The Friends of the Rye

Celebrating 30 years of commitment to the Rye Water and its valley

intel

Dedication to Jim Carroll

Jim Carroll
"Friend, Fisherman, Guardian of the Rye"- An epitaph on a plaque beside a tree planted on the banks of the Rye in memory of the late Jim Carroll who sadly passed away suddenly in 2016.

The void left by Jim would be well nigh impossible to fill.

A native of Leixlip, Jim lived for many years in Moyglare with his loving wife Noreen where they raised their family Sarah, Joyce and Damien who sadly died tragically in 2013.

Jim was a dedicated working man and very gifted with his hands crafting many gems for home, garden or work.

A passionate angler both in the boat and on the bank of the river and a marvellous friend to have.

However, all who knew and loved Jim would probably question where they came in the pecking order when it came to Jim's love of The Rye Water.

A small river or stream to most but to Jim the most beautiful and important river in the world.

Jim spent countless hours over many years walking the banks and protecting the river, producing his court appointed water keeper papers to fend off would be pollutors or poachers often with scant regard for his own personal safety.

His love and dedication to the Rye over his lifetime, often ploughing a lone furrow, was priceless and vital to the survival of the river.

If Jim is looking down on us, we hope he rests in the peaceful knowledge that we in The Friends of The Rye will do all in our power to protect his legacy for future generations

The Friends of the Rye

Celebrating 30 years of commitment to the Rye Water and its valley

Compiled by Oscar Flynn[1], Mary Kelly-Quinn[1], Lisa Harlow[2] and Jan-Robert Baars[1]

With contributions from Sarah Sexton, Conor Halpin, Niall Keogh, Aidan Crean, Gavin McDermott, John Plummer, Fergal Caffrey, Kate O'Leary, Heather Swanwick, Edward Cox, Leixlip and District Anglers Association and acknowledging Maria Callanan, Róisín Lyons, Jim O'Brien, Martin Butler, Martin O'Grady and John Bracken for their contributions to the Remarkable Rye Water

Commissioned illustrations by Aoife Quinn and Eva McParland

Photographs unless acknowledged by Jan-Robert Baars and Oscar Flynn

Published by Glasseye 2022

[1] School of Biology and Environmental Science, University College Dublin & AQUENS Ltd.

[2] Intel Ireland

Preface

Since first establishing operations at the Leixlip campus in 1989, Intel has been aware of the rich biodiversity contained within parts of our site and also the significance of the Rye Water and its valley.

The Rye Water, like all rivers, has been intimately linked to the inhabitants of its valley through time. Historically the river was harnessed by mills and in 1758 the site in Leixlip was used as a linen printing mill. Later the Rye Vale distillery was built, producing more than 20,000 gallons of whiskey annually by 1837. The distillery closed in the 1890s and has since been converted into apartments. While people have always benefited from the presence of the Rye Water, it also has inherent worth as one of the important salmon-spawning tributaries of the River Liffey and hosts an abundance of aquatic life. This publication celebrates thirty years of investigations over which a wealth of surveys, studies and monitoring has been conducted in order to document the river's aquatic life and water quality. Additionally, a significant amount of rehabilitation, restoration and enhancement works have been completed with the aim of increasing the biodiversity and water quality associated with the Rye Water and its catchment.

Fish studies have tracked changes in trout and salmon populations with a particular focus on their responses to habitat enhancement works that were undertaken on the Rye Water in 1994. The findings of these investigations have been presented as commissioned annual limnological reports to Intel Ireland but they have also contributed to two doctoral studies in the School of Biology and Environmental Science, University College Dublin. In addition to these fish studies, Intel has sponsored water quality studies utilising macroinvertebrates - aquatic 'bugs' which live on the river bed - as well as crayfish surveys, plant surveys, bird surveys, moth surveys and more.

More recently, Intel has continued its support with further enhancement works carried out in 2016 and 2021 with the aim of increasing water quality and fish habitat quality along the Rye Water and its tributaries.

For the last 30 years Intel has supported these works and we are deeply committed to preserving and enhancing this valuable resource. This publication compiled by AQUENS Ltd. of University College Dublin mainly focuses on the activities that have taken place over the last 10 years since we celebrated the 20 year anniversary of these studies. In particular it celebrates the continued dedication of the Friends of the Rye.

A complete chronology of studies is available on the opposite page.

Chronology of Studies

1983
A survey of the Rye Water catchment area, first of the UCD studies.

1990
Initial baseline survey of the chemical and biological quality at four sites in compliance with planning for development at the Intel Ireland site.

1992
Survey extended to encompass additional sites upstream and downstream of the Intel Ireland site.

1992
First annual limnological monitoring of the Rye Water by UCD team.

1993
An Intel supported fisheries enhancement plan is drawn up by Dr Martin O'Grady *(Inland Fisheries Ireland)* in collaboration with Mr John Curtin *(OPW)* and Prof. John Bracken *(UCD)*.

1993
Annual limnological monitoring continues.

1993
PhD study on the fisheries enhancement of the Rye Water *(Kelly, 1996)*, completed in 1995.

1994
Fisheries enhancement programme carried out over a six-week period in July and August.

1994 -1997
Annual limnological monitoring continues.

1997
PhD study evaluates the effects of the fisheries enhancement scheme on other biota of the Rye Water *(McCreesh, 2000)*, completed in 1999.

1998
Annual limnological monitoring continues.

1998
Crayfish survey conducted as part of a PhD study (*McDonnell, 2005*).

1999
Annual limnological monitoring continues.

1999
Master's thesis on chemical and biological monitoring of the Rye Water.

2000 - 2005
Annual limnological monitoring continues.

2005
Further crayfish study on the Rye Water.

2006
Tracking the movement of trout in the Rye Water to assess the factors that influence fish movement,and a comparative assessment of the diet of salmon and trout.

2006 - 2016
Annual limnological monitoring continues.

2016
Pilot study in collaboration with Kildare County Council initiated to improve small tributaries takes place on the Clonshambo tributary of the Lyreen.

2016
Biodiversity meadow established in the north fields of the Intel property.

2017-2019
Annual limnological monitoring continues.

2019
Kildare County Council in collaboration with farmers targeting upper Rye Water near Kilcock, limiting cattle access and protecting riparian habitat.

2020-2021
Annual limnological monitoring continues.

2021
Fish habitat improvement works on the Rye Water along the Intel site.

2022
Annual limnological monitoring continues.

Eurasian blackcap *Sylvia atricapilla*
Credit: Niall T. Keogh

Contents

1. Natural History of the Rye Water 9
2. Intel, Water, and the Friends of the Rye 18
3. Fish Species and Fishery Enhancement Works 26
4. Thirty Years of Fish Studies 38
5. Macroinvertebrates and Water Quality 44
6. Water Quality Improvement Works 52
7. Crayfish 58
8. Birds of the Rye Water Valley 65
9. Meadow for Biodiversity and other Wildlife of Interest 70
10. Fly Fishing on the Rye Water 80

Mallard *Anas platyrhynchos*
Credit: Jimmy Cahill

1. Natural History of the Rye Water

Course of the Rye Water

The Rye Water rises in the flatlands west of Agher Cross, Co. Meath, approximately eight kilometres northwest of Kilcock, Co. Kildare. The source consists of a series of small streams which join together to form the Rye Water.

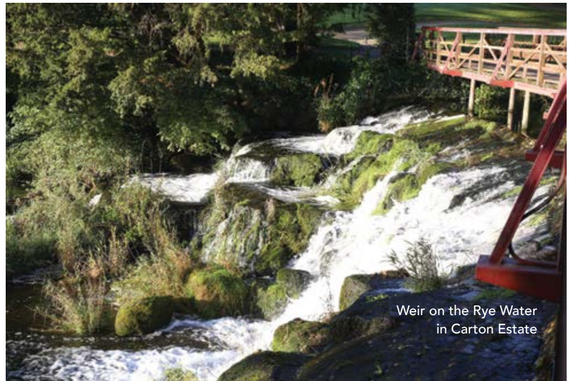
It follows an east-southeast course for ~31 kilometres before joining the River Liffey at Leixlip, Co Kildare.

The Rye Water at Carton Estate

Covering a catchment of approximately 100km^2, the Rye Water drains predominantly agricultural land. The river flows through Carton Estate for approximately 3.5 km where there are two artificial lakes created in the 1800s by the Duke of Leinster.

Deep section of the Rye Water above the weir in Carton Estate

A weir bordering one of the artificial lakes on the estate is thought to impede the upstream migration of salmonids in the Rye Water. The river continues south easterly under a series of bridges and through the lands adjacent to the Intel Ireland facility. It flows under a bridge termed the Aqueduct which carries the Royal Canal and a twin rail track.

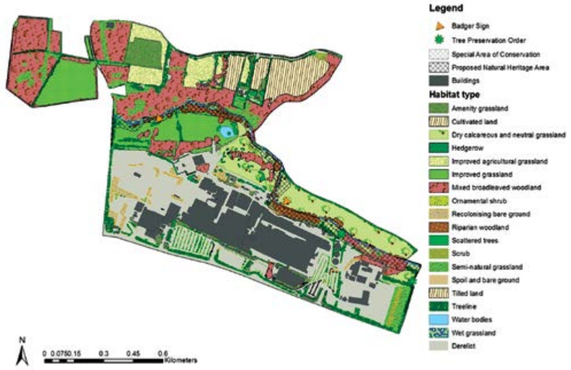


Weir on the Rye Water in Carton Estate

The confluence of the River Liffey and the Rye Water

The Rye Water continues along its course and almost divides the town of Leixlip in two where it passes under the Rye Bridge, west of the main street, and then enters the River Liffey at the round boathouse below Leixlip castle which is only a few hundred metres downstream from the Leixlip hydroelectric dam. Although some sections have been drained in the past, the river is relatively fast flowing for most of its course.

Intel Leixlip Campus Habitat Map
July 2016



Habitats along the Rye Water

Historically, the Rye Water valley was largely agricultural grassland. Much of this land was left fallow, and hedgerows have since matured. The grasslands have also matured, forming improved agricultural grasslands *(Fossit 2000 Code GA1)*. Some areas were planted with native trees including oak, hazel and birch which have now formed broad-leaved woodlands *(WD1)*.

The river had a considerable amount of in-stream vegetation but little vegetated riparian habitat directly adjacent to the stream. This was remedied with the planting of bankside trees, which have spurred a lot of natural regeneration of the riparian habitat. As a result of the construction of the Intel plant several urban habitats have also been formed including an artificial lake/pond *(FL8)*, spoil and bare ground *(ED2)*, and flower beds and borders *(BC4)* presenting a diversity of habitats in the landscape.

Rye Water Valley / Carton SAC *(Site Code 001398)*

A Special Area of Conservation *(SAC)* is a European designation defined in the European Union's Habitats Directive *(92/43/EEC)*, protecting one or more special habitats and/or species. The Rye Water Valley / Carton SAC lies along the Rye Water between Leixlip and Maynooth. It has several rare and threatened plant and animal species *(Anonymous, 2010; NPWS, 2011)*. There are also several protected plant species present in this SAC which include hairy St. John's-Wort (*Hypericum hirsutum)*, the hairy violet *(Viola hirta)* which has not been recorded recently, the green figwort *(Scrophularia umbros)* a Red Data Book listed species and the rare Myxomycete fungus *(Diderma deplanatum)*.

Hairy St. John's-Wort
Hypericum hirsutum

Common spotted orchid
Dactylorhiza fuchsia

Pyramidal orchid
Anacamptis pyramidali

Adjacent to the Rye Water there are also some special habitats that support diverse plant communities, in particular the mineral spring located at the Louisa Bridge. Mineral springs are points at which water wells up to the surface from an underground source, containing dissolved minerals such as salts. A wetland has formed at Louisa Bridge between the spring and the Rye Water. This habitat is considered rare in Europe and is protected under the EU Habitats Directive *(Annex I)*.

The mineral spring was historically diverted to what is essentially an outdoor, open-air bathing pool, known locally as Leixlip Spa.

The mineral spring at Louisa bridge

Charophytes in a pool at Louisa bridge

Wetland formed by the mineral spring

The semi-aquatic snails *Vertigo angustior* and *V. moulinsiana* are found in the marsh habitat around the spring. These species are rare in Ireland and Europe and are therefore listed in Annex II of the EU Habitats Directive.

Credit: Mark Caffrey

Another protected species is the kingfisher *(Alcedo atthis)* which is listed in Annex II of the EU Birds Directive.

Arterial Drainage in the Rye Water

Arterial drainage involves draining a major river channel in order to reclaim water-logged land in the surrounding area. The Rye Water drainage scheme was completed in 1957 in order to provide an increased 344 hectares of land for agriculture within the catchment *(John Murphy OPW pers. comm.)*. In total, 24 km of the main Rye Water was channelised as well as 8km of its tributaries; a relatively small operation in comparison to those conducted on other rivers. The works that were undertaken from above Kilcock to close to Leixlip town are still maintained every 1 to 7 years, mainly to remove silt at Kilcock *(John Murphy OPW, pers. comm)*.

