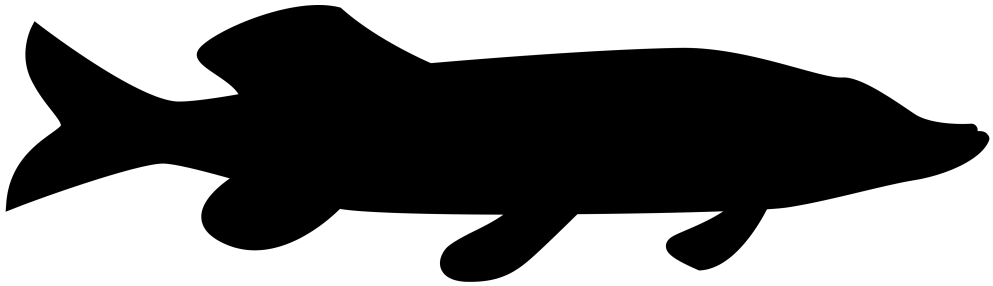

Lough Corrib Pike Research & Control Group

www.loughcorrib.ie

Submission to
Inland Fisheries Ireland

Public Consultation
-
Sligo District – Conservation of Trout on Lough Arrow (Inc the Unshin River)

January 12th 2025

1.0 LOUGH ARROW & UNSHIN RIVER SYSTEM

Lough Arrow, located in Counties Sligo and Roscommon, is a large limestone lake that conforms to a type listed on Annex I of the EU Habitats Directive. The lake is sheltered on three sides by hills and is the source of the Unshin River. Lough Arrow is unusual in being a mesotrophic natural lake, which has changed little in the last forty years. It is largely spring-fed and very sheltered for its size, and, as such, is hydrologically different from most other lakes. The site is a Special Area of Conservation (SAC) selected as a hard water lake habitat. The lake is an important game fishery, managed by Inland Fisheries Ireland (IFI), with good stocks of brown trout and eels. The lake was once stocked with brown trout but this practice has now been discontinued (O'Reilly, 2007). Wild brown trout average 0.45kg in weight, with fish up to 2.7kg having been taken on the fly rod. A fisheries enhancement programme to increase spawning and nursery area for brown trout was initiated in the Lough Arrow catchment over the period 1998 to 2000 involving re-creation of pools and a natural meander pattern, fencing of streams from livestock and placing of additional spawning gravels in streams where appropriate (O'Grady, 2004)[1].

The Unshin River runs from Lough Arrow north to Ballysadare Bay, Co. Sligo. The river is largely undrained and unaltered along much of its course. The site is a SAC selected for the following habitats and/or species listed on Annex I/II of the EU Habitats Directive; floating river vegetation, orchid-rich calcareous grassland, molinia meadows, alluvial forests, Atlantic salmon (*Salmo salar*) and otter (*Lutra lutra*)[2]. The marginal vegetation associated with the river is also included in the SAC, along with other semi-natural habitats adjacent to the river (included in order to enhance its protection). Many of these habitat types are interesting and of conservation value in their own right. Other watercourses included within the site are the Owenboy/Owenbeg and a number of smaller tributaries. The Unshin River flows across a number of geological boundaries between sandstone, shales and limestone. This results in unusual physico-chemical qualities, which in turn are reflected in the rich and varied plant and animal populations. The Unshin and its tributaries form a very important system for Atlantic salmon, a species that is listed on Annex II of the EU Habitats Directive. The Owenboy/Owenbeg river is the principle spawning and nursery tributary for the system's Atlantic salmon fishery. The

[1] Connor, L., Morrissey, E., Coyne, J., Corcoran, W., Cierpial, D., Gavin A., Brett A., McLoone, P., Delanty, K., Rocks, K., Gordon, P., O' Briain, R., Matson, R., McCarthy E. and Kelly, F.L. (2018) Fish Stock Survey of Lough Arrow, August 2018. National Research Survey Programme, Inland Fisheries Ireland, 3044 Lake Drive, Citywest Business Campus, Dublin 24.

[2] NPWS (2016) Site Synopsis: Unshin River SAC 001898. National Parks and Wildlife Service, Department of Arts, Heritage and Gaeltacht.

Unshin and its tributaries is the most important salmon producing river in Co. Sligo. The system also supports a good population of brown trout. Atlantic salmon, are not a "qualifying interest" for Lough Arrow SAC and haven't been recorded at the site (IFI, 2024).

