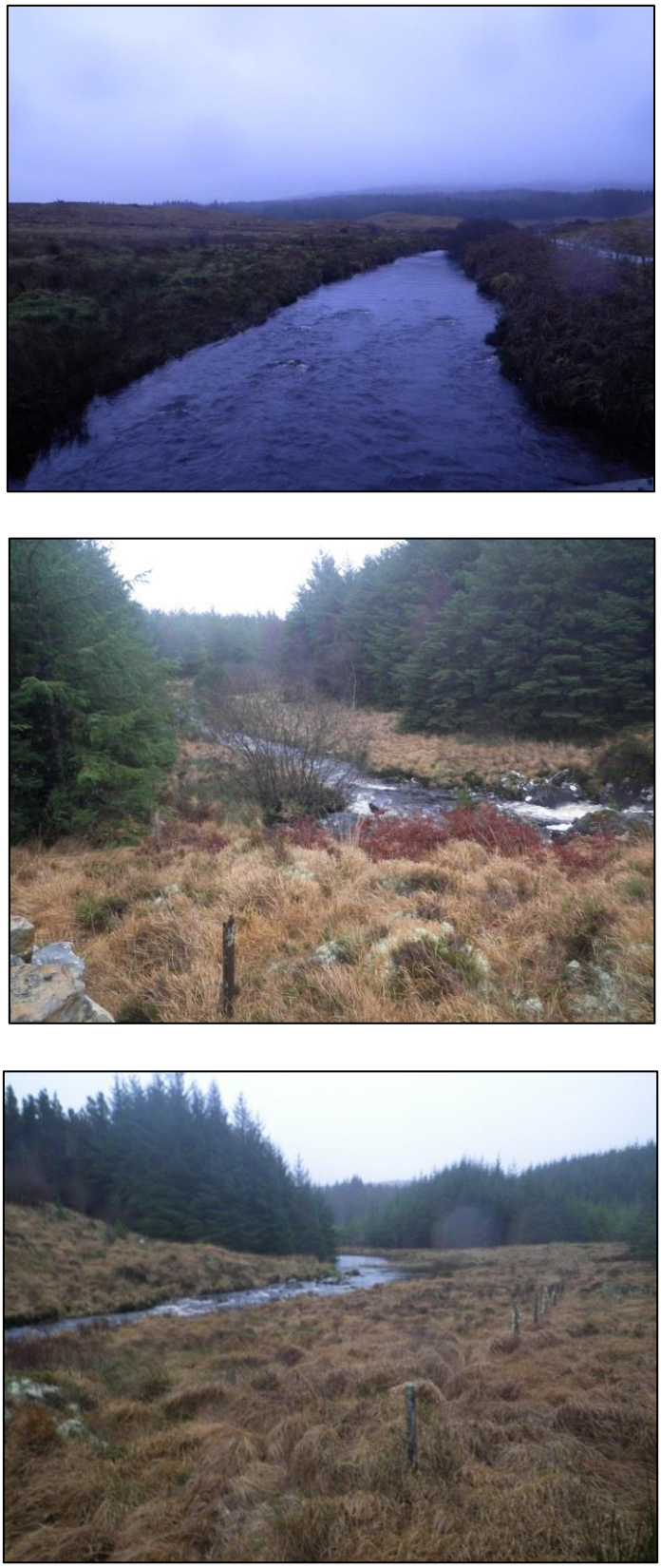

Plate 14. **Examples of Glengawbeg river habitat**

Derradda Sub-catchment

This sub-catchment flows into the Owenriff main channel (West/ RHB) between Lough Ateeann and Lough Agraffard (Fig. 1). A 1.5km section of the main channel was included in the habitat assessment survey, from the Owenriff confluence upstream. Details are presented below (Table A9) and photographically in Plate 15.

Table A9: Derradda Tributary habitat assessment (9)

	Habitat description
Channel type:	High energy high gradient channel, cascade step pool type. Though small number of low gradient deeper water sections noted on occasion in middle reaches.
Range of widths:	0.5 to 3.5m
Substrate type:	Cobble and boulder strewn mostly with some gravels and bedrock outcrops. In deeper slow flowing sections more finer material present (peat).
Instream vegetation:	Limited, some present in slower flowing sections
Riparian Cover:	Occasional to moderate levels of gorse though not an issue and bog grasses and rushes.
Salmonid channel type:	Habitat type suggests this channel would favour salmon over trout, due to bed material and gradient.
Channel form:	Appears natural and undisturbed, good evidence of natural features and channel sinuosity.
Landuse/ Land cover:	Forestry on LHB and peat bog on RHB.
	Problems identified
Fencing:	Partial, mostly along LHB.
Artificial Barriers:	None seen
Drained:	No
Issues:	Forestry
Access:	Very poor access to this channel.
	Recommendations
Enhancement Recommendations:	Could possibly improve spawning opportunities by adding suitable mix of gravels. Minor fencing programme.