The Rye Water drains a primarily agricultural catchment

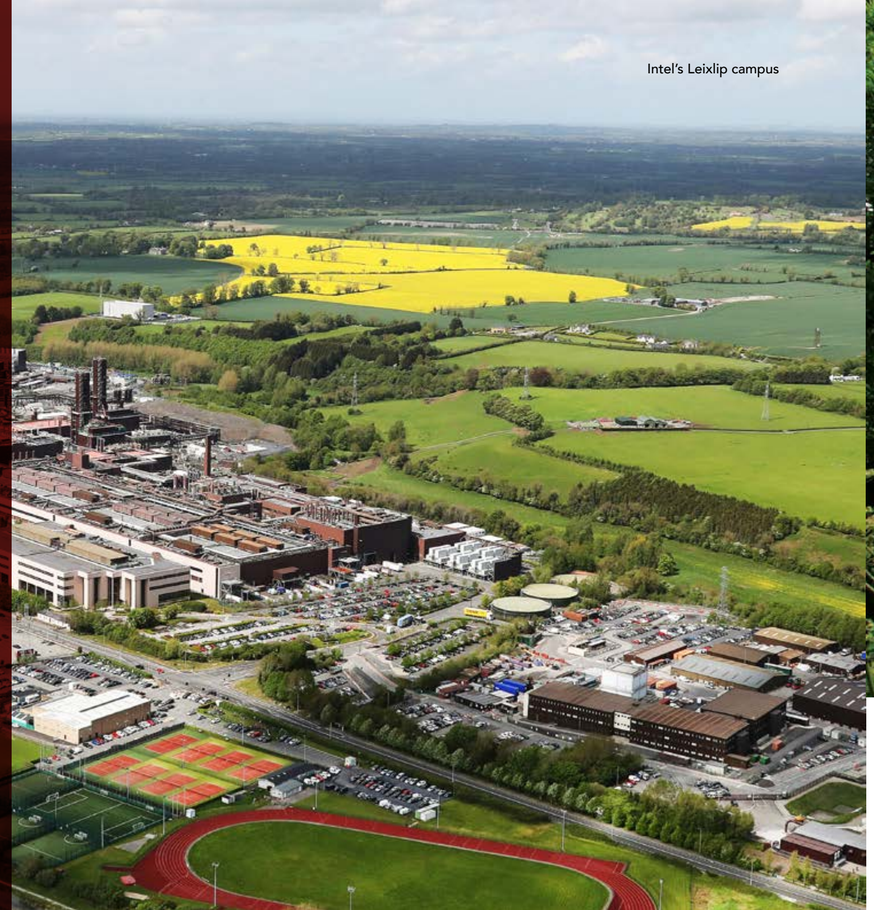
2. Intel, Water, and the Friends of the Rye

Intel in the Rye Water Valley

Intel Ireland's Leixlip campus, located in County Kildare, began operations in 1989. More than €30 billion has been invested in turning the 360-acre former stud farm into one of the most technologically advanced manufacturing locations in Europe.

Since first establishing operations at the Leixlip campus, Intel has been aware of the rich biodiversity contained within parts of its site and also the significance of the Rye Water and its valley. Intel has a long standing commitment to the monitoring of the river through the funding of detailed annual reports that provide extensive information on features of the Rye Water.

This detailed monitoring of the Rye Water, one of the longest running continuous freshwater assessments of salmonid populations, reached an important milestone in 2022 as it was the 30th year of reporting.



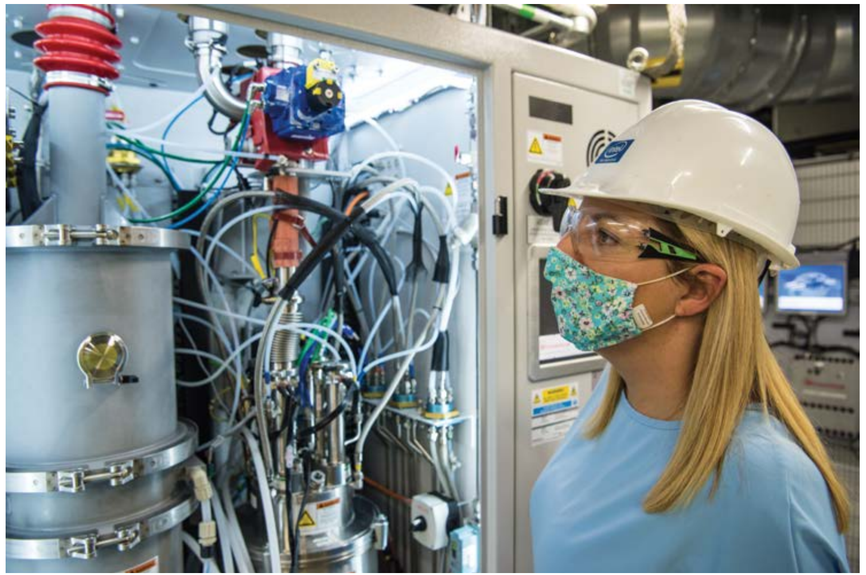
Intel's Leixlip campus

Water usage at the Intel Leixlip campus

Although the Rye Water runs along the back of Intel's Leixlip campus, Intel does not abstract any water from it. In fact, the majority of water supplied to the Leixlip facility comes from the River Liffey via the water treatment plant in Leixlip. Approximately 87% of this water is returned to the Leixlip wastewater plant where it is treated before being returned to the River Liffey.

Intel uses approximately 750 million litres of water per month at their Leixlip site in order to manufacture its microprocessors - miniature electronic devices that are found in a variety of digital technologies from personal computers to mobile devices and servers. The primary use of this water in the manufacturing process involves rinsing the surface of the silicon between each step in the operation.

As these microprocessor chips become more complex, so does the manufacturing process, and therefore an increasing amount of ultra-pure water is required. Water is also used on site in Leixlip to support employees onsite and other manufacturing processes such as humidification, cooling, and scrubbing emissions.



A retention pond at Intel

Intel's Environmental Health and Safety *(EHS)* team works with the Environmental Protection Agency *(EPA)* to oversee water management at the Leixlip campus. There are three key aspects of Intel's water management system:

1. Storm water is water originating from rain falling onto the campus on roofs and hard surfaces such as roads and paths. All storm water within the river valley eventually ends up in the Rye Water, including that which falls on agricultural fields and hard surfaces within Intel's Leixlip campus. A number of protective systems have been put in place on campus to ensure that there is no discharge of contaminants to the Rye Water. The retention pond is the final step in a series of mitigation measures and has a capacity to collect three million litres of storm water. Intel continually monitors the flow of water out of the pond and conducts regular water quality analyses.

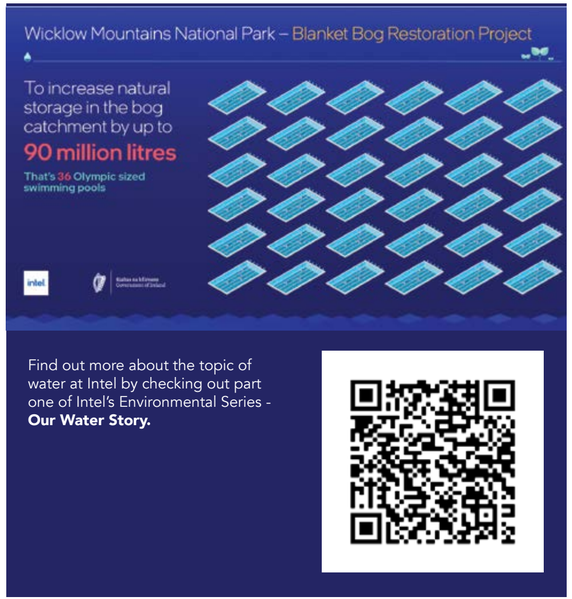
2. Ground water, the water beneath the Earth's surface, is also managed passively, i.e. it is not actively treated, but it is monitored to ensure there are no adverse effects from Intel's operations.

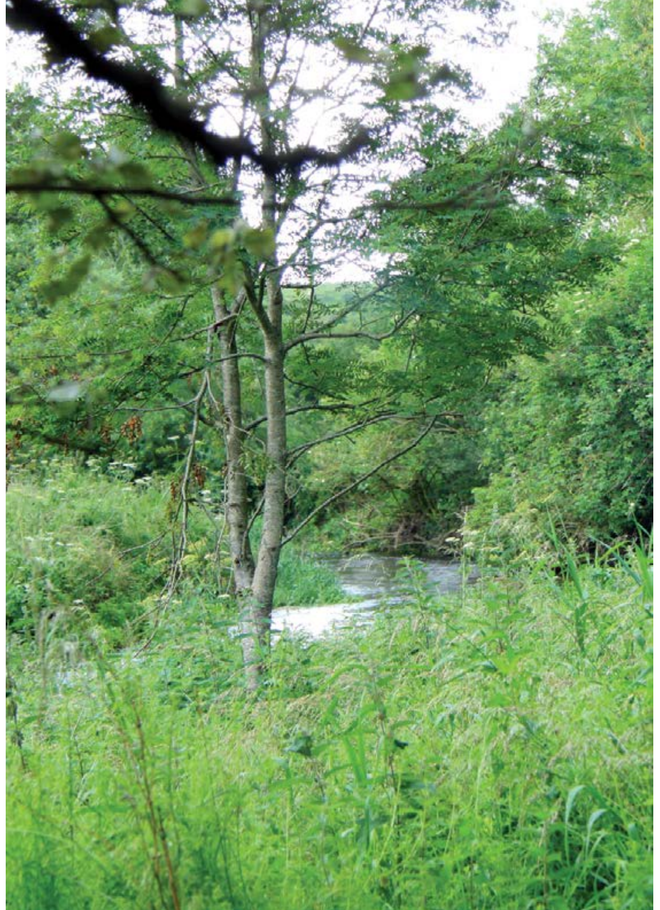
3. Wastewater generated during the manufacturing process is known as process effluent. Before this wastewater is discharged to the local wastewater treatment plant, it is pre-treated onsite to ensure that it meets discharge requirements. Intel has a strict monitoring programme in place to ensure compliance with environmental licence requirements.

Intel's Lisa Harlow at a blanket bog in the Wicklow Mountains National Park

Intel is working towards net positive water use by 2030. This means that by 2030, Intel aim to put more water back into the system than is taken out. This will be achieved through a combination of water conservation and restoration works, such as the blanket bog restoration project in the Wicklow mountains.

In May 2021, Intel Ireland launched, together with the National Parks and Wildlife Service, a blanket bog restoration project in the Wicklow Mountains National Park





The Friends of the Rye

When Intel Ireland first located on its site, the Rye Water was at risk due to large overgrowth of aquatic plants as a result of heavy silting which destroyed the natural fish habitat. Only a few salmon spawning beds had managed to survive the siltation and bankside erosion. Intel recognised their potential to improve the Rye Water and since 1994, they have sponsored many rehabilitation works in order to enhance its potential as natural salmon and trout habitat. As a result of partnerships formed through the rehabilitation project, the 'Friends of the Rye' group was established.

The Friends of the Rye group is a great forum to discuss the current state as well as future plans for the river. It has representatives from many of the stakeholders such as Inland Fisheries Ireland, Leixlip district anglers, the riparian owners, local authorities, and AQUENS Ltd. This group meets regularly and is interested in the welfare of the Rye Water catchment and its management.

Members of the Friends of the Rye

Leixlip District Angling Association
As represented by Aidan Crean

Ryevale Lawns Residents Association
As represented by Denis McCarthy

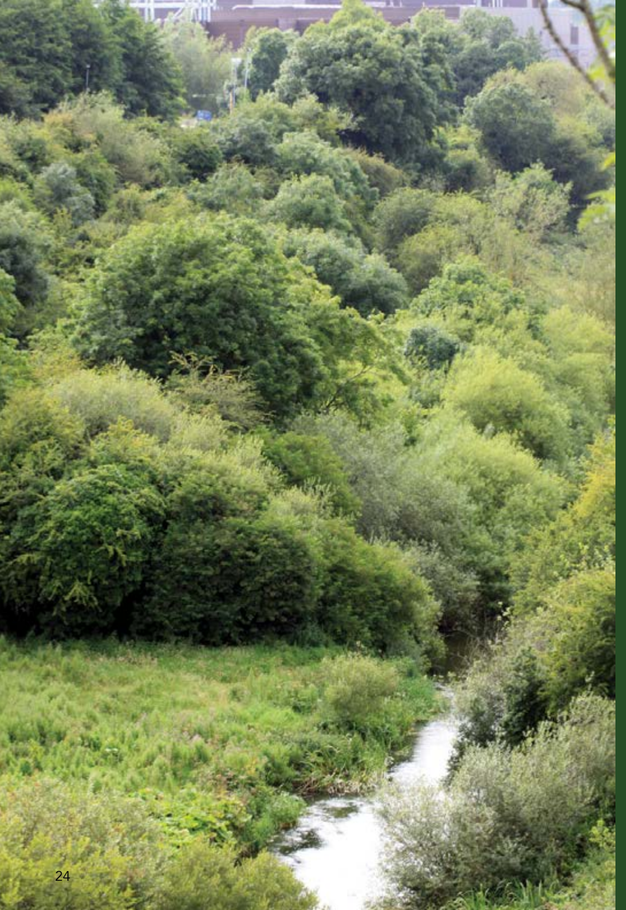
Kildare County Council
As represented by Gavin McDermott

Inland Fisheries Ireland
As represented by Fergal Caffrey

Intel Ireland
As represented by Lisa Harlow and Conor Halpin

AQUENS Ltd.
As represented by Mary Kelly-Quinn and Jan-Robert Baars

Carton House
As represented by John Plummer



Reflections from Friends of the Rye

Fergal is an assistant inspector with Inland Fisheries Ireland, some of his duties include patrolling rivers managing habitat projects and carrying out electro fishing surveys.

"From an Inland Fisheries perspective, the river is critical for maintaining a healthy stock of salmon in the wider Liffey catchment, because of the many challenges this fish species face at present.

As well as having a representative on the Friends of the Rye, IFI provides assistance to AQUENS Ltd. with the annual survey by conducting electrofishing. IFI also has an important role in remaining vigilant on water quality issues as well as providing advice and assistance with habitat restoration projects such as gravel raking.

Personally, it's great to be involved in the electrofishing aspect of the annual limnological monitoring. At this stage, the electrofishing survey is a fixture in our calendar. The survey must be the longest running study on the east coast of Ireland and provides invaluable data on the Rye Water from a fisheries perspective. I've been involved for nearly 20 years and It's been a very interesting journey to see the cyclical fluctuations of juvenile trout and salmon populations on the river."

Fergal Caffrey
Inland Fisheries Ireland

Aidan is the founding member of Leixlip and District Anglers Association and chairperson for almost 30 years.

"The L&DAA was founded in 1990 and was, we believe, one of, if not the first local organisations to contact and form a relationship with Intel Ireland. That relationship continues to this day not least in our participation in The Friends of The Rye group. This group has been and continues to be, in our opinion, vital to the river and the overall river environment. Its environmental and biodiversity ethos has not only maintained but also improved the Rye Water and its immediate environment. L&DAA would like to thank Intel for hosting this group and all the other stakeholders involved in it for their vital contributions.