2.0 THE PROPOSED BROWN TROUT BAG LIMIT BYE-LAW

IFI has proposed to (1) reduce the daily bag limit per angler of four brown trout to two brown trout on Lough Arrow and the Unshin River and (2) increase the current size limit for the taking of brown trout from 12 inches to 14 inches on Lough Arrow. The proposed legislation is silent on size limit restrictions for the Unshin River **(APPENDIX I)**. The current daily bag limit of four brown trout for Lough Arrow is included in the North Western Region (Lough Arrow) Bye-law (No. 731) 1997 **(APPENDIX II)**. The current statutory size limit of 12 inches for Lough Arrow is legislated for under the Sligo District Bye-law (No. 586) 1976. The daily brown trout bag limit on the Unshin River is not legislated for under the North Western Region (Lough Arrow) Bye-law (No. 731) 1997. Ipso facto there is currently no brown trout bag limit on the Unshin River.

3.0 THE LACK OF EVIDENCE FOR THE PROPOSED BYE-LAW

"Inland Fisheries Ireland are always trying to solve problems that they don't have but never the substantive problems that they do have" - Anon. Lough Corrib Angler

On Tuesday December 10th last year, IFI issued a press release regarding this proposed bye-law and its public consultation. At the same time, IFI didn't publish any accompanying appropriate assessment screening, scientific report, stock survey or angling catch reports with data that would qualify and quantify why a brown trout bag limit reduction would be warranted on the Lough Arrow/Unshin River system. From December 10th to date, IFI hasn't published any appropriate assessment screening document as warranted under the EU Habitats Directive for plans or projects in SACs, which should highlight all the evidence that would necessitate the proposed legislative change. The non-publishing of a screening document, flies in the face of the 'open government policy' of the Irish State as mandated by the Department of the Taoiseach in 2005[3]. All other public consultations run by Irish statutory bodies/public authorities regarding plans or projects that affect SACs, allow stakeholders to examine all environmental documentation during the consultation phase. Consequently, what have IFI

[3] https://assets.gov.ie/9615/7f6b1c1187d949299d740c517eefef23.pdf

got to hide from the public? The same stunt was pulled by IFI during the public consultation in 2023 for the proposed Conservation of Trout in the Rivers Clare, Abbert, Dalgan, Grange and Sinking Bye-Law. Amazingly, the screening document only appeared online in the aftermath of the legislation being signed off on March 28th last year[4].

The last fish survey report available in the public domain for Lough Arrow was published on July 10th 2019 **(APPENDIX III)**. This 2018 survey conducted under the EU Water Framework Directive (WFD) lake monitoring programme, stated that "***brown trout ranged in length from 15.5cm to 54.5cm and ranged in age from 1+ to 6+, indicating reproductive success in six of the previous seven years***"[5]. The report never indicated that anthropogenic influences such as the alleged overexploitation or excessive harvesting of wild brown trout under current conservation legislation, were having a detrimental impact. As a point of note, no fish stock survey reports for Lough Arrow have been published in the public domain since 2019.

A 2015 Lough Arrow Fish Survey Report was published on September 21st 2016 by IFI **(APPENDIX III)**. This survey was also conducted under the triennial EU Water Framework Directive (WFD) lake monitoring programme. With regards to brown trout, the 2015 document made the following statement, "***trout captured ranged in length from 14.8cm to 56.0cm and ranged in age from 1+ to 7+, indicating reproductive success in seven of the previous eight years. The dominant age class was 4+. Length at age analyses revealed that brown trout in the lake exhibit a very fast rate of growth according to the classification scheme of Kennedy and Fitzmaurice (1971)***"[6]. As in 2018, this 2015 report gave no indication that excessive angling catches were having a measurable impact on brown trout stocks considering the consistent reproductive successes of the indigenous brown trout population.

A 2012 Lough Arrow Fish Survey Report was published on August 10th 2012 by IFI **(APPENDIX III)**. This survey was also conducted under the triennial EU Water Framework Directive (WFD) lake monitoring programme. With regards to brown trout, the 2012

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[4] https://assets.gov.ie/289900/c07f5e08-bd93-4724-973d-24b1dd7d6e01.pdf

[5] Connor, L., Morrissey, E., Coyne, J., Corcoran, W., Cierpial, D., Gavin A., Brett A., McLoone, P., Delanty, K., Rocks, K., Gordon, P., O' Briain, R., Matson, R., McCarthy E. and Kelly, F.L. (2018) Fish Stock Survey of Lough Arrow, August 2018. National Research Survey Programme, Inland Fisheries Ireland, 3044 Lake Drive, Citywest Business Campus, Dublin 24.