Plate 15. Examples of Derradda river habitat

Rusheeny / Clooshgereen Sub-catchment

This sub-catchment drains into Lough Ateeann. Lough Shannaghree is located in the upper reaches (Fig. 1). The habitat assessment survey commenced at the lake and continued upstream of Lough Beg (approximately 1.5km). Details are presented below (Table A10) and photographically in Plate 15.

Table A10: Rusheeny / Clooshgereen Tributary habitat assessment (10)

	Habitat description
Channel type:	Varies from high gradient cascading pool type upstream of 3rd landbridge to slower flowing deeper glide like waters with some moderate gradient riffle zones – typical of a drained river.
Range of widths:	1 to 4.5m
Substrate type:	High gradient section is cobble and boulder strewn with cascading pools, gravels not abundant. Lower section more finer bed materials with smaller cobble and gravels within the riffle areas.
Instream vegetation:	In drained slow flowing sections yes have water-celery, *Myriophyllum* sp. and mosses.
Riparian Cover:	Mixed levels of gorse and heavy scrub & willow to none
Salmonid channel type:	Lower reaches more suited to trout (and pike) but higher gradient sections more to salmon. Possibility of an impassable barrier upstream of 3rd land bridge.
Channel form:	Section walked has been modified through OPW drainage scheme, upstream of drained section river remains undisturbed and retains many natural features.
Landuse/ Land cover:	Peat bog and minor rough grazing.
	Problems identified
Fencing:	Partial
Artificial Barriers:	At least 4 private road bridges
Drained:	Yes, from 3rd land bridge down to L. Ateeann
Issues:	Land drainage
Access:	Possible within the lower reaches but very limited further upstream until you get to L. Shannaghree
	Recommendations
Enhancement Recommendations:	Good potential here for instream development works within some of the drained sections.

Plate 15. Examples of Clooshgereen river habitat

Bunowen Sub-catchment

This sub-catchment enters the Owenriff main channel immediately downstream of Lough Ateeann (Fig. 1). The section included in the habitat assessment survey went from the confluence point up to 1st land bridge (approx. 2.5km). Details are presented below (Table A11) and photographically in Plate 16.

Table A11: Bunowen Tributary habitat assessment (11)

	Habitat description
Channel type:	For the most part series of extended riffle and glides, with some pools. Moderate to high gradient.
Range of widths:	2 to 5m.
Substrate type:	Mainly cobble and gravel with some boulders and bedrock outcrops
Instream vegetation:	Rare
Riparian Cover:	Gorse, ferns and occasional to moderate tree cover especially lower reaches.
Salmonid channel type:	Gradient and bed material type suggest more suited to salmon slightly more so than trout, good spawning potential and nursery.
Channel form:	Modified through drainage, level of recovery moderate, old spoil heaps still visible in places.
Landuse/ Land cover:	Rough grazing and peat bog with forestry in upper reaches.
	Problems identified
Fencing:	Lower recently maintained section only.
Artificial Barriers:	Minor, 1 landbridge.
Drained:	Yes, lower to middle section.
Issues:	Drained and occasionally some sections maintained.
Access:	Possible
	Recommendations
Enhancement Recommendations:	Selective vegetation management, instream development and addition of spawning gravels. This channel has recently undergone a fisheries management pruning programme but needs to be extended. Fencing required in places.

Plate 16. Examples of Bunowen river habitat

Derrylaura Sub-catchment

This sub-catchment enters the Owenriff River in Oughterard (Fig. 1). The last 300m approximately of which flows underground making access to this river impassable to salmon. The river was included in the Corrib drainage scheme. The section of channel included in the habitat assessment survey covered from the second road bridge to where river goes underground. Details are presented below (Table A12) and photographically in Plate 17.