We look forward to hopefully being involved with the Friends of The Rye long into the future and the continued good health of our beautiful river."

Aidan Crean
Leixlip and District Anglers Association

Lisa Harlow is the External Relations Manager for Intel Ireland and is a founding member of the Friends of the Rye River and today continues to facilitate the meetings on campus.

"I am very passionate about the environment, particularly biodiversity. I live in Leixlip I get to fully appreciate the work of the Friends of the Rye River. Being a member of this group has shown me how the combined efforts of industry, local authority and community can positively impact on the water course. The members have one passion which is the health of the Rye Water. Over recent years we have focused our efforts on projects upstream to help improve the health of the catchment. I would like to recognise the dedication of the members and I look forward to working with them in the future and what we can achieve."

Lisa Harlow
Intel Ireland

Gavin McDermott is a Senior Executive Technician in Kildare County Council's Environment Section working on the enforcement of environmental legislation aimed at protecting and improving both surface water and groundwater quality.

"I have represented Kildare County Council on the Friends of the Rye group since 1998 and over the years have seen this fantastic river withstand the growing pressures on water quality from many sources. Water quality trends will no doubt influence how future legislation is framed but we must be reminded that without the different statutory bodies and organisations working together the task of achieving good status objectives will be more difficult. The catchment area of the Rye Water is set within a difficult landscape making water quality management very challenging but by focusing on the right measure in the right place and with the full cooperation of the relevant stakeholders small improvements can be achieved. I look forward to participating in the valuable work being done by the Friends of the Rye."

Gavin McDermott
Environment Section
Kildare County Council

John Plummer has been the Golf and Resort Superintendent at Carton House for the past 22 years. As such he has had a pivotal role in maintaining 3.5 km of the Rye Water that runs along the Estate and its associated Special Area of Conservation.

"The one constant that Carton estate has had since the 11th century is its waterway. We have always had a great interest in it from an amenity point of view and as a natural habit. We are lucky to have the Friends of the Rye, which brought together everyone involved in the river in one forum. From my observations, the water quality has had peaks and troughs, but overall it is improving. Everybody measures the quality of an establishment by its waterway, and so when you look at the water and it's clean, there is good fish life and insect life, it means something is going right. We would like to think that it is a sustainable, well managed, well cared for waterway."

John Plummer
Carton House

Jan-Robert Baars is a director of the campus based company AQUENS Ltd., an environmental consultancy which was first established by John Bracken, Declan Murray and Mary Kelly-Quinn of UCD.

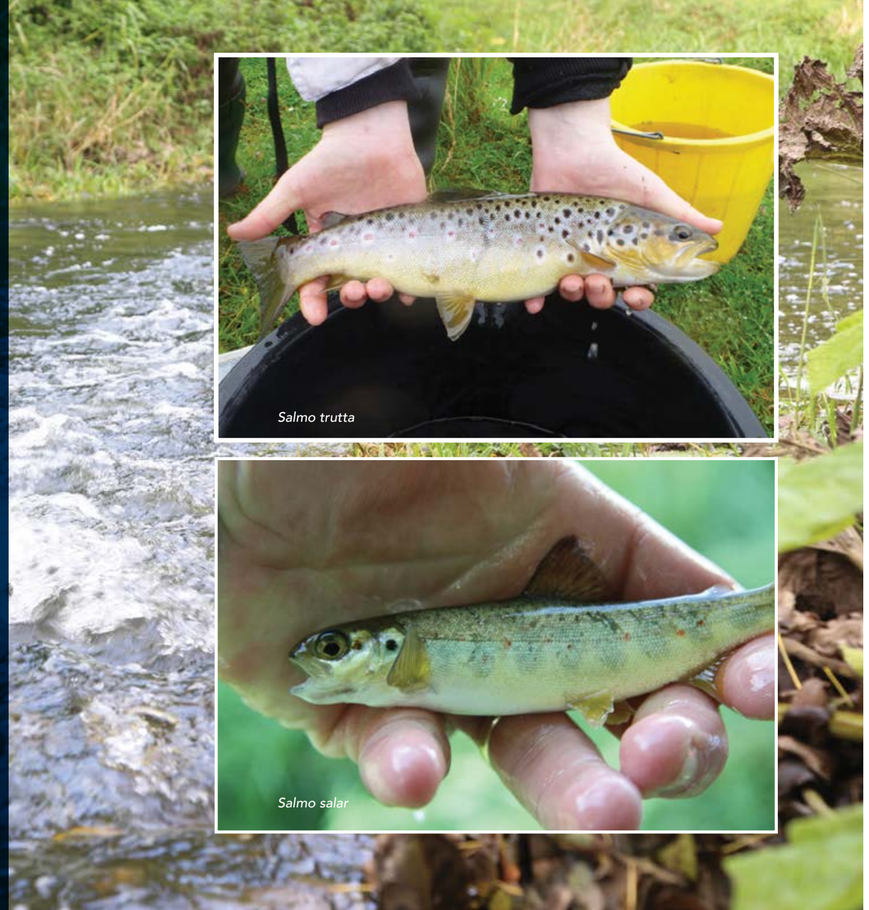
"Commissioned by Intel, our environmental consultancy has been associated with the monitoring of water quality and fish populations in the Rye Water for the past 30 years. Since the time our company was first established by John Bracken we have been associated with University College Dublin and the then Department of Zoology. Over the years the Rye Water has been the subject of many ecological studies which have led to a better understanding of its fish, insects and invertebrates and their response to environmental pressures. The monitoring over the years has been an excellent training ground for our undergraduate and post-graduate students at UCD, and provided valuable and memorable field experiences since 1993. We are proud to be part of the Friends of the Rye and benefited enormously from the collaborations with its partners."

Jan-Robert Baars
AQUENS Ltd.

3. Fish Species and Fishery Enhancement Works

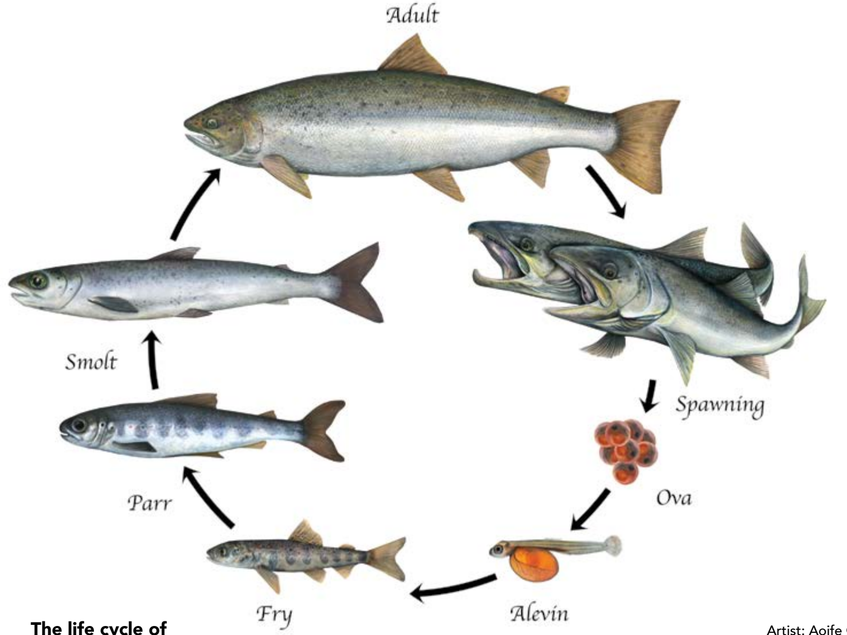
Brown trout *(Salmo trutta)* and Atlantic salmon *(Salmo salar)* are closely related species from the family of fish known as Salmonidae.

These slender colourful fish require clean water to thrive and shallow rivers and streams in order to lay their eggs and reproduce successfully.



Salmo trutta

Salmo salar



The life cycle of Atlantic salmon.

Artist: Aoife Quinn

A rare sight - A sea run salmon caught during an electrofishing survey on the Rye Water

The life cycle of brown trout and salmon are quite similar in the early years. Both deposit eggs into clean, loose gravel beds during the winter months. The eggs remain in these gravel nests or redds, lodged between the small stones free of sediment, until the fry hatch. The redds can be easily distinguished amongst undisturbed gravels and are most noticeable in the early winter months.

Fry emerge during spring, and after initially living off the remaining egg yolk they feed on small invertebrates. While some brown trout migrate downstream to lakes or the sea, the majority tend to remain in the river all their life. In contrast, salmon live for the first two years in the river and then migrate to sea as two year old fish. The salmon return to their native river to spawn after a period at sea. Although they can occupy similar stretches the juvenile salmon are usually found in the faster flowing sections (riffles and fast glides).

Salmonids are very opportunistic and largely feed on invertebrates that live in the water or become trapped on the water surface. Much of the diet comes from the adult stages of aquatic and terrestrial insects, such as true flies, especially during the summer months. Only larger brown trout feed on other small fish, such as minnows, and freshwater crayfish.

The Rye Water provides suitable habitat for both salmonid species. Various Intel sponsored rehabilitation works and routine enhancement works by inland Fisheries Ireland conducted throughout the years have improved the habitat for the various life cycle stages.

Other fish species in the Rye Water

Pike *(Esox lucius)* prefer sluggish rivers and streams with areas of dense vegetation but are not very particular and may generally be found in any fish-holding body of freshwater.

The stoneloach *(Barbatula barbatula)* has similar habitat preferences to salmonids, requiring gravel and fast flowing rivers. The 3-spined sticklebacks *(Gasterosteus aculeatus)* like the cover provided by vegetation

Minnows shoaling

and a muddy or sandy riverbed. Minnows *(Phoxinus phoxinus)* are a small shoaling species that are common in all fish-holding water bodies in Ireland and they are particularly abundant in the Rye Water.

The three aforementioned species are commonly known as *"pinkeens"* in Ireland and may act as prey species for larger trout.

Left: 'Critically endangered' freshwater eels *(Anguilla anguilla)* are regularly encountered in the Rye Water. They live in freshwater but migrate to the sea to breed

Rainbow trout *(Oncorhynchus mykiss)*, an invasive species, are only rarely found in the Rye Water. They are more tolerant of warmer, poorer quality waters than the native brown trout.

Above: River lamprey *(Lampetra fluviatilis)* are primitive jawless fish of conservation interest which inhabit coastal waters as adults but spawn in fast-flowing rivers where the juveniles mature and eventually migrate to the sea

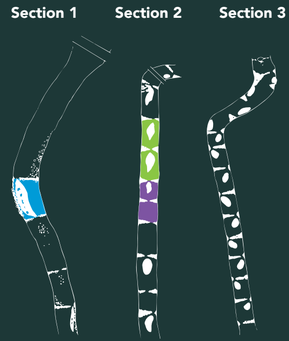
1994
Fishery Enhancement Works

In 1994 a fisheries habitat enhancement programme was initiated by Dr Martin O'Grady, Inland Fisheries Ireland, in collaboration with the Office of Public Works and funded by Intel Ireland on a 2.5km stretch of the Rye Water downstream of Sandford's Bridge. The enhancement work involved considerable physical alteration of the river bed and banks with the objective of increasing water depth, improving spawning gravels and creating more natural sinuous flow with adequate pool depth to support older fish *(O'Grady and Curtin, 1993)*. The works also aimed to protect the river banks from erosion and enhance the riparian vegetation. Thirty two new pools were constructed and eight existing pools were enlarged.

The enhancement works defined the three areas for future monitoring. Within each there was a control (i.e. no in-stream improvement works) and experimental reach. Over the years the benefit of the enhancements influenced the whole fish population across the stretches and as a result the monitoring now assesses the fish over a 600m stretch of the Rye Water.

Before the Fisheries Enhancement works

Credit: John Bracken (1994)



After the Fisheries Enhancement works

Aerial photograph of a stretch of the Rye Water at the back of Intel Ireland after the enhancement works. The works are described in more detail in Kelly *(1996)* Fisheries Enhancement of the Rye Water – a Tributary of the River Liffey. PhD Thesis, University College Dublin

Credit: John Bracken

2021
Gravel introduction and raking

Salmonids require clean loose gravel beds in which to deposit their eggs in the winter. Over time, these gravel beds become clogged with fine sediment which is less suitable to incubate the eggs of fish. In a 300m stretch of the Rye Water, where the gravels became unsuitable over time, enhancement works were conducted in September 2021 to improve the spawning habitat for both trout and salmon. Gravel was introduced to two distinct stretches measuring approximately 10m in length. First, a digger disturbed the existing substrate, freeing the silt and sand trapped between the cobbles which was reducing both the spaces within the substrates and oxygen available for macroinvertebrates and salmonid eggs. After this, gravel was introduced.

A digger disturbing the sediment at a gravel introduction site

Introduction of gravel to the Rye Water

Before gravel introduction site

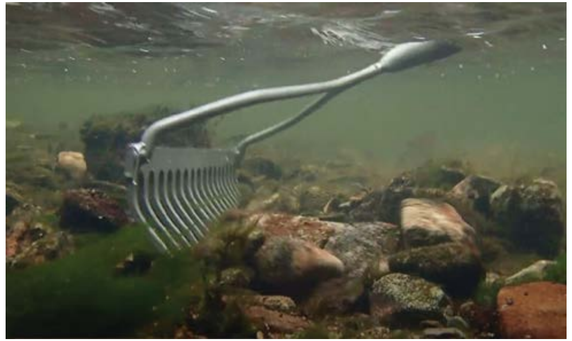
After gravel introduction site

The river bed after the introduction of gravel, showing loose cobbles which are not embedded with fine sediment - perfect for spawning salmonids

Raking also occurred on two ~10m stretches of river with the goal of agitating and freeing embedded sediments.

Ecological surveys were conducted before and after the works in order to determine the effect of the gravel introduction and raking on river fauna, algal composition and sediment particle size. The sites with gravel and raking were compared to sites left untreated which provides a method to assess the effectiveness of these enhancements over time.