[6] Kelly, F.L., Connor, L., Delanty, K., McLoone P., Coyne, J., Morrissey, E., Corcoran, W., Cierpial, D., Matson, R., Gordon, P., O' Briain, R., Rocks, K., Walsh, L., O' Reilly, Sinead., O' Callaghan, R., Cooney, R. and Timbs, D. (2016) Fish Stock Survey of Lough Arrow, July 2015. National Research Survey Programme, Inland Fisheries Ireland, 3044 Lake Drive, Citywest Business Campus, Dublin 24.

document made the following statement, "***trout ranged in age from 0+ to 6+, indicating reproductive success in the previous seven years. Length at age analyses revealed that brown trout in the lake exhibit a very fast rate of growth according to the classification scheme of Kennedy and Fitzmaurice (1971)***"[7]. As in the 2015 and 2018 reports, IFI made no reference to excessive brown trout angling catches and any harvesting of brown trout was having a negligible impact on their reproductive success.

A 2009 Lough Arrow Fish Survey Report was published on July 20th 2009 by the Central and Regional Fisheries Boards **(APPENDIX III)**. As per later surveys, this research was the inception of the triennial EU Water Framework Directive (WFD) lake monitoring programme. With regards to brown trout, the 2009 document made the following statement, "***the mean brown trout CPUE in Lough Arrow was similar to other high alkalinity lakes surveyed. Although Lough Arrow exhibited a lower mean brown trout CPUE than Lough Carra and Lough Cullin and a higher mean CPUE than Lough Mask and Lough Derg these differences were not statistically significant. Brown trout ranged in age from 1+ to 5+ indicating reproductive success in the last number of years. Length at age analyses revealed that brown trout in the lake exhibit a very fast rate of growth according to the classification scheme of Kennedy and Fitzmaurice (1971)***". As per the 2012, 2015 and 2018 reports, the Central Fisheries Board (CFB) made no reference to excessive brown trout angling catches and any harvesting of brown trout was having a negligible impact on their reproductive success.

In February 2003, prior to the commencement of the EU WFD lake monitoring programme, the CFB published a 2002 Fish Stock Assessment of Lough Arrow **(APPENDIX IV)**. With regards to brown trout, the 2002 document made the following statement, "***length frequency distributions for the brown trout taken in this survey show an absence of younger fish, in the 19–39 cm length range (or in the 2–3 year old range). More than 80% of the population were greater than 40cm and 3+ or older. Of the 11 trout stomachs examined contained large amounts of asellus, and in some samples other invertebrates were also found. Pike numbers, in relation to the trout catch, were significant. A length frequency distribution for pike showed the majority of fish to be in the 35 to 80 cm range, with over 50% of the catch greater***

[7] Kelly, F.L., Connor, L., Morrissey, E., Wogerbauer, C., Matson, R., Feeney, R. and Rocks, K. (2013) Water Framework Directive Fish Stock Survey of Lough Arrow, July 2012. Inland Fisheries Ireland, Swords Business Campus, Swords, Co. Dublin, Ireland.

than 65cm. Dietary analysis found that fish were encountered in 8 of the stomachs examined, another seven contained invertebrates and 25 stomachs were empty. The large number of empty stomachs is characteristic of fish in their spawning season. The majority of pike were ripe fish with a 2.88 to 1 female to male ratio". The 2002 report made further comments with regards to the absence of juvenile trout, "***the decline in the trout stock in Lough Arrow over the period 1979 to date (2002) is of concern in fisheries management terms – a fall in trout CPUE values from a figure of 2.83 in 1979 to 0.766 in 2002 suggests that the current trout population is now only circa 27% of the stock density present in 1979. This trend is also reflected in poor angling catches from the lough in recent years***". The 2002 report concluded with this statement, "***the significant failure of these fish (juvenile trout) to survive in Lough Arrow to adulthood in repeated years may well be as a consequence of the greatly increased population of adult pike in the lake in 2002, compared to previous years. A comparison of fish numbers in the 1979 and 2002 surveys suggests a 4.5 fold increase in the pike stock over this period. Research has shown that the pike in question (predominately fish in the 50 to 80cm length range) specifically target trout, 25 to 40cm in length, as prey items. It is therefore hardly coincidental that it is this size range of trout which are most poorly represented in the 2002 survey***".