Table A12: Derrylaura Tributary habitat assessment (12)

	Habitat description
Channel type:	Moderate to low gradient, riffles and glides present though pool areas are limited as is depth in general. A channel typical of drainage. Limestone ledges and mini fissures/cracks present
Range of widths:	0.5 to 3m
Substrate type:	Mixed, gravels, small cobble, silt, broken limestone bedrock, occasional boulders and some bedrock.
Instream vegetation:	Limited by heavy riparian cover.
Riparian Cover:	Moderate to heavy, briars, scrub and tree cover.
Salmonid channel type:	Shallow with moderate flows and bed materials make it more suitable to trout.
Channel form:	Over-wide and shallow drained channel which lacks defined pool areas.
Landuse/ Land cover:	Mostly improved grassland and farming.
	Problems identified
Fencing:	Common
Artificial Barriers:	1 minor instream concrete structure and 1 ford crossing.
Drained:	Yes
Issues:	Lower section of this river goes underground before entering Owenriff main channel. Lots of mini caves and disappearing river. Excessive riparian cover. Compacted gravels.
Access:	Possible
	Recommendations
Enhancement Recommendations:	Pruning programme required, would benefit from instream development works to increase channel features and diversity. Raking and topping up of spawning gravels recommended.

Plate 17. Examples of Derrylaura River habitat

Owenriff Main Channel

The section of main channel included in the habitat assessment covered the river in Oughterard only (Fig. 1). Details are presented below (Table A13) and photographically in Plate 18.

Table A13: Owenriff main channel habitat assessment (13)

	Habitat description
Channel type:	Very large extended riffle very little depth or pool areas in section downstream of town main road bridge. Upstream of bridge river gradient has increased and large limestone ledges present along RHB.
Range of widths:	6 to 15m
Substrate type:	Cobble, gravel and bedrock outcrops dominate.
Instream vegetation:	Minimal, light levels of algae.
Riparian Cover:	Moderate tree cover on RHB limited cover on LHB (some scrub and occasional trees).
Salmonid channel type:	Good spawning potential for both really.
Channel form:	This section of the river since drainage has remained overly wide and relatively shallow. Lack of depth and fish cover remains an issue.
Landuse/ Land cover:	Urban area
	Problems identified
Fencing:	No, but not an issue.
Artificial Barriers:	Road bridge
Drained:	Yes
Issues:	Large freshwater pearl mussel population present, urban area.
Access:	Possible
	Recommendations
Enhancement Recommendations:	Instream low level weirs installed by IFI to help with summer low flows in an area that is over-wide and relatively shallow. Draft enhancement plan already developed.

Plate 18. Examples of Owenriff main channel river habitat in Oughterard

Appendix 2: Owenriff River (Main Channel) Preliminary Fisheries Enhancement Notes

Owenriff River (Main Channel) Preliminary Fisheries Enhancement Notes

Plan type:	**Capital Works**
Scheme:	**Corrib Headford**
Channel ref:	**CH9 Section 1**
Channel name:	**Oughterard**
Chainage from:	**1330**
Chainage to:	**2000**
Bank walked:	**Left hand bank**
Channel walked by:	**K. Delanty, Tommy Kelly & M. Butler (IFI),**
Plan prepared by:	**K. Delanty**
Date:	**21/4/16**