Inland Fisheries Ireland and AQUENS Ltd. staff raking sediments in the Rye Water



A modified Surber sampler was used to quantify the presence of certain particle sizes on the riverbed

An algal torch was used to assess algae on rocks taken from the river

4. Thirty Years of Fish Studies

Electrofishing on the Rye Water

An electrofishing survey of the Rye Water was first conducted in 1992, prior to the implementation of the initial fishery enhancement works *(Kelly, 1996)*. A 2.4km stretch of the river was electrofished qualitatively to determine the composition and distribution of the fish present before works began.

A post enhancement quantitative assessment of the fish population was then conducted between 1994 and 2006 over three stretches of the Rye Water located downstream of Sandford's Bridge. Nine sites in total, divided into control and experimental sections, were fished on an annual basis during this period.

In 2007, tthe number of sites surveyed was reduced to seven by exclu ding the two most upstream sites. Thus, a significant proportion of the original sites surveyed in the years prior to this were retained and have continued to be surveyed on an annual basis, providing a valuable long-term dataset.

A stop net ensures fish do not escape downstream

Despite the image we think of when we hear "electrofishing", the scientific community generally considers it to be the most benign and effective way to survey freshwater fish populations *(Snyder, 2003)*. It involves creating an electrical field in the water by submerging electrodes. This electrical current stuns affected fish, allowing them to be caught easily with a handheld net. While backpack-mounted systems may be used for smaller streams, Inland Fisheries Ireland utilises a boat-mounted electrofishing setup on the Rye Water.

Control and experimental stretches were selected to assess how the salmonids would respond to the rehabilitation works. Most stretches were approximately 100m in length and represented several riffle-run-pool sequences. Stop nets are placed at the beginning and end of each stretch before fishing to ensure that fish do not escape downstream. Each stretch is fished three times as this allows a statistical method known as "depletion sampling" to be used in order to estimate the total population size. Once Inland Fisheries Ireland completes one of their runs through a stretch, the fish are handed off to personnel from AQUENS Ltd., who measure, weigh and where necessary, take scales from the fish to age them. The fish are held in well oxygenated, cool water before these measurements are carried out. Once processed, the fish are held in keep nets upstream in the river *(right)*, until IFI have finished fishing the nearby stretch. They are then returned to the river.

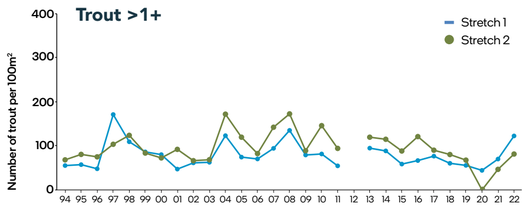
A small sample of scales is taken from the fish to determine their age. The concentric rings on these scales can be used to age the fish, much like the rings of a tree. Growth during the cooler times of the year result in rings clustering together as indicated by the arrows in the adjacent photos a. >1 year old fish *(1+)*, b. >2 year old fish *(2+)*

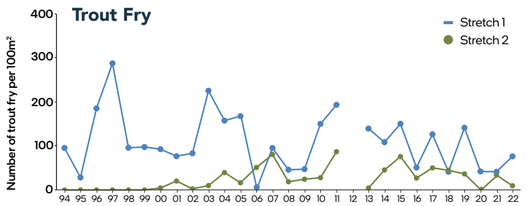
Trends in Salmonid Stocks

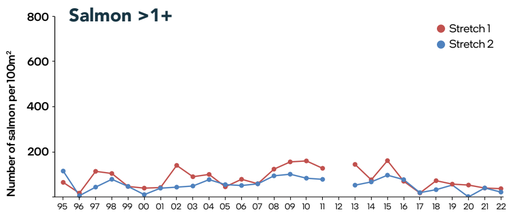
It is clear from the long-term trend results presented below that both the trout and salmon fry responded, rapidly increasing in density after the rehabilitation works. There are no clear differences between the control and experimental stretches as these contiguous stretches have benefited from the changes made to the river habitat as a whole.

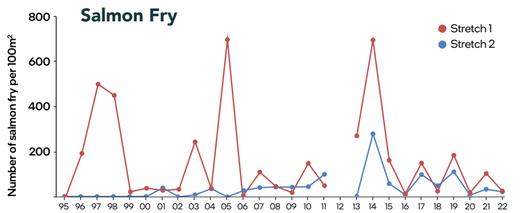
The Rye Water supports a healthy stock of both brown trout and salmon. The river is considered to be very productive and fish densities are relatively high. As with most fish, an abundance of eggs are produced by the adults to overcome the naturally low survival rates of the juvenile stages, such as eggs and fry. Their survival is dependent on many factors including the environmental extremes that the eggs and fry experience. Factors such as low oxygen levels, low water quality, high water temperatures, flood events, drought and heavy siltation can all affect the survival of these particularly vulnerable stages. The eggs and fry are also prey to many species such as the great diving beetle, damselfly larvae and larger animals such as birds, mink and older fish.

It is clear from our survey results, as presented in the graphs *(below)*, that the numbers of fry in particular, fluctuate considerably from one year to the next with no discernable pattern. Salmon fry numbers reached very high densities from time to time, as indicated in the 1997/98 and 2005 surveys. The trout fry also peaked in some years but did not reach densities as high as the salmon fry. On average over the 27-year period trout fry were more abundant. The long-term data show that despite the occasional high fry numbers of both salmon and trout the older fish population did not increase as a result. It appears that the abundance of 1+ fish (the age class that should respond most to the previous year's fry numbers) remains relatively stable.This could suggest that the fish population has reached carrying capacity under the current environmental conditions. The surplus fry may act as food for other animals in the Rye Water or may move downstream to populate the main Liffey which has a good stock of wild brown trout and salmon downstream of Leixlip. Further improvement in the water quality of the Rye Water may increase the salmonid carrying capacity in the future.







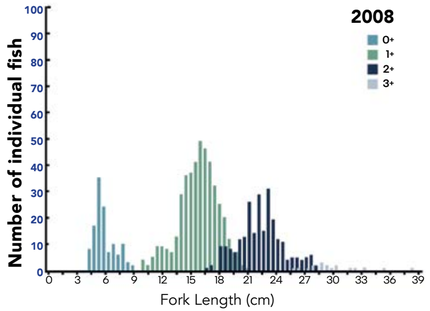


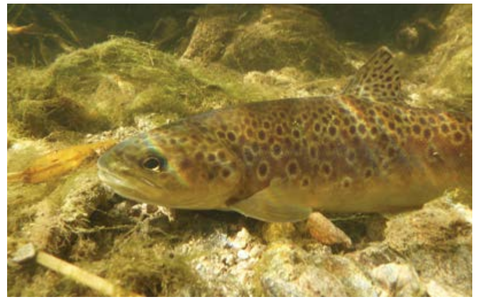
Trout

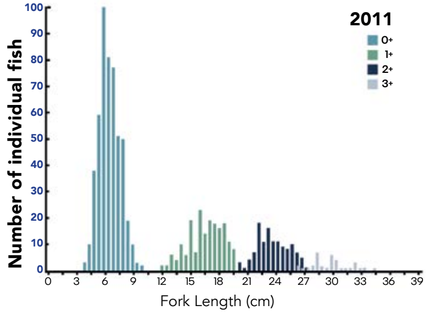
The trout in the Rye Water are generally represented by four age classes.This includes the fry (0+) that have hatched early in the year and 1+, 2+ and 3+ fish. On some occasions 4+ fish are encountered, but these are generally exceptional.

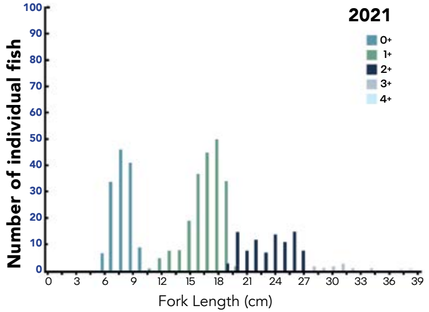
The proportion of fry fluctuates annually. In some years fry made up only a small proportion of all the fish and in others the fry dominated the population. The older fish population structure is generally more stable with a higher number of 1+, fewer 2+ and fewer again 3+, i.e. 1+ > 2+ > 3+. While some of the variation in numbers can be attributed to the movement of salmonids between stretches, it is apparent nevertheless that overall abundances fluctuate from year to year.

The trout have been usually in good condition and attained lengths of about 10cm, 19cm, 27cm, and 33cm at 0+, 1+, 2+, and 3+ years, respectively. Fish attaining such lengths are indicative of a productive river where the conditions, such as water quality and food availability, supports fast growth.







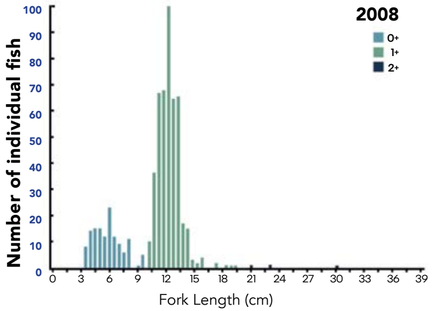


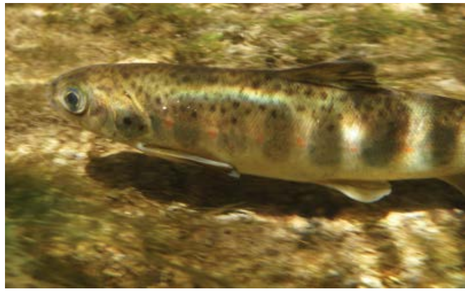
Salmon

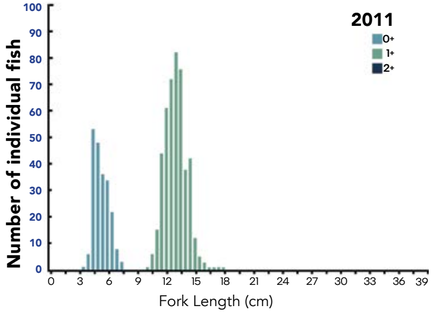
The salmon in the Rye Water, like most Irish rivers, are represented by a smaller range of age classes depending on the time of year. Eggs usually hatch in March and the fry become progressively more noticeable later in the growing season. Fry surviving the first year persists as 1+ fish throughout the following year.

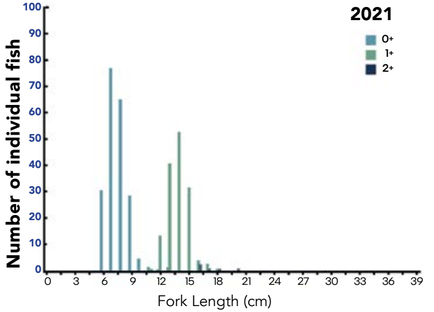
The salmon tend to be smaller than the trout attaining length of about 6cm, 13cm, and 23cm at 0+, 1+, and 2+ years, respectively. Salmon usually remain in the river for only two years and then migrate to the sea as smolts in spring and early summer. Adult salmon return to the river after a variable period of time at sea in order to spawn and complete their life cycle. The timing of the salmon run is influenced by flood events but usually occurs in the autumn and the early winter months. The survey results presented here are based on summer assessments, and indicate that the population at this time consisted of fry and 1+ fish. On occasion, a few smolts *(2+)* that still remain in the river are encountered.

Due to the timing of the survey adult salmon are usually not captured, although on one occasion two adult salmon were caught in one of the large pools constructed during the rehabilitation works. Adult salmon can usually be seen in the larger pools during the winter months.





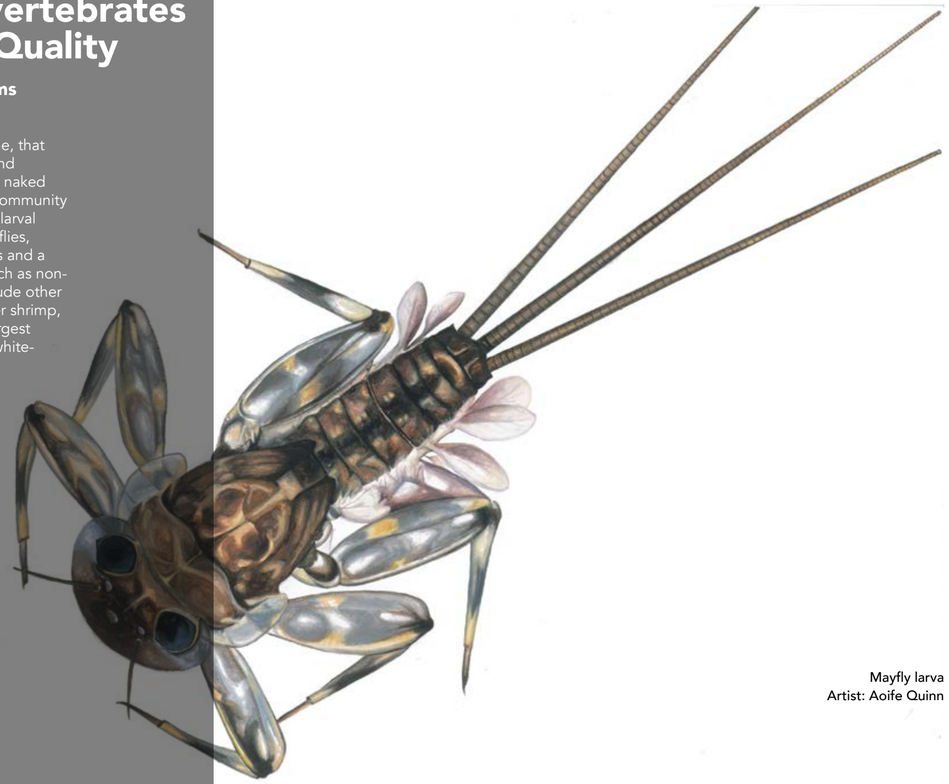




5. Macroinvertebrates and Water Quality

River-dwelling organisms

Macroinvertebrates are small organisms, lacking a backbone, that live on the bottom of rivers and streams and are visible to the naked eye. The macroinvertebrate community is typically dominated by the larval stages of insects such as mayflies, stoneflies, caddisflies, beetles and a variety of other fly species such as non-biting midges. They also include other non-insects such as freshwater shrimp, snails, worms and Ireland's largest freshwater invertebrate, the white-clawed crayfish.