Twenty two years later, IFI Lough Arrow stock management (pike culling) data sheets from last year (2024) validate the findings from the 2002 CFB Fish Stock Assessment, showing preferential predation on brown trout compared to other potential prey species/fodder fish within the water column of Lough Arrow such invasive perch or invasive roach **(APPENDIX V)**.

The aforementioned WFD fish survey reports from 2009 to 2018, consistently identify Lough Arrow perch as the most dominant species in terms of both abundance (CPUE) and biomass (BPUE). Perch (*Perca fluviatilis*) are classed as non-native to Ireland by IFI[8]. They are also classed as 'non-native influencing ecology' in Ireland under IFI's very own FIL2 classification model for WFD purposes[9] **(APPENDIX VI)**. Perch being a non-native species has a direct negative impact on EQR (Ecological Quality Ratio) scores determined under the FIL2 model, which in turn has a direct negative impact on Ireland's compliance

[8] https://www.fisheriesireland.ie/species/perch-perca-fluviatilis

[9] Kelly, Fiona & Champ, Trevor. (2015). Classification Tool for Fish in Lakes: Plan for Development/Conceptual Model. Task 6.9. NS Share Report. 10.13140/RG.2.1.2838.5768.

with the EU WFD. Lough Fern in Co. Donegal is a perfect example of this ecological impact[10]. Considering this negative impact, IFI have attempted to control invasive perch populations to protect salmonids and vulnerable Arctic char populations in other SAC lakes such as Lough Inagh in the Twelve Bens/Garraun Complex SAC **(APPENDIX VII)**. To compound matters perch are conserved throughout Ireland under the Conservation of and Prohibition on Sale of Coarse Fish Bye-Law (No. 806) 2006, which is also in direct conflict with Ireland's legal obligations under the EU Habitats Directive as invasive/non-native fish species are protected in SACs. The impact of invasive/non-native fish in Irish waters was confirmed by Dr. Cathal Gallagher, the current IFI Head of Research and Development, in a submission made on December 10th 2015 to the Department of Environment, Community and Local Government regarding Significant Water Management Issues in Ireland (SWMI). Dr. Gallagher made the following statement, "***the native Irish freshwater fish fauna has been augmented by a large number of non-native species (e.g. perch, pike, dace, bream, tench, roach and rainbow trout). These have been introduced either deliberately or accidentally, e.g. angling activities, aquaculture and the aquarium trade. A non-native species is one that has been either intentionally or accidentally released in to an environment outside of its natural geographical habitat range. Many non-native fish species have become established in the wild throughout Irish lakes and rivers, e.g. perch, roach, rudd and bream. Roach is a species which has been shown to affect salmonid production and cause a decline in brown trout angling catches. Within a few years of being introduced into a water body they can become the dominant species due to their high fecundity and they usually displace brown trout. Water bodies with non-native invasive fish species such as roach will not meet high status for EU Water Framework Directive (WFD) purposes due to the presence of these species. Future introductions of non-native species will also lead to a downgrading of the ecological status of a water body***" **(APPENDIX VIII)**.

After examining the published evidence, the only identifiable threat to brown trout stocks in Lough Arrow apart from invasive perch are invasive pike as previously referenced. The existential threat to Lough Arrow brown trout stocks by invasive pike has been further confirmed by IFI, in the 2024 Lough Arrow Stock Management Plan/Appropriate Assessment Screening **(APPENDIX IX)**. With regards to the presence of invasive pike in

[10] http://wfdfish.ie/wp-content/uploads/2021/08/Fern_2020.pdf

Lough Arrow, the 2024 Stock Management Plan stated, "***the principal aim of the 2024 management plan is to remove Pike (Esox lucius L.) which are known to prey on brown trout (O'Grady & Delanty 2008) from the lake by electrofishing and gill netting. In Lough Arrow, pike are thought to have been introduced approximately 250 years bp (Pedreschi et al. 2014) and large numbers these fish have been removed, formerly by the Inland Fisheries Trust, the North Western Regional Fisheries Board and by IFI. In more recent years, pike removal operations have been undertaken as a conservation measure for indigenous salmonids***". Furthermore, the 2024 Stock Management Plan confirmed that "***the principal purpose for this project is the conservation of an important recreational wild brown trout fishery***". Finally, the 2024 Stock Management Plan never mentioned or highlighted rod and line angling pressure regulated by the current four fish bag limit as a contradiction to brown trout sustainability in Lough Arrow.