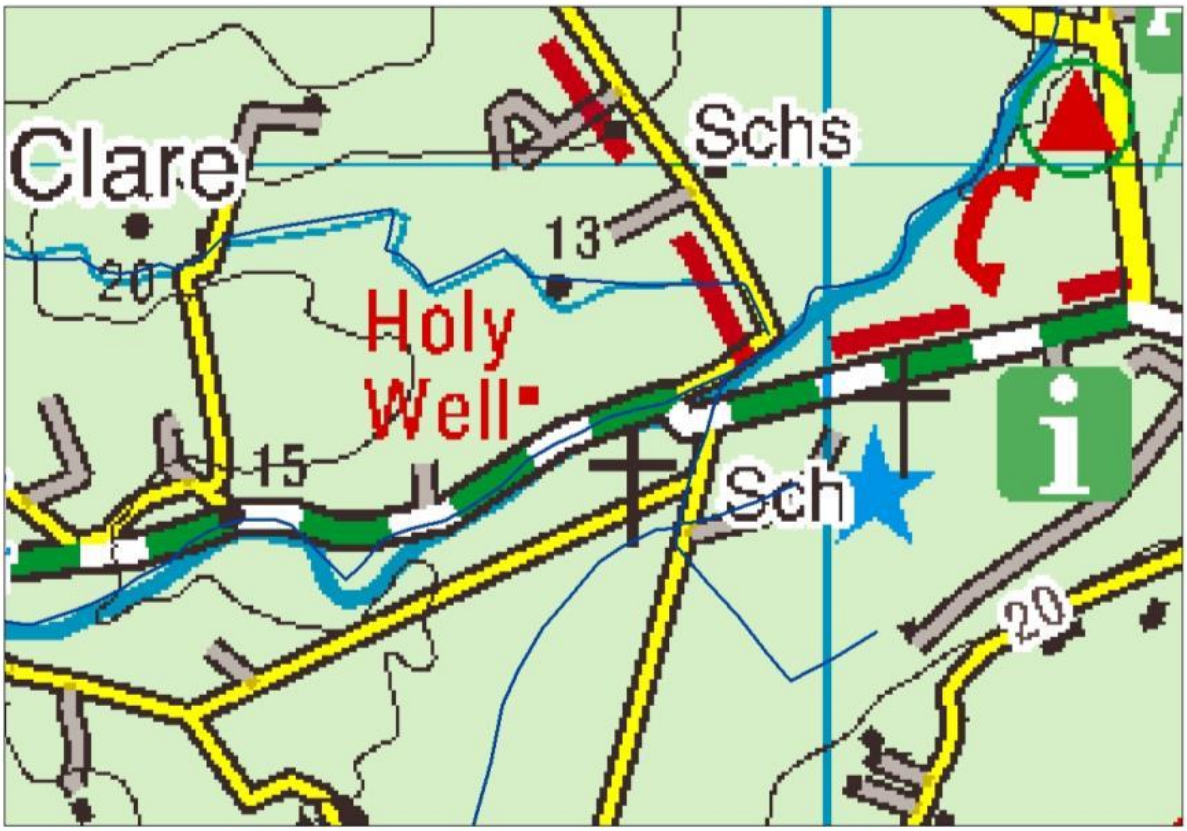

Fig. A21. Section of Oughterard River identified for Works

Weir type and Structure

It is proposed to re-work the partially existing old stone weirs (which were used to hold/pond back water in low flows and stop the river from exposing the freshwater pearl mussel (FPM), creating small pockets/pools of water during periods of low flows that were not connected to the main flow, thus stranding fish and exposing pearl mussels in the dried out sections).

- The base of these weirs are still obvious and mostly intact but they need to be re shaped and need to be slightly higher than are currently
- There are approximately 5 to 6 weir structures below the road bridge and 4 above the bridge.
    - Previous weirs were simple straight line stone weirs
    - Option to construct similar, or modify to slight horse-shoe shaped version or other measures??
    - No pools required downstream of weirs as their function is only to hold back enough water during periods of low summer water flows which would prevent the channel from almost drying in in patches/sections throughout this area.
    - Such would not only benefit the fish communities present but also the significant freshwater pearl mussel (FPM) present.
    - Options for working in FPM sections (to be discussed with NPWS)
        - Check for presence of FPM in areas where weirs to be worked on
        - Investigate removing FPM from this section only or larger areas while work on going and them replacing back to river (keep in mesh net bags like ones observed in Donegal)
        - Could choose new areas for weirs with less FPM present (but still in same stretch of river) silt traps