Mayfly larva
Artist: Aoife Quinn

Larval *Baetis rhodani*

Adult *Ecydyonurus venosus*

Oligochaeta worm

Adult *Siphonoperla torrentium*

Macroinvertebrates are important to the river ecosystem on several different levels and form an important component of the aquatic food chain. Supporting this food chain in the Rye Water are the primary producers like the algae *(attached to all the surfaces as the slimy layer on rocks or as filamentous strands)* and the in-stream vegetation such as fool's-water-cress or bur-reed, which along with plant material introduced from the riparian habitat *(the strip of vegetation along a river bank)*, are eaten by the grazing and shredding macroinvertebrates. In turn the macroinvertebrates are a food source for larger animals such as fish.

Many bird and mammal species live near rivers because they provide a rich source of food in the form of fish and macroinvertebrates. The Rye Water is particularly productive, supporting a diverse number of macroinvertebrate species which sustain a healthy salmonid fish community.

Gammarus shrimp

Glossosomatidae caddisfly larvae

Blackfly *Simuliidae* larvae

Common blue damselfly
Enallagma cyathigerum

Larval *(left)* and adult *(right)* forms of the stonefly *Perla bipunctata*

Larval *(left)* and adult *(right)* forms of the mayfly *Heptagenia sulphurea*

Aquatic habitats are intricately linked to the surrounding terrestrial land as organisms from both habitats are interdependent. Many small invertebrates such as spiders inhabiting areas near rivers feed on the adult stages of aquatic organisms and these in turn provide food for those that live in the water. For example, a large proportion of a fish's diet is often made up of terrestrial insects that fall into the water.

Terrestrial insects such as grasshoppers may fall into the water and become food for fish such as trout whereas the adult forms of aquatic insects such as the stonefly *Leuctra fusca* may become food for birds

Common green grasshopper
Omocestus viridulus

Adult stonefly
Leuctra fusca

Macroinvertebrates as bioindicators

River-dwelling organisms have been used worldwide for over 50 years to detect water pollution and provide a measure of water quality. The term "bioindicator" is used to describe these organisms and among the most commonly used are invertebrates.

Macroinvertebrates are used as bioindicators as they are numerous and all the species vary in the way they tolerate different types of pollution. Many invertebrates are present in the water for months to years and are exposed to the conditions of the water throughout their immature life cycle. Although they may remain unharmed during a short exposure to a pollution event they rely on the prevailing conditions to be suitable for their food, growth and reproduction. As a community the macroinvertebrates therefore provide insight into the past water quality of the river as those most sensitive to pollution are lost in impacted rivers. In contrast, chemical analysis of water samples only provides a snapshot in time and may miss intermittent or diffuse pollution events that singularly or in combination prove toxic to aquatic organisms.

The gradient of response to pollution by macroinvertebrates has been incorporated into scoring systems that aim to classify a water course into water quality bands. One such scoring system developed in Ireland by the Environmental Protection Agency *(EPA)* is known as the Q-value system. This ranges from Q5 *(unpolluted / high status)* to Q1 *(serious pollution / low status)*. Intermediary values of moderate pollution e.g. Q2-3 may also be used.

Caddisfly
Sericostoma personatum

Adult mayfly
Alainites muticus

Adult four-spot chaser dragonfly
Libellula quadrimaculata

Subimago adult mayfly *Ephemera danica*

The Q-value system has been utilised on the Rye Water for the past 30 years to establish the water quality. Initially water quality was assessed at a small number of sites located along the Rye Water. With increasing concern to determine what the source of pollution was in the Rye Water catchment, sites monitored were increased to 27 taking into account the smaller tributaries that drain into and thereby influence the water quality of the Rye Water.

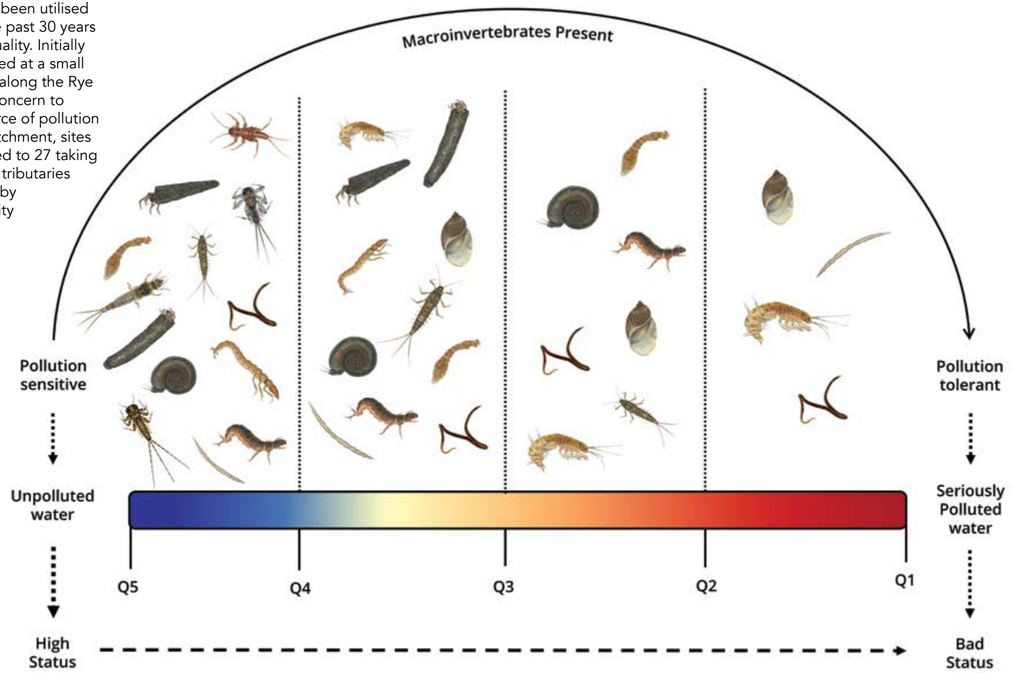


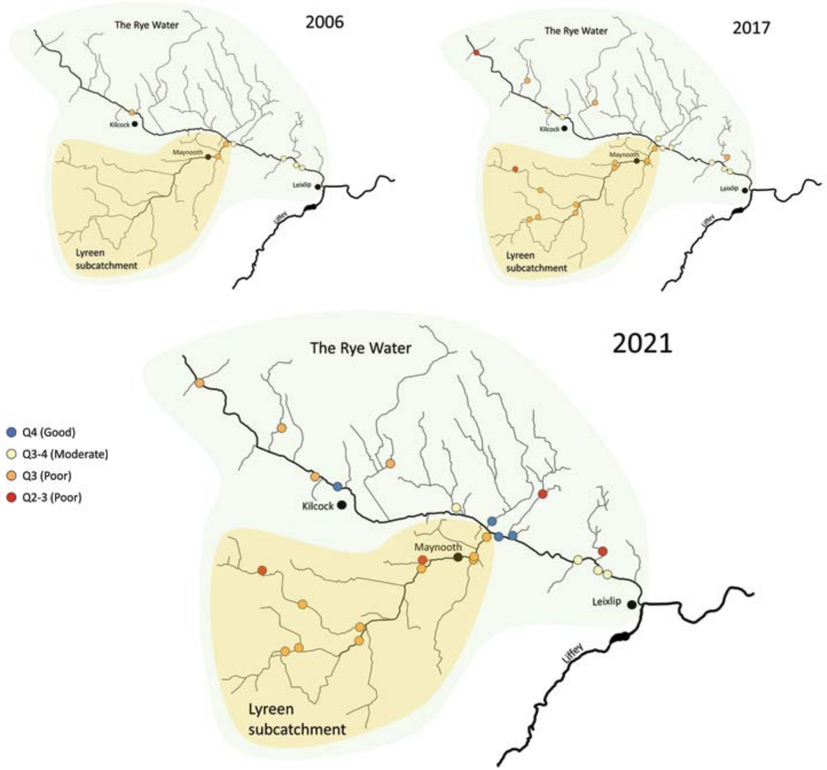
Illustration on the response of macroinvertebrates to water pollution. As a stream's water quality deteriorates, more and more of the sensitive macroinvertebrate groups are lost, with Q1 rivers containing only pollution tolerant shrimp, worms and snails

Macroinvertebrate illustrations by Aoife Quinn

Trends in the water quality of the Rye Water Catchment

The national monitoring scheme implemented by the EPA shows that the Rye Water catchment has a long history of poor water quality. The catchment, as discussed earlier in the book, drains a complex, predominantly agricultural landscape with a significant influence from urban, densely populated areas and rural dwellings. The environmental pressures in the catchment as a result are varied and need to be addressed to improve water quality.

The water quality assessments conducted on an annual basis on behalf of Intel Ireland have shown that the main Rye Water channel and one of its main subcatchments the Lyreen, have remained moderately polluted and at best slightly polluted. In the Q-value system this meant values ranged from Q2-3 to Q3-4. The combined influence of each tributary impacts the water quality of the Rye Water, and as a consequence the monitoring was extended into the main tributaries to identify where pressures on water quality were located. Various stakeholders and local authorities (like Kildare County Council) have long been trying to address pressures where the chemical signal of the water suggested a potential pressure.

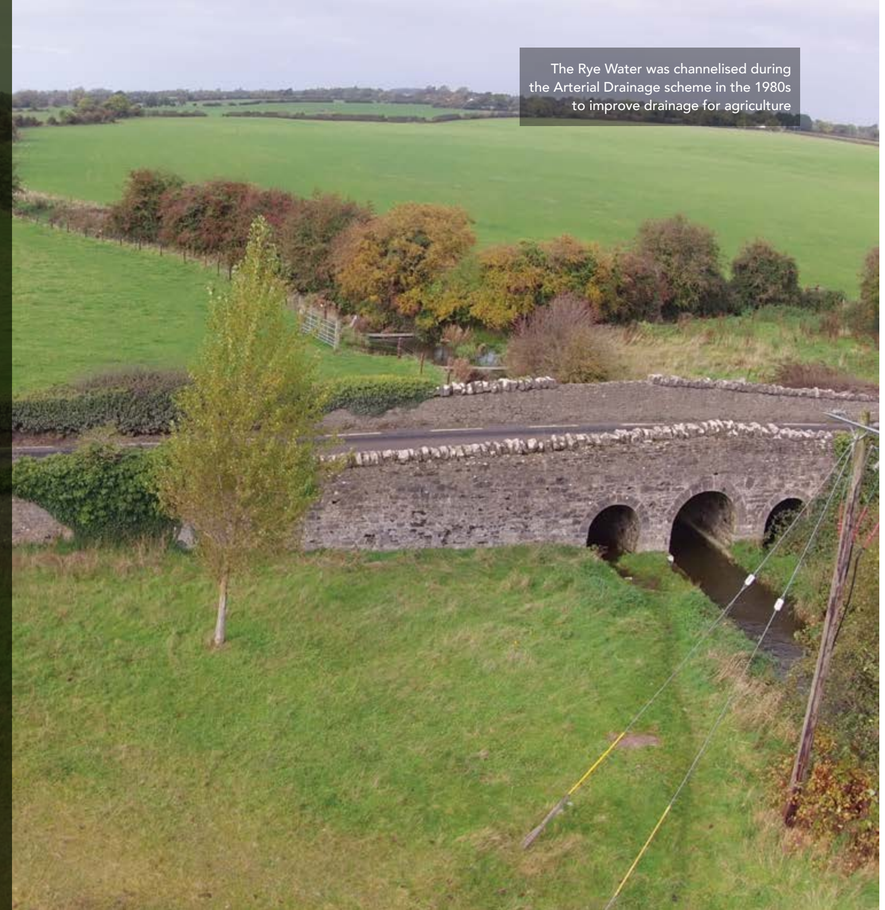


6. Water Quality Improvement Works

Monitoring reveals water quality issues on the Rye Water

As disclosed in the previous chapter, water quality monitoring of the Rye Water and its tributaries indicates that almost the entire channel length is of 'poor' or 'moderate' ecological status. While the Water Framework Directive requires that 'good' status be achieved in all water bodies in Ireland, only 4 of 25 sites on the Rye Water achieve such a status. Poor water quality in the Rye Water system is the result of numerous different pressures, some of which can not feasibly be managed.

For example, some streams have been heavily modified *(channelised with steep banks)* in order to improve drainage for the surrounding agricultural land and to avoid flooding further downstream. Other pressures, such as cattle having direct access to streams and degraded riparian habitats can be tackled more effectively.



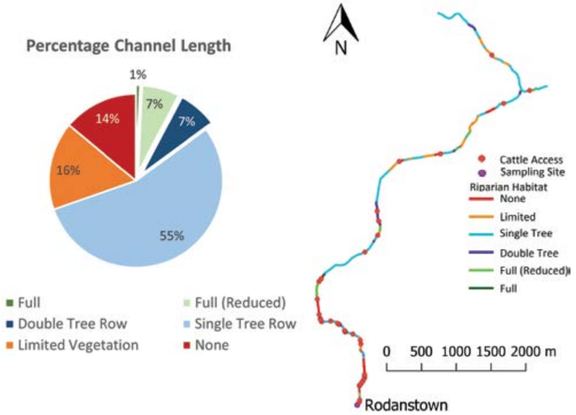
The Rye Water was channelised during the Arterial Drainage scheme in the 1980s to improve drainage for agriculture

Although the water quality has improved in recent years along some parts of the Rye Water, achieving a Q4 status, the vast majority of the channel length of the catchment represented by the small streams is still at times achieving poor water quality. Some small tributaries have improved to a Q4 on a few occasions but their small volume makes them particularly vulnerable to even small pollution inputs. In the agricultural landscape much of the channel has either no or limited riparian habitat that might buffer these small water bodies from pollution. Furthermore, where lands are used for grazing a significant length of channel seems to be accessible to cattle.