Angling pressure on Lough Arrow brown trout stocks is minimal as per the four cited fish stock survey reports (2009-2018) conducted under the EU Water Framework Directive (WFD) lake monitoring programme. Last year, the Lough Arrow/Unshin River system was abruptly closed to all angling from July 17th to August 21st inclusive under the Conservation of Salmon and Sea Trout Ballysadare (Closed River) Bye-Law (No. C.S. 336) 2024 **(APPENDIX X)**. During this time period local angling clubs, local anglers and angling tourism bodies were silent with regards to the closure, indicating that Lough Arrow is not viewed as an important recreational game angling asset and therefore is subject to minimal angling pressure. Additionally, Lough Arrow is closed to brown trout angling from October 1st to March 31st inclusive each year, therefore the resident brown trout population are unmolested for six months out of every twelve.

In summary, why are IFI pushing for a reduction in the brown trout bag limit on Lough Arrow since the current harvesting regime and angling season over a twenty eight year period since February 1997 has made no material impact on brown trout stocks or their sustainability? The most appropriate conservation policy for brown trout stocks in Lough Arrow would be the wholesale removal of invasive pike, invasive perch and invasive roach for the above outlined reasons.

4.0 THE RUSE OF BROWN TROUT CONSERVATION

It is pretty evident for the last twenty odd years that there has been a covert state policy to undermine and diminish our wild salmonid fisheries even in the face of growing EU legislation (EU Habitats, Water Framework & Nature Restoration Directives) that is designed to protect the very same fisheries and their integrity. Part of this covert policy is to frame the game (salmonid) angler as being the greatest threat to conservation whilst deliberately ignoring political bombs in respect of agricultural/urban pressures on water quality plus the wanton spread of invasive/non-native fish and their subsequent legislative conservation. It's so easy for IFI, DECC and their proxies to spin this narrative of the 'neanderthal/anti-conservation game angler' particularly on social media platforms where so many willing vacuous cheerleaders exist from Irish pike/coarse angling lobby groups ably supported by their international lackeys. This proposed bye-law is further proof that the IFI SMT (Senior Management Team) are unwilling and petrified to deal with the substantive issues of water quality and invasive/non-native fish within the Lough Arrow/ Unshin River system but instead are succumbing to irrelevant societal pressures and a form of pseudo-morality vis-à-vis fish harvesting. Essentially, this proposed bye-law is another blatant two fingers to game angling stakeholders particularly when so many submissions from the said stakeholders were completely ignored during two rounds of public consultations on the Western Lakes Management Plan (WLMP) in 2022 and 2023. Lough Arrow was included in the WLMP that never was and the plan itself was just another example of deliberate obfuscation and stalling by both IFI and DECC for the last three years. Nevertheless, Eamon Ryan the former TD and incumbent government minister responsible for Inland Fisheries (DECC), made numerous Dáil statements in recent times that are completely at odds with IFI's push for legislative change on Lough Arrow. On July 23rd last year in response to a parliamentary question from Catherine Connolly TD with regards to the WLMP, Eamon Ryan made the following statement, "***any regulatory change that may be considered for SAC-designated waters in the Great Western Lakes will be done in the context of the implementation of the long-term management plan for our Western Lakes***". On July 11th last year in response to a parliamentary question from Mairéad Farrell TD with regards to the introduction of inland fisheries legislation, Eamon Ryan made the following statement, "***any legislative change that may be considered for SAC-designated waters will be done so in the context of this plan (WLMP)***". On July 3rd last year in response to a parliamentary question from Mairéad Farrell TD with regards to inland fish species, Eamon Ryan made the following

statement, "***any legislative change that may be considered for SAC-designated waters, will be done in the context of this plan (WLMP)***". On March 28th 2023 in response to a parliamentary question from Noel Grealish TD with regards to specific fisheries legislation, Eamon Ryan made the following statement, "***any legislative change that may be considered for SAC-designated waters will be done in the context of this plan***". The pertinent point is that IFI's Lough Arrow/Unshin River system legislative proposal being in direct conflict with recent statements from the responsible government minister. Why is there a consistent stream of false and misleading statements emanating from IFI and DECC in the last number of years?