Plate A2.1. Weir 1 Owenriff River main channel

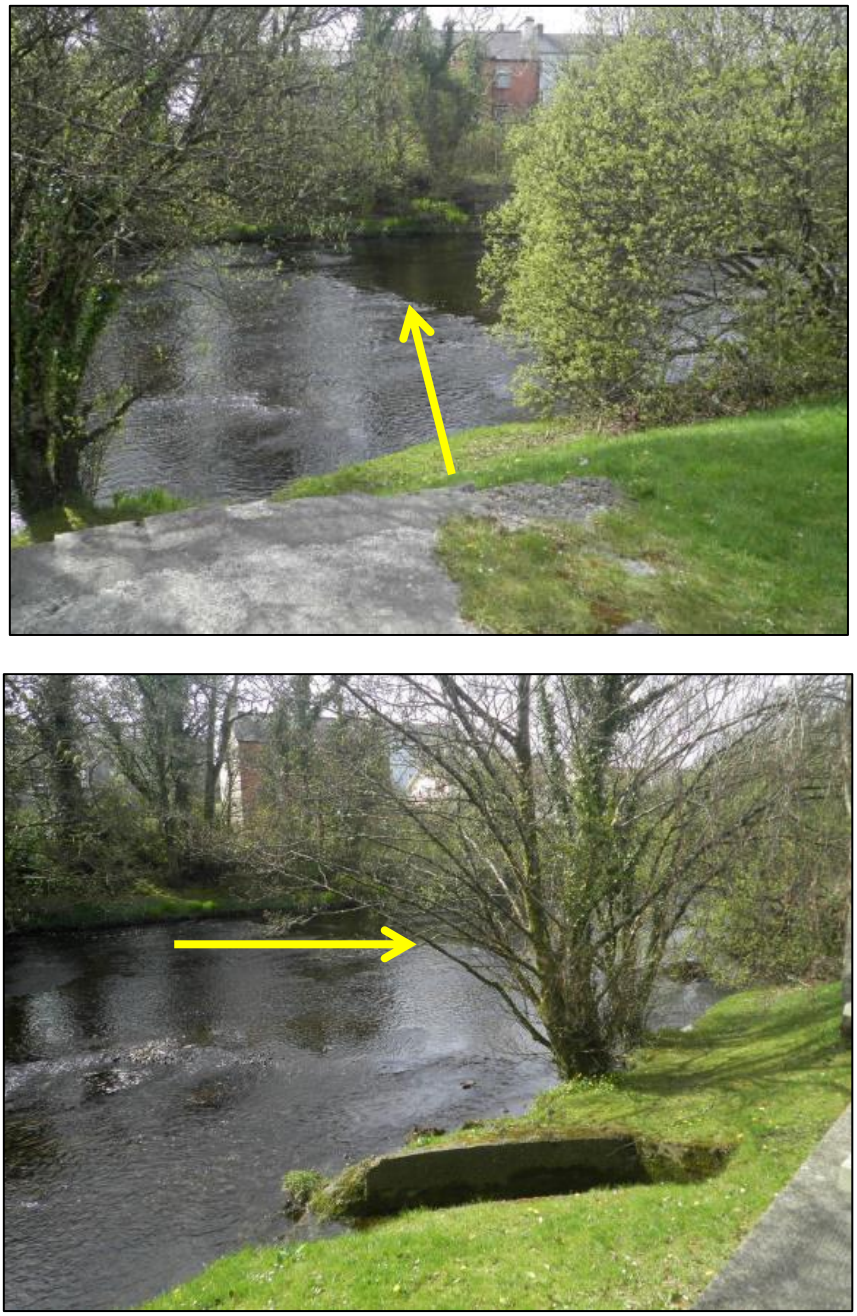

Plate A2.2. Weir 2 Owenriff River main channel

Plate A2.3. Weir 3, Owenriff River main channel

Plate A2.4. Weir 4, Owenriff River main channel

Plate A2.5. Weir 5, Owenriff River main channel

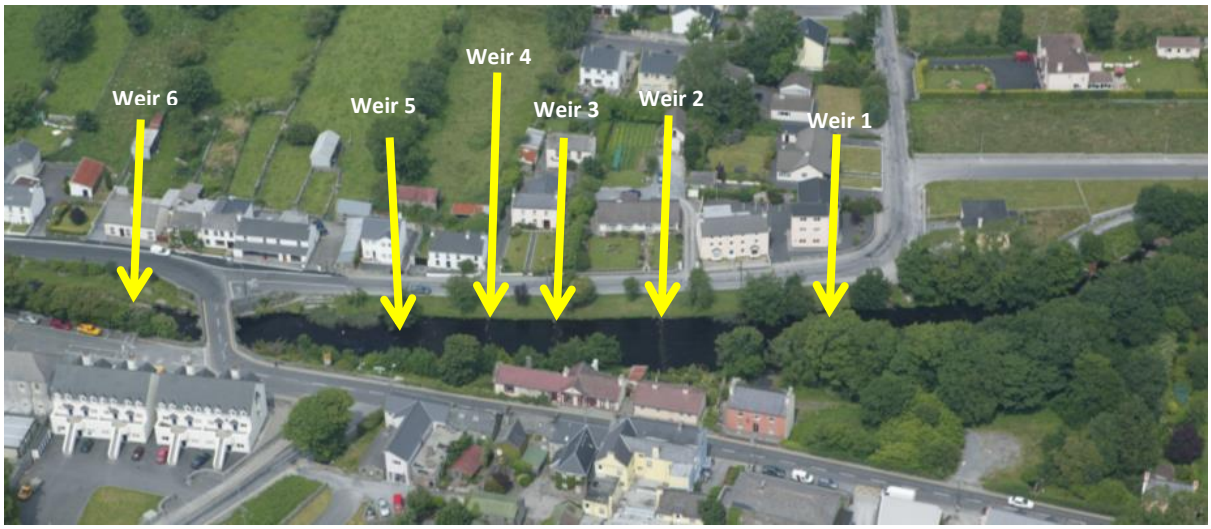

Plate A2.6. Location of weirs on the Owenriff River main channel in Oughterard, Co. galway

Plate A2.7. Weir 6, Owenriff River main channel

Plate A2.8. Weir 7, Owenriff River main channel

Plate A2.9. Weir 8, Owenriff River main channel

Plate A2.10. Weir 9, Owenriff River main channel

Inland Fisheries Ireland
3044 Lake Drive,
Citywest Business Campus,
Dublin 24,
Ireland.
D24 Y265

www.fisheriesireland.ie
info@fisheriesireland.ie

+353 1 8842 600