Scientific literature informs us that poor water quality in agricultural catchments may result from degraded riparian areas and a high number of areas where cattle have direct access to a river or stream *(Collins et al. 2013; Conroy et al. 2016)*. In order to see if these factors could be contributing to poor water quality on the Rye Water, a remote desktop-based analysis was conducted on two tributaries *(Jenkintown and Brownrath streams)*. This involved looking at satellite imagery, categorising the different types of riparian habitat present and finding the number of potential cattle access points.

Only 14 and 25% of the riparian habitat was deemed to be in good condition on the Jenkintown and Brownrath streams, respectively.

Further, only 1% of the channel length of the Jenkintown Stream was described to be close to its natural state. Coupled with this, cattle had direct access to 12.5 and 16.8% of the channel length in the Jenkintown and Brownrath streams, respectively. These figures highlight issues on these tributaries which may be influencing their water quality. Given that the water quality of these tributaries directly affects the Rye Water, action is required to improve the riparian zone and limit cattle access if 'good' water quality is to be achieved across the wider Rye Water catchment.



High densities of *Cladophora* algae is a symptom of nutrient pollution, common in agricultural catchments

Cattle can damage riparian vegetation and instream habitat

A healthy riparian area

Cattle access and the riparian zone

Unrestricted cattle access can result in a range of impacts on aquatic organisms, instream habitat, water quality, and the integrity of riparian zones *(O'Sullivan et al. 2019a; O'Callaghan et al. 2019)*. The riparian zone is a vegetated strip of land along the banks of rivers and streams and is a crucial link between the land and the river environment. The composition and health of the riparian area has a large influence on stream health. Riparian buffers provide many benefits, such as moderating instream temperatures due to shading *(Bowler et al. 2012)*, controlling riverbank erosion *(Zaimes et al. 2019)* and providing food for aquatic life *(Bunn 1993)*. A riparian zone of sufficient width and composition is required to intercept or "buffer" sediment, nutrients and pesticides entering a stream or river.

However, the presence of cattle and subsequent grazing leads to reduced vegetation cover and health in riparian areas, resulting in soil erosion and elevated levels of sediment entering the stream *(O'Sullivan et al. 2019b; Conroy et al. 2016)*. Cattle gaining direct access to the stream bed cause further problems, physically disturbing the substrate by trampling and adding organic matter and nutrients to the water in the form of manure – in fact, evidence exists showing that cows prefer to defecate in water bodies than in fields *(Oudshoorn et al. 2008)*. As manure decomposes, oxygen levels are depleted and declines in oxygen-sensitive macroinvertebrates and fish species, particularly salmonids, may be seen *(Braccia and Voshell 2006)*. Animal waste being deposited in rivers may also pose a threat to human health by acting as a vector of harmful pathogens such as *E. coli* and Cryptosporidium *(Nagels 2002)*.

Solar pumps *(above two photos)* and nose pumps *(left photo)* are two alternatives to allowing cattle to drink directly from a waterbody

Riparian zone improvement works and sediment removal on the Rye Water

The riparian zone is very narrow and for the most part non-existent along much of the Rye Water and its tributaries. As a result, runoff from fields containing nutrients and fine sediments is at risk of ending up in streams after even just moderate amounts of rainfall. Because these streams hold such a small volume of water, the addition of even small amounts of nutrients and sediments can have significant deleterious effects on the water quality. Only when a sufficient length of the river channel and riparian habitat of the Rye Water, Lyreen and tributaries are improved would there be a discernible improvement in water quality. To this end, Kildare County Council in conjunction with landowners and other stakeholders (like Intel Ireland) have implemented improvement works as a pilot study on the Clonshambo stream and on the main channel of the Rye Water. These works included the removal of fine sediments, the improvement of the quality of the riverbed, and the restriction of cattle access and installation of drinking troughs.

Working alongside landowners, Kildare County Council has installed approximately 4km of fencing along agricultural stretches of the Rye Water. Now, instead of the cattle drinking directly from the river and damaging both the riparian and instream habitats in the process, they drink from troughs which are supplied with water pumped up from the river. This has allowed the riparian vegetation to regenerate. Where there was once short grass and bare mud is now a mosaic of different plants which slow the flow of water entering the Rye Water, trapping sediment in the process. Over time, shrubs and trees will grow, stabilising the banks further and providing habitat for birds and cover for fish.

Elevated silt levels are one of the most prevalent and harmful stressors to aquatic life and disrupt biological functions by clogging spaces in the river bed *(Jones et al. 2012; Grabowski 2011; Bruen et al. 2017; Davis et al. 2018)*. Such conditions were prevalent on the Rye Water and its tributaries due to intensive animal agriculture in combination with an inadequate riparian zone. Kildare County Council has worked with landowners to remove sediment from the Rye Water and tributaries. After sediment was removed, larger cobbles and rocks were placed in the channel to provide habitat for macroinvertebrates.

Additionally, boulders known as "deflectors" were placed at different intervals in order to create a variety of flow conditions. The faster flow provides a natural means of cleaning the sediments out of the river bed, thereby maintaining its suitability for insects and other aquatic animals as well as the algae that provides food for these species.


Before riparian zone work and cattle exclusion


After

A tributary of the Clonshambo: before *(top)* and after *(bottom)* riparian zone fencing

Before and after the removal of sediment, improving flow

To assess how these efforts are improving the conditions for aquatic animals and plants and ultimately the water quality, several biological and physical elements have been monitored by AQUENS Ltd. *(commissioned by Intel)* since the improvements in 2016. These include a quantitative assessment of the invertebrates *(routinely used as bioindicators of water quality)* in the stream, and the amount of fine sediment and algal growth on the riverbed.

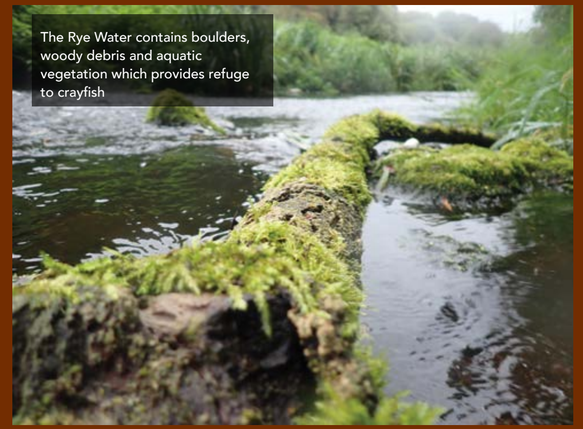
The improvement works at Kilcock may be contributing to the fact that water quality on the Rye Water at Kilcock has achieved "good" status in 2020 and 2021

Date	Month	Site 14	Site 15	Site 13	Site 17 (Kilcock)
2018	M	Q3	Q2-3	Q3-4	Q3
2018	S	Q3	Q2-3	Q3-4	Q3
2019	M	Q3	Q3	Q3-4	Q3
2019	S	Q2-3	Q2-3	Q3	Q3
2020	J	Q2-3	Q3	Q3-4	Q4
2020	S	Q2-3	Q3	Q3	Q4
2021	M	Q3	Q3	Q3-4	Q4
2021	S	Q3	Q3	Q3	Q4

7. Crayfish

Crayfish in Ireland

The white-clawed crayfish *(Austropotamobius pallipes)* is Ireland's largest freshwater invertebrate and only native crayfish species. It is one of the few freshwater invertebrate species which is protected under both Irish and European law *(Annex II and V of the EU Habitats Directive 92/43/EEC)*. The native status of the crayfish has been debated for years and was most likely a medieval or later introduction to Ireland (Reynolds 2020). More recent genetic studies have shown that the white-clawed crayfish was most likely introduced from western France. Even so, the species is considered to be naturalised and it is generally accepted to be of conservation value.



The Rye Water contains boulders, woody debris and aquatic vegetation which provides refuge to crayfish

Crayfish occur in most rivers and lakes which are not too severely polluted and have sufficient calcium content, such as the lime-rich, slow flowing streams of the Irish midlands. Crayfish utilise muddy banks in order to build burrows, and do particularly well in water bodies that have boulders, woody debris and in-stream vegetation which provide cover.

In addition to providing refuge, aquatic vegetation also provides juveniles and small adults with low flow habitat where food is usually plentiful. Crayfish are omnivorous, consuming aquatic plant material and a range of invertebrates such as snails and insect larvae. Crayfish, in turn, are an important food source for salmonid fish, birds such as herons, and otters.

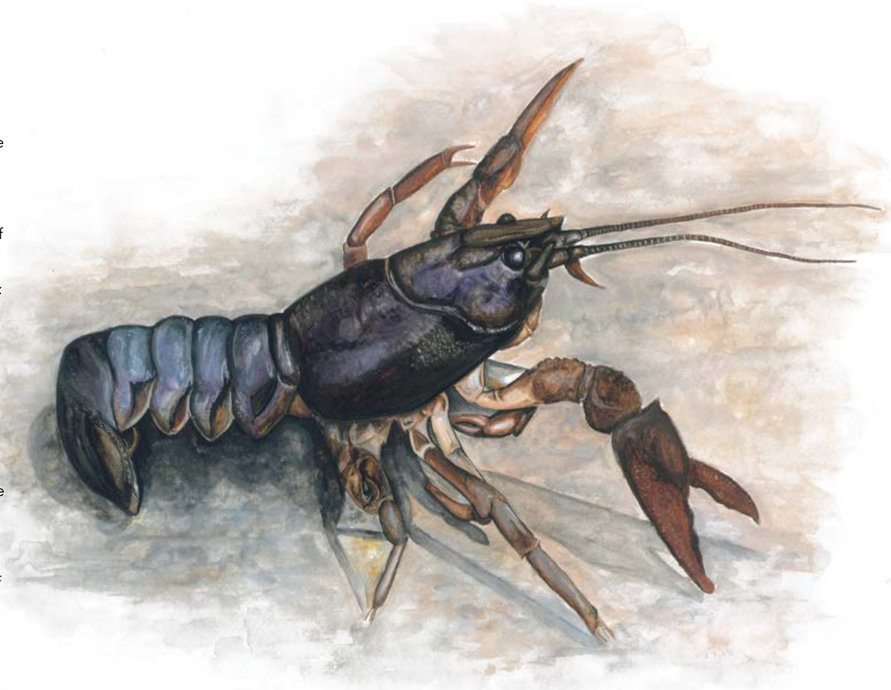
Crayfish remains found in otter scat

Crayfish have declined in many rivers and lakes across Europe over the past 30 years and it is suspected that reduced water quality and the prevalence of a range of diseases such as crayfish plague and porcelain disease are contributing factors.

Ireland is considered a last frontier for the white-clawed crayfish, holding one of the largest surviving populations in Europe. This is in part due to Ireland being among the few countries in Europe which have not been heavily invaded by non-native alien species of crayfish *(Reynolds 2014)*.

The non-native yabby crayfish *(Cherax destructor)* was discovered in Mallow, Cork in 2019. Even so, the yabby remains restricted to this single pond in Mallow and there is no widespread invasive crayfish populations in Ireland. It is vital that invasive crayfish such as the yabbi and signal crayfish *(Pacifastacus leniusculus)* do not become widely established in Ireland as they are capable of outcompeting our native crayfish and may spread the devastating crayfish plague to white-clawed crayfish populations.

Additionally, non-native crayfish have been linked to reduced recruitment of salmonids and the erosion of stream-banks due to excessive burrowing *(Reynolds 2014)*.



Artist: Aoife Quinn

North American signal crayfish are a threat to Ireland's native species

Crayfish on the Rye Water

Crayfish have often been recovered as by-catch during the annual macroinvertebrate and electrofishing surveys. Even so, specific crayfish surveys were conducted in 1999, 2005, and 2021, due to the importance of Ireland's populations for the species conservation globally.

Juvenile crayfish found on the Rye Water

Three sampling methods are commonly used to survey crayfish. Trappy-traps, similar in mechanism to lobster traps, attract only adults as crayfish are opportunistic feeders. In contrast, Surber samplers indicate the number of crayfish per unit area, allowing a quantitative estimate of the number of crayfish in a given stretch of river. This is especially useful for estimating abundances of juveniles. Finally, timed searches may be completed with a bathyscope , after which the number of individuals found per unit effort *(individuals found per minute)* may be calculated and comparisons may be made across sites. It is important to use a variety of methods when sampling crayfish as the adults and juveniles prefer different habitats and juveniles are unlikely to be tempted with a baited trap.

Baited traps were used to assess the crayfish population on the Rye Water in 1999 while baited traps and Surber samplers were used in 2005. The 2021 survey utilised baited traps, Surber samplers and timed-searches.

A bathyscope allows the user to look underwater and facilitates timed-searches of crayfish

A Surber sampler is used to measure the number of crayfish per unit area

Trappy traps are baited and set out overnight in order to catch crayfish, similar to lobster traps

Crayfish may be sexed by looking at appendages on the underside of their carapace

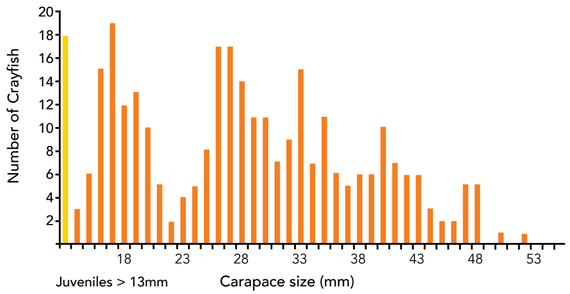
All individuals collected were measured and weighed in order to characterise the population and assess their general condition before returning them to the water

A crayfish which is carrying eggs attached to its tail or elsewhere on its body is described as being "berried"

The state of the population

The results from all three sampling periods have indicated that crayfish populations within the Rye Water are healthy with a good number of adults and juveniles present. The latest study in 2021 showed that juveniles were abundant, indicating that recruitment is high and that the population is sustainable. Additionally, adults have been found in the size range *(13 to 51 mm carapace length)* expected for productive rivers such as the Rye Water.

While all individuals were sexed and healthy numbers of both males and females were discovered, baited trapping usually resulted in a sex bias, i.e. a greater number of males *(Hogger 1988)* and so sex data may not accurately reflect the population structure. The Surber samples taken in 2021 estimate that there are over 3000 individuals in a 70m stretch of the Rye Water that runs alongside the Intel plant. Earlier studies found that crayfish populations were not equally distributed along different stretches of the Rye Water at the back of the Intel site. This is likely due to a variability in in-stream habitats resulting from significant changes in certain stretches of the river following rehabilitation works.