5.0 SUMMARY

IFI hasn't published in the public domain any scientific evidence/data or even an appropriate assessment screening that warrants this proposed bye-law. The perceived angling pressure on brown trout in the Lough Arrow/Unshin River system is an absolute red herring. If IFI truly believe that angling pressure is a major factor influencing brown trout conservation in the west of Ireland then why are IFI happy to still have an unlimited wild brown trout rod catch on Loughs Conn and Cullin in Co. Mayo under the North Western Fisheries Region - Lough Conn and Lough Cullin (Conservation of Brown Trout) Bye-Law (No. 827) 2007 **(APPENDIX XI)**. Both lakes are part of the River Moy SAC. Moreover, IFI see no duplicity or inconsistency in allowing an angler to harvest unlimited brown trout of twelve inches or more per day from Loughs Conn and Cullin but potentially only two trout of fourteen inches or more from Lough Arrow.

It would be far more prudent of IFI and DECC in terms of salmonid conservation to cease protecting invasive/non-native fish in Lough Arrow and the Unshin River SACs. Current fisheries legislation such as the 806 and 809 Bye-Laws of 2006 protecting pike and other invasive/non-native freshwater fish must not conflict with or contravene the conservation objectives of the EU Habitats and Water Framework Directives. The bizarre situation whereby invasive coarse fish such as pike, roach, perch, bream, carp, tench, dace, chub, various hybrids etc. being protected in salmonid/SAC fisheries must end. Is it morally acceptable that invasive pike or perch, which are classed as non-native to Ireland under the EU Water Framework Directive (WFD) have more protection under current questionable legislation than our native Atlantic salmon which inhabit the Unshin River SAC? The 806 and 809 Bye-Laws as currently worded also validate the presence of

invasive/non-native coarse fish no matter where they have been deliberately introduced or will be introduced in the future including all lacustrine/riverine SACs. The 806 and 809 Bye-Laws are illegal and must be revoked. The current IFI CEO on paper is perfectly aware of the situation and IFI stated such in a 2021 submission to its parent government department - DECC **(APPENDIX XII)**. Not alone are the 806 and 809 Bye-Laws repugnant to current Irish and EU legislation but they were formulated in 2006 without any legally required appropriate assessment screenings on the basis of perceived threats, false facts and latent racism towards Eastern Europeans by pike/coarse angling lobbyists[11]. How could IFI in the most hypocritical manner attempt to reduce the brown trout bag limit on the Lough Arrow/Unshin River system while continually ignoring the ecological damage that invasive pike and invasive coarse fish cause in the very same salmonid systems?

Water bodies with invasive/non-native coarse fish species such as pike will not meet high status for WFD purposes due to the presence of these species. Future introductions of invasive/non-native fish species will also lead to a downgrading of the ecological status of a water body under the WFD. Stricter border controls especially in the post Brexit era and strengthening of present legislation for moving these species internally in Ireland is required immediately. Legislation currently exists under Regulation 49 (Prohibition on introduction and dispersal of certain species) of the European Communities (Birds and Natural Habitats) Regulations 2011 (S.I. 477). We are calling on DECC/IFI to advocate for the addition of all invasive/non-native coarse fish (covered by the 806 & 809 Bye-Laws) including zander (*Sander lucioperca*), barbel (*Barbus barbus*), wels catfish (*Silurus glanis*) and topmouth gudgeon (*Pseudorasbora parva*) to the Third Schedule (Part 2A) of S.I. 477, which already lists chub, dace, roach and carp. No additional legislation is required. Heavier fines and custodial sentences are also required if individuals are found transporting these invasive species into Ireland and within the country. An interesting footnote to S.I. 477 of 2011 is the absence of pike from the Third Schedule (Part 2A). During a consultation held on the draft regulations in 2011 by the Department of Environment, Heritage and Local Government, IFI made a submission requesting that pike be added to the Third Schedule[12]. Why were pike deliberately left off this list (Third Schedule) but still are classed as ‘non-native influencing ecology’ under the WFD?

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[11] “National Identity, Moral Panic and East European Folk Devils” by Kevin Howard, which appeared in a 2011 academic textbook titled “Globalization, Migration and Social transformation - Ireland in Europe and the World” edited by Bryan Fanning of University College Dublin and Ronaldo Munck of Dublin City University.

[12] AIE request AIE-0105-2021. Department of Housing, Local Government and Heritage.

In conclusion, events over the past seven to eight years have shown IFI to be a completely inadequate, morally bankrupt, rudderless, dysfunctional, incompetent and fractured organisation. This proposed Lough Arrow/Unshin River system legislation is another pathetic and misguided attempt by a broken statutory body to manage the angler whilst deliberately ignoring substantive issues such as water quality and invasive/non-native freshwater fish, which directly influence brown trout conservation and their sustainability.

The cynic might say that the drive for this legislative change is a political trade-off with Co.Sligo anglers after the 'mysterious' killing of over one thousand Atlantic salmon in the Ballysadare River last summer and the subsequent bizarre increase in the Atlantic salmon harvest quota for the same river this calendar year, 2025[13]. Low-hanging fruit is always on the menu in Citywest.

The Lough Corrib Pike Research & Control Group,

January 12th 2025.

info@loughcorrib.ie

"Northern pike are a problem, not an opportunity".

[13] https://assets.gov.ie/315973/a7ebb2d9-6dad-4d63-b630-676363014f32.pdf

APPENDIX I

DEPARTMENT OF ENVIRONMENT, CLIMATE AND COMMUNICATIONS,

INLAND FISHERIES ACTS 1959 TO 2017

SLIGO DISTRICT - CONSERVATION OF TROUT ON LOUGH ARROW (INCLUDING THE UNSHIN RIVER) BYE-LAW NO. XXX, 2024/5.

I, {Minister Name to be inserted}, Minister for the Environment, Climate and Communications, in exercise of the powers conferred on me by section 57 of the Inland Fisheries Act 2010 (No. 10 of 2010) (as adapted by the Communications, Climate Action and Environment (Alteration of Name of Department and Title of Minister) Order 2020 (S.I. No. 373 of 2020)), hereby make the following bye-law;

1. This Bye-law may be cited as the Sligo District - Conservation of Trout on Lough Arrow (including the Unshin River) Bye-law No. XXX, 2025.

2. This Bye-law comes into operation on the day after the day of its making.

3. In this bye-law –

"specified waters" means the waters of Lough Arrow and the River Unshin and the tributaries flowing into them, in the No. 12 or Sligo District

4. In any one day, a person shall not take from the specified waters or have in his or her possession at any place in, on or near the said waters more than two brown trout.

5. (1) No person shall –

(a) troll on, in, under or through the specified waters using more than one fishing line, or

(b) fish from a boat so that there are more than two fishing lines used for trolling at the same time.

(2) In this Bye-law "troll" means to fish from a boat, which is being rowed or mechanically propelled through water, by trailing or towing, on, in, under or through the water, a fishing line with a hook, bait or lure attached, and "trolling" shall be construed accordingly.

(3) In respect of a prosecution to which Article 5 (1)(b) relates, it shall be presumed until the contrary is shown that any person found in the boat at the relevant time was fishing from the boat.

6. Notwithstanding paragraph 5 of the 'Lough Arrow Close Season by-law No. C.S. 93, 1940, and Paragraph 3 of **Sligo District. Close Season Bye-law No. C.S. 6, 1871** or anything contained in any previous Bye-law regulating the seasons for angling for salmon or trout in the specified waters, the annual close season for angling for salmon or trout in the specified waters shall commence on the 1st day of October in any year and cease on the 31st day of March in the year following both said dates inclusive.

7. It is hereby prohibited to take and kill by any means whatsoever in the waters of Lough Arrow, in the No. 12 or Sligo District any brown trout of less than 14 inches (35.56 centimetres) in length measured in a straight line from the tip of the snout to the fork of the tail, or to have in possession on or near the said waters any such fish of less than the said length, and any such fish which may be taken shall be carefully handled and returned alive to the waters.

8. Article 7 does not apply to the waters of the River Unshin or the tributaries flowing into such river, in the No. 12 or Sligo District.

9. The following bye-laws are revoked;
The North Western Region (Lough Arrow) Bye-law No. 731, 1997,
The North Western Fisheries Region (Lough Arrow) Bye-law No. C.S. 172, 1991,
The North-Western Fisheries Region (Lough Arrow) Bye-law No. C.S. 158, 1990,
The Sligo District Bye-law No. 586, 1976.

GIVEN under my hand,
[date to be inserted].

_____

Minister for the Environment, Climate
and Communications.

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EXPLANATORY NOTE

(This is not part of the Bye-law and does not purport to be a legal interpretation)

This Bye-law prohibits:

1. (a) the taking of more than 2 brown trout from the waters of Lough Arrow and the River Unshin as referred to in the bye-law, or have in possession in any place on or near the said waters.

   (b) the taking of any brown trout of less than 14 inches (35.56 centimetres) in length measured in a straight line from the tip of the snout to the fork of the tail from the waters of Lough Arrow.

   (c) a person shall not troll on the said waters using more than one fishing line, or

   (d) fish from a boat so that there are more than two fishing lines used for trolling at the same time.