Crayfish Diseases

A number of random individuals were also swabbed and tested for crayfish plague in 2021. The results showed that there is no evidence of the crayfish plague in the Rye Water.

Burn spot disease has been present in the population for decades and porcelain disease was discovered during the survey in 2021. Fortunately, both of these diseases are considered to be sublethal, and populations remain healthy and viable in their presence. In contrast, crayfish plague can be devastating, with long-term studies on the River Goul *(a tributary of the Erkina, County Laois and Kilkenny)* showing that populations have still not recovered 15 years after an outbreak of the plague. As the spores of this deadly fungus are easily transferred between water bodies (attached to fishing and kayaking equipment like nets, waders and boats) *(Unestam 1973)*, all water users should be aware of this risk to the Rye Water.

Swabbing for crayfish plague

8. Birds of the Rye Water Valley

An updated assessment of the status of birds present along the Rye Water was carried out in 2022, with a field visit in October to complement surveys conducted in previous years *(Ní Lamhna and Collins 2004; Flynn 2010)*, followed by a desk study to search for additional records from the wider area. A total of 59 species of bird has now been recorded inside the study site *(up from 47 as noted in the previous Rye Water publication)* and at least 81 species have been seen across the wider area incorporating adjacent farmland, Carton Estate and the Leixlip section of the Royal Canal.


Grey heron *Ardea cinerea*
Credit: Andrew Fitzgerald

The Rye Water itself hosts some of the more notable species in the area, such as the stunning and much-loved kingfisher *(Alcedo atthis)* as well as the poorly named grey wagtail *(Motacilla cinerea)*, with its vibrant flash of yellow under the tail. Perhaps less well-known or not as obvious to most people, but equally wonderful, is the white-throated dipper *(Cinclus cinclus)* which can be seen perched on rocks at fast-flowing sections of river and often near bridges (under which they nest). It is an indication of good water quality when all three of these are found together on the same stretch of river.

In addition, species such as grey heron *(Ardea cinerea)*, great cormorant *(Phalacrocorax carbo)*, moorhen (*Gallinula chloropus)*, mallard *(Anas platyrhynchos)* and mute swan *(Cygnus olor)* can all be seen along the Rye Water and adjacent wetlands, completing the set of waterbirds one would be hoping to record in this area.

Kingfisher *Alcedo atthis*
Credit: Ken Garry

Grey wagtail *Motacilla cinerea*
Credit: Emma O'Higgins

White-throated dipper *Cinclus cinclus*
Credit: Jimmy Cahill

Grey heron *Ardea cinerea*
Credit Ken Garry

Mute swan *Cygnus olor*
Credit: Niall T. Keogh

Moorhen *Gallinula chloropus*
Credit: Andrew Power

Robin *Erithacus rubecula*
Credit: Ken Garry

Along the banks of the river, one can find flushes of marshy habitat complete with stands of willow and alder. Here is where you can hear the gentle song of willow warbler *(Phylloscopus trochilus)* in spring, catch a glimpse of the furtive common reed bunting *(Emberiza schoeniclus)* and possibly flush a well camouflaged common snipe *(Gallinago gallinago)* from its foraging spot on a patch of mud. During spring and summer, be sure to enjoy the aerial acrobatics of mixed flocks of common swift *(Apus apus)*, swallow *(Hirundo rustica)*, sand martin *(Riparia riparia)* and house martin *(Delichon urbicum)* over the Rye Water valley, foraging on winged insects hatching from the wetland and riparian woodland habitats below.

The more mature stands of trees in the area support a suite of woodland species. Long-eared owl *(Asio otus)* is known to breed here, and it is probable that Eurasian sparrowhawk *(Accipiter nisus)* and common buzzard *(Buteo buteo)* also do. With all these predatory birds around, you will likely hear the raucous call of a Eurasian jay *(Garrulus glandarius)*, a woodland crow, giving away their presence. The songs of Eurasian blackcap *(Sylvia atricapilla)* and chiffchaff *(Phylloscopus collybita)* are a regular feature here in spring and careful observation of rugged trunks and branches should reveal treecreepers *(Certhia familiaris)* gleaning insects here and there.

Those with a keen eye should spot woodcock *(Scolopax rusticola)* leaving their winter woodland roosts at dusk to forage in nearby pastures and careful scanning of wood pigeons *(Columba palumbus)* in flight may produce the occasional sighting of the shy and gentle stock dove (*Columba oenas*). Once absent from our woodlands, the re-colonisation of great spotted woodpecker *(Dendrocopos major)* since 2005 has been celebrated by Irish birdwatchers and ornithologists.

The westward spread of the woodpecker quickly included Co. Kildare, and a pair has been seen in the woods along the Rye Water adjacent to the Intel site as recently as 2019.

Sparrowhawk *Accipiter nisus*
Credit: Niall T. Keogh

Eurasian jay *Garrulus glandarius*
Credit: Niall T. Keogh

Common wood pigeon
Columba palumbus
Credit: Niall T. Keogh

Stock dove *Columba oenas*
Credit: Niall T. Keogh

Great spotted woodpecker
Dendrocopos major
Credit: Niall T. Keogh

Greater yellowlegs
Tringa melanoleuca
Credit: Niall T. Keogh

Mistle thrush
Turdus viscivorus
Credit: David Corley

River systems often act as migration corridors and can funnel rare or unusual species on the move into the area. A western osprey *(Pandion haliaetus)* seen flying east over the Rye Water in May 2010 must have been an impressive sight and hopefully one which will become more regular as their numbers increase here during spring and autumn migration between breeding grounds in Scotland and wintering quarters in Africa.

The pond along the Rye Water in Carton Estate hosted greater yellowlegs *(Tringa melanoleuca)* for three days in late July 2022. This long-billed wader with bright yellow legs *(as its name suggests)* is the North American equivalent of our greenshank *(Tringa nebularia)*, and most likely reached Europe by accident during its southbound migration. Strong winds may have steered it off course and helped it cross the Atlantic, ending up in Co. Kildare, where it became the first record for the county and just the 15th time this species has been seen in Ireland. This notoriety drew in large numbers of birders and photographers to see it, much to the amusement of the local golfers!

The diversity of bird species found along the Rye Water and adjacent habitats falls in line with what would be expected from the available habitats yet includes several specialist species and includes many of which are listed as of conservation concern. A recent assessment of threatened bird status in Ireland *(Gilbert et al. 2021)* shows that of the 59 species recorded in the study site here, no less than 8 are "Red listed" *(populations undergoing severe declines of >50% over 25 years)* and as many as 17 are "Amber listed" *(populations undergoing moderate declines of 25-49% over 25 years)*.

In addition to this, the kingfisher found along the Rye Water is also an Annex I species under the EU Birds Directive, thus of highest regard when it comes to protection. Furthermore, the coal tits, Eurasian jays and white-throated dippers also found on the site are subspecies endemic to Ireland, and as such found nowhere else. With this in mind, it is clear that the Rye Water supports threatened and specialist bird species requiring good quality habitats which should be both maintained and enhanced *(where possible)* for the foreseeable future.

9. A Meadow for Biodiversity and other Wildlife of Interest

A Meadow for biodiversity

In October 2016, Intel Ireland planted a wildflower meadow on approximately two acres of land adjacent to the planted woodland which borders the Rye Water. The meadow provides food and nesting sources for local pollinators such as bees, moths and other insects, and the birds and mammals that feed on them. The meadow, along with native trees in the area, has a positive knock-on effect for biodiversity beyond its boundary.

Seeds were provided by Design By Nature, a company selling only native Irish wildflower seeds

The progression of the meadow in its first year

Even in the meadow's first year, a wide range of wildflowers were found, some 22 native species.

Name	Scientific name
Daisy	*Bellis perennis*
Dandelion	*Taraxacum officinale*
Thistle	*Cirsium*
Fumitory	*Fumaria officinalis*
Primrose	*Primula vulgaris*
Dead Nettle	*Lamium*
Sun Spurge	*Euphorbia helioscopia*
Red Clover	*Trifolium pratense*
White Clover	*Trifolium repens*
Buttercup	*Ranunculus acris*
Oil Seed Rape	*Brassica napus*
Bluebell	*Hyacinthoides non-scripta*
Common Vetch	*Vicia sativa*
Common Poppy	*Papaver rhoeas*
Ribworth Plantain	*Plantago lanceolata*
Speedwell	*Geranium robertianum ssp. celticum*
Herb Robert	*Veronica chamaedrys*
Ox Eye Daisy	*Leucanthemum vulgare*
Common Chickweed	*Stellaria media*
Cornflower	*Centaurea cyanus*
Hawk's-beard	*Crepis capillaris*
White Campion	*Silene latifolia*

Artist: Eva McParland

Northern eggar *Lasiocampa quercus*

Early thorn *Selenia dentaria*
All moth photos provided by Wild Kildare Moth Project

Moth Survey

In 2019, a moth survey was conducted by the Wild Kildare Moth Project in the meadow and along the banks of the Rye Water at Intel Ireland, Leixlip *(Strickland et al. 2020)*. Moths are a major part of the biodiversity present in meadows, woodlands, and along rivers, and play a vital role in the ecosystem as pollinators and as a food source for birds and bats. Much like macroinvertebrates, moths act as bioindicators as they are numerous, diverse and many are sensitive to changes in habitat conditions.

Two different recording methods were employed during the moth survey. Light traps were placed in various habitats and left overnight. Dusking, searching for species in the evening up until darkness, is especially effective for micro-moth species which fly during this period. Weather has a considerable effect on capture rates and warm, muggy nights are most ideal to record moths.

Mercury vapour Robinson's light traps are left overnight and the contents examined early the following morning, the species are identified and released unharmed

Brimstone moth
Opisthograptis luteolata

Brown china-mark
Elophila nymphaeata

Burnished brass
Diachrysia chrysitis

Pebble hook-tip
Drepana falcataria

Poplar hawk-moth
Laothoe populi

Swallow-tailed moth
Ourapteryx sambucaria

Rush wainscot
Globia algae

Broad-bordered yellow underwing
Noctua fimbriata

Hare *Lepus timidus*
Credit: Ken Garry

Otter *Lutra lutra*
Credit: Billy Clarke

Badger *Meles meles*
Credit: Billy Clarke

Mammals

Ní Lamhna and Collins *(2004)* and Flynn *(2010)* surveyed mammals at Intel's Leixlip campus. In 2004, eight species were recorded. These included the pygmy shrew *(Sorex minutus)*, fox *(Vulpes vulpes)*, badger *(Meles meles)*, fallow deer *(Dama dama)*, mountain hare *(Lepus timidus) (Annex V, Habitats Directive)*, rabbit *(Oryctolagus cuniculus)*, grey squirrel *(Sciurus carolinensis)* and house mouse *(Mus musculus)*. In the 2010 survey, eight species were also noted but three were new records. The three additional species included the brown rat *(Rattus norvegicus)*, stoat *(Mustella ermine)* and otter *(Lutra lutra) (Annex II, Habitats Directive)* bringing the total mammal count to eleven species. The authors of both surveys agree that the Intel site contains ample habitat for larger mammals such as deer and moreover good habitat exists for other mammal species such as pine martin *(Martes martes)*.

A red fox *Vulpes vulpes* and sika deer *Cervus nippon* photographed by a camera trap

Credit: Adam Smith

The smooth newt *Lissotriton vulgaris* is another protected species found within the Rye Water valley

Moss survey

In 2011, Denyer Ecology was commissioned by Kildare County Council to undertake a bryophyte survey of the marsh which is located to the south and north of the Rye Water at Louisa Bridge, Leixlip. A total of 97 species consisting of 84 mosses and 13 liverworts were recorded *(Denyer 2011)*. This survey recorded no rare or scarce bryophyte species but 8 were new records for County Kildare.

Butterflies in the Rye Water Valley

Butterflies are a familiar part of our countryside and probably one of the most recognisable insect groups in the world. Like most insects, each species has a particular flight period in the year and they are best viewed on a sunny day when the adults actively fly. The immature stages of butterflies usually depend on a small number of plant species to complete their life cycle. The white butterflies (Pieridae) are particularly fond of plants that belong to the cabbage family *(Brassicaceae)* and as a result usually occur where these plants are plentiful.

The larvae of the small tortoiseshell *(Aglais urticae)* and peacock *(Aglais io)* feed on nettles and are therefore some of our most commonly encountered butterflies. In grassy habitats the two most common species include the meadow brown *(Maniola jurtina)* and ringlet *(Aphantopus hyperantus)* which are abundant in the grasslands in the Rye Water valley. Two species of butterflies, the red admiral *(Vanessa atalanta)* and painted lady *(Vanessa cardui)* are migratory and are usually only found in Ireland when conditions are right for them to migrate from parts of southern Europe and North Africa.

Male common blue *Pollyommatus icarus*

Pedunculate oak
Quercus robur acorns

10. Fly Fishing on the Rye Water

What is fly fishing?

Fly fishing is a unique form of angling which helps foster a connection between the fisher and aquatic life in a river or lake. This is because it requires knowledge and understanding of fish, their diet and the lifecycle of the macroinvertebrates that they consume. By the time a fly fisher becomes competent at their craft, they will have a good understanding of the river habitat, having gleaned and honed their knowledge from hours of observation.

Terrestrial insects often fall into rivers and are an important part of a trout's diet

In contrast to traditional fishing, which relies on a rigid rod with a light line and use of a static bait or lure, fly fishing utilises a flexible rod with a weighted line and unweighted or relatively light flies. These files may be as light as a feather and rely on the flex in the rod and the weight of the line to be cast accurately towards a targeted fish or appropriate habitat.

Fly patterns are tied to mimic all of the different types of animals that make up a salmonids diet. Salmonids are opportunistic predators and therefore feed on a variety of different food sources from the terrestrial and aquatic environment. Therefore, fly patterns may imitate the larval and adult forms of aquatic insects such as mayflies and stoneflies, terrestrial insects such as beetles and crane flies, and even fish such as minnows.

Cranefly imitation

Fly patterns, such as this crane fly, which mimic terrestrial insects, are an important part of a flyfisher's toolbox

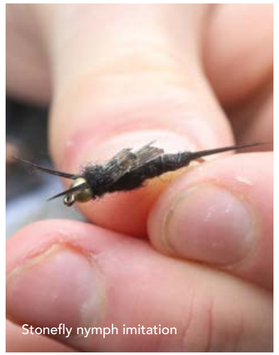
Cranefly

Streamers are bigger flies which imitate larger invertebrates such as crayfish and fish such as minnows and small trout. These flies specifically target larger fish which require bigger prey items to sustain themselves. After casting, the fisher actively retrieves the streamer, giving the impression that their imitation is swimming through the water.


Minnow imitation


Minnow

Nymph patterns aim to mimic the larval stage of macroinvertebrates, which are known as nymphs. The fisher tries to place these flies so that they sit deep in the water or bounce along the riverbed, imitating fly larvae which are moving or swimming between habitats. Depending on the age of the fish these larval stages of insects may make up a high proportion of a trout or salmon's diet, especially for younger fish.


Stonefly nymph imitation


Stonefly

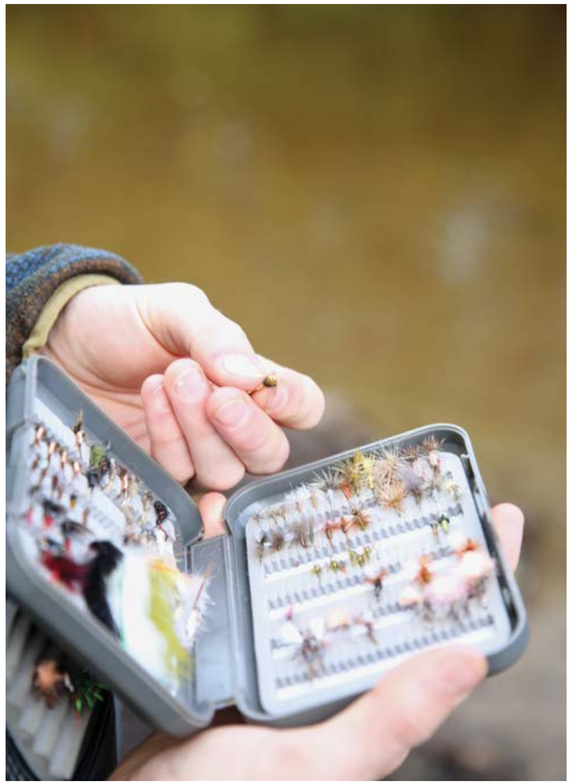
Dry flies sit on the surface of the water and mimic insects emerging from the water. These flies must dry off their newly formed wings and are therefore easy prey for fish. They may also imitate flies which have returned to the water to deposit eggs.

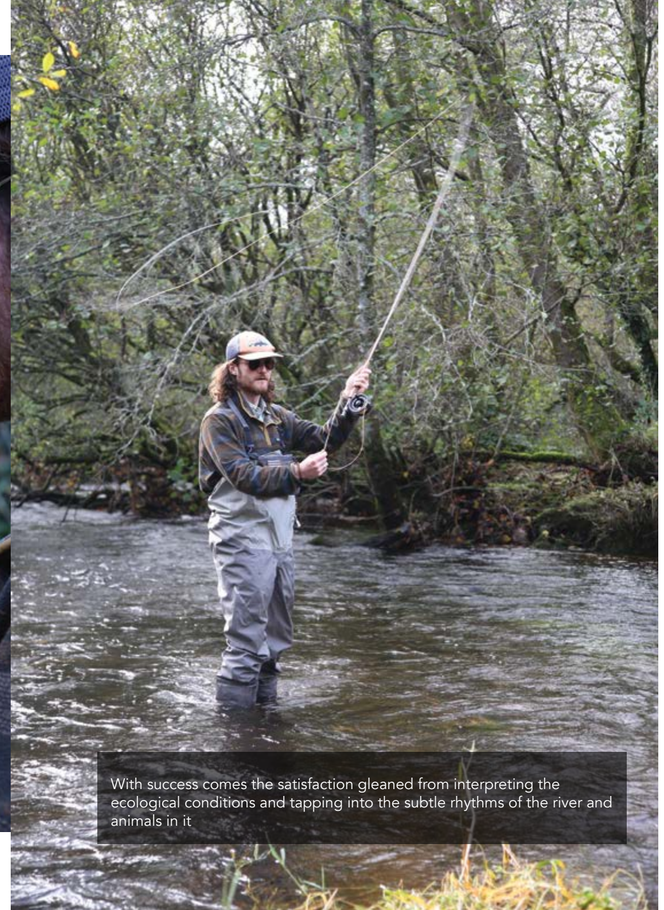
Emerger patterns imitate insects undergoing a metamorphosis from larvae into their adult stage. During this time insects generally sit high in the water, just below the surface, where they make an attractive prey item for fish.

Having completed egg laying, mayfly adults can often be seen on the surface of the water and are known as spent adults. Dry flies may also mimic "spent" flies - those which have completed mating and drop dead into the water having completed their life cycle.

In productive rivers such as the Rye Water, huge hatches of midges, mayflies, stoneflies and other aquatic insects occur from the months of April to August. During this time flies may emerge from the water in their thousands to perform a mating dance over the water. These hatches provide a feast for fish, and trout and salmon may be seen sipping flies off the surface of the water.

In order for a dry fly fisher to be successful they must "match the hatch", i.e. they must be able to identify what type of insect is hatching and match it to a pattern of similar shape, size and colour from their fly box. After that, they require the patience, skill, and dexterity to cast their fly in such a way that it lands gently on the water above an unsuspecting fish.





With success comes the satisfaction gleaned from interpreting the ecological conditions and tapping into the subtle rhythms of the river and animals in it

Leixlip and District Angling Association

For over 30 years the Leixlip and District Anglers have fished the Rye Water from the back of Intel Ireland to the confluence with the River Liffey in the town of Leixlip. The club has progressed from its inception as a local fishing club to become a community organisation with conservation and enhancement of the natural environment in and around the Rye Water foremost on its list of priorities. Over the years the club has engaged with the other stakeholders and local voluntary organisations to help enhance the river for all, but mainly for the fish. The Rye Water holds a special place for a lot of the club members with some fishing the river for over 40 years. Those members will testify to the changes over the years, from a river that was clogged with weed and silt, heavily polluted with farm and factory runoff to a river which is now one of the cleanest tributaries of the River Liffey, albeit it with continuing eutrophication problems in some areas. Conservation has been a mainstay of the club for most of the last 30 years with the members unanimously voting for a catch and release policy over 20 years ago and every year since (the first fishing club on the River Liffey and tributaries to do so). This policy has proven very successful as today the club still enjoys a healthy stock of trout and salmon.

The Rye Water means a lot to the community of Leixlip and the town wouldn't be the same without it, from the excitement of the children following the annual duck race along its banks, to the anglers who seek peace and quiet in it (while catching the odd fish), to the person who sits on its banks to read a book or just watch the world go by, you cannot replace the 'Beautiful Rye'

To celebrate the 25th anniversary of Leixlip and Distract Angling Association, the Liffey Shield, the annual Liffey River inter club competition, was fished on the Rye Water (a tributary of the River Liffey). Teams from Clane Anglers, Dublin Trout Anglers, Leixlip and District Anglers, and North Kildare and Kilcullen angling clubs contested the Shield. It was a red letter day for the hosts as the team won the event for the first time in the clubs history, with Dermot Mitchell finishing top rod - the team consisted of L-R Gianluca Paolella (Team Captain), Brian Coffey, Jason Nolan and Dermot Mitchell. This was the first time the Liffey shield was ever fished on the Rye Water.

Don't turn your back on the Rye

We have a friend and from her source to her end,
She's more classy than Itchen or Tweed.
She's friendly and warm and bustles along, past hedges and bridges and reed.
She's lovely and dear, but these past years she's shed tears,
When her anglers just cast her aside,
Now she's had some work done to her face and her bum,
So fish her, and restore her pride.
In the summer she's low and her bones start to show,
And her lush reeds get burnt to a stalk.
But somewhere in there, the trout still have their lairs,
For you know they can't get out and walk.
Don't go drive,n for miles you'll just end up with piles,
Instead just go down where you're wanted.
It's for her daughters and sons that she's had the work done,
So fish her, and just let her flaunt it!
She's proud of her trout, she won't just give them out,
She'll make you work hard for your thrill.
But when she gives up a trout don't, take him out,
For they're far too precious to kill.
So if during the season, so you don't lose your reason,
You need to go casting a fly,
With a few hours to spend, go see an old friend
and don't turn your back on the Rye.

A Poem by Mattie Cunningham (Leixlip and District Anglers Club Secretary)

Bibliography

Anonymous (2010) Appropriate assessment screening report, Leixlip local area plan. Golders Associates. Kildare County Council Report Number 08 507120196/A.1

Bowler DE, Mant R, Orr H, Hannah DM, Pullin AS (2012) What are the effects of wooded riparian zones on stream temperature? Environmental Evidence 1(1): 3

Braccia A, Voshell JR (2006) Benthic Macroinvertebrate Fauna in Small Streams Used by Cattle in the Blue Ridge Mountains, Virginia. Northeastern Naturalist 13(2): 269–286

Bruen M, Rymszewicz A, O'Sullivan JJ, Turner JN, Lawler DM, Conroy E, Kelly-Quinn M (2017) Sediment Flux - Measurement, Impacts, Mitigation and Implications for River Management in Ireland. Environmental Protection Agency, Wexford, Ireland

Bunn SE (1993) Riparian-stream linkages: research needs for the protection of in-stream values. Australian Biologist, 6(1): 46–51.

Collins KE, Doscher C, Rennie HG, Ross JG (2013) The Effectiveness of Riparian 'Restoration' on Water Quality—A Case Study of Lowland Streams in Canterbury, New Zealand. Restoration Ecology 21(1): 40–48

Conroy E, Turner JN, Rymszewicz A, O'Sullivan JJ, Bruen M, Lawler D, Lally H, Kelly-Quinn M (2016) The impact of cattle access on ecological water quality in streams: Examples from agricultural catchments within Ireland. Science of The Total Environment 547: 17–29

Davis SJ, Ó hUallacháin D, Mellander PE, Kelly AM, Matthaei CD, Piggott JJ, Kelly-Quinn M (2018) Multiple-stressor effects of sediment, phosphorus and nitrogen on stream macroinvertebrate communities. Science of The Total Environment 637–638: 577–587

Denyer J (2011) Leixlip Spa Bryophyte Survey. Unpublished report for Kildare County Council, Kildare, Ireland

Flynn B (2010) Terrestrial Mammal and Bird Survey at Louisa Bridge, Leixlip. Report produced by Flynn, Furney Environmental Consultants for Kildare County Council and supported by the Heritage Council.

Fossit B (2000) A Guide to Habitats in Ireland. The Heritage Council, Ireland

Gilbert G, Stanbury A, Lewis L (2021) Birds of Conservation Concern in Ireland 4: 2020–2026. Irish Birds 43: 1–22

Grabowski RC, Droppo IG, Wharton G (2011) Erodibility of cohesive sediment: The importance of sediment properties. Earth-Science Reviews 105(3): 101–120

Hogger JB (1988) Ecology, population biology and behaviour. In: Freshwater Crayfish: Biology, Management and Exploitation (ed D. M. Holdich & R. S. Lowery), Croom Helm Ltd, Kent, UK, pp 114-144

Jones JI, Murphy JF, Collins AL, Sear DA, Naden PS, Armitage PD (2012) The impact of fine sediment on macro-invertebrates. River Research and Applications 28(8): 1055–1071

Kelly F (1996) Fisheries Enhancements of the Rye Water - a Tributary of the River Liffey. PhD Thesis, University College Dublin, Ireland

Nagels JW, Davies-Colley RJ, Donnison AM, Muirhead RW (2002) Faecal contamination over flood events in a pastoral agricultural stream in New Zealand. Water Science and Technology: A Journal of the International Association on Water Pollution Research 45(12): 45–52

Ní Lamhna E, Collins R (2004) Audit of habitats and species - a baseline environmental audit. Unpublished report conducted on behalf of Intel Ireland Ltd., Leixlip, Ireland

NPWS (2011) Conservation Objectives for Rye Water Valley / Carton SAC [001398]. Generic version 3.0. Department of Arts, Heritage & the Gaeltacht

O'Callaghan P, Kelly-Quinn M, Jennings E, Antunes P, O'Sullivan M, Fenton O, hUallacháin DÓ (2019) The Environmental Impact of Cattle Access to Watercourses: A Review. Journal of Environmental Quality 48(2): 340–351

O'Grady MF, Curtin J (1993) The Enhancement of Drained Salmonid Rivers in Ireland - A Bioengineering Perspective. Hydroécologie Appliquée 5: 7–26

O'Sullivan M, hUallacháin D, Antunes PO, Jennings E, Kelly-Quinn M (2019a) The impacts of cattle access to headwater streams on hyporheic zones. Biology and Environment: Proceedings of the Royal Irish Academy 119B(1): 13

O'Sullivan M, Ó hUallacháin D, Antunes PO, Jennings E, Kelly-Quinn M (2019b) The impacts of cattle access points on deposited sediment levels in headwater streams in Ireland: Cattle access mediated stream sediment responses. River Research and Applications 35(2): 146–158

Reynolds J (2014) Crayfish in Ireland: A last European frontier. Crayfish News 36: 5

Reynolds J (2020) Crayfish in Irish Rivers. In: Kelly-Quinn M, Reynolds J (ed) Ireland's Rivers. University College Dublin Press, Ireland, pp 141–155

Snyder DE (2003) Invited overview: conclusions from a review of electrofishing and its harmful effects on fish. Reviews in Fish Biology and Fisheries 13(4): 445–453

Female *Calopteryx haemorrhoidalis* damselfly

Artist: Eva McParland

Intel Ireland 2022
www.intel.ie
www.exploreintel.com/ireland