2. This Bye-law provides that the annual close season for angling for salmon or trout in Lough Arrow and the River Unshin shall commence on the 1st day of October in any year and cease on the 31st day of March in the year following both said dates inclusive.

FOOTNOTE

Section 57 (7) of the Inland Fisheries Act, 2010 provides that any person aggrieved by this Bye-law may within 28 days after its publication in the Iris Oifigiúil, appeal against same to the High Court.

APPENDIX II

DEPARTMENT OF THE MARINE
FISHERIES ACTS, 1959 to 1995

NORTH WESTERN REGION (LOUGH ARROW) BYE-LAW NO. 731, 1997

I, Eamon Gilmore, Minister of State at the Department of the Marine, in exercise of the powers conferred on me by section 9 (as amended by section 3 of the Fisheries (Amendment) Act, 1962 (No. 31 of 1962), and section 50 of the Fisheries Act, 1980 (No. 1 of 1980)), of the Fisheries (Consolidation) Act, 1959 (No. 14 of 1959), section 33 of the Fisheries (Amendment) Act, 1962, the Fisheries (Transfer of Departmental Administration and Ministerial Functions) Order, 1977 (S.I. No. 30 of 1977) (as adapted by the Tourism, Fisheries and Forestry (Alteration of Name of Department and Title of Minister) Order, 1987 (S.I. No. 82 of 1987)) and the Marine (Delegation of Ministerial Functions) Order, 1997 (S.I. No. 68 of 1997), hereby make the following Bye-law:

1. This Bye-law may be cited as the North Western Region (Lough Arrow) Bye-law No. 731, 1997.

2. This Bye-law shall come into operation on the 25th day of February, 1997.

3. In any one day, a person shall not take from the waters of Lough Arrow in the No. 12 or Sligo District or have in his or her possession at any place in, on or near the said waters more than four brown or rainbow trout.

4. (1) No person shall -

(a) troll on, in, under or through the said waters using more than one fishing line, or

(b) fish from a boat so that there are more than two fishing lines used for trolling at the same time.

(2) In this Bye-law "troll" means to fish from a boat, which is being rowed or mechanically propelled through water, by trailing or towing, on, in, under or through the water, a fishing line with a hook, bait or lure attached, and "trolling" shall be construed accordingly.

(3) In respect of a prosecution to which Bye-law 4 (1)(b) relates, it shall be presumed until the contrary is shown that any person found in the boat at the relevant time was fishing from the boat.

5. Notwithstanding anything contained in any previous Bye-law regulating the seasons for angling for salmon or trout in the said Lough Arrow, the annual close season for angling for salmon or trout in Lough Arrow shall commence on the 1st day of 0ctober in any year and cease on the 31st day of March in the year following.

Given under my hand
this 25th day of February, 1997.

Eamon Gilmore
Eamon Gilmore
Minister of State at the
Department of the Marine

EXPLANATORY NOTE

(This is not part of the Bye-law and does not purport to be a legal interpretation)

This Bye-law prohibits:

1. **(a)** **the taking of more than 4 trout from the waters of Lough Arrow or have in possession in any place on or near the said waters.**

(b) **a person shall not troll on the said waters using more than one fishing line, or**

(c) **fish from a boat so that there are more than two fishing lines used for trolling at the same time.**

2. **This Bye-law provides that the annual close season for angling for salmon or trout in Lough Arrow shall commence on the 1st day of 0ctober in any year and cease on the 31st day of March in the year following.**

FOOTNOTE

Section 11 of the Fisheries (Consolidation) Act, 1959 provides that any person aggrieved by this Bye-law may within 28 days after the 28 day of February, 1997 appeal against same to the High Court.

APPENDIX III

Lough Arrow

Sampling Fish for the Water Framework Directive - Lakes 2009

The Central and Regional Fisheries Boards

ACKNOWLEDGEMENTS

The authors wish to gratefully acknowledge the help and co-operation of the CEO Mr. Vincent Roche, Assistant CEO Dr. John Conneely and their staff from the North Western Regional Fisheries Board. The authors would also like to gratefully acknowledge the help and cooperation of all their colleagues in the Central Fisheries Board (CFB).

The authors would also like to acknowledge the funding provided for the project from the Department of Communications, Energy and Natural Resources for 2009.

1.1 Introduction

Lough Arrow (Plate 1.1, Fig. 1.1) is a large limestone lake situated in Co. Sligo, approximately 24km south-east of Sligo town and 6.4km north-west of Boyle, Co. Roscommon. The lake is sheltered on three sides by hills and is the source of the Unshin River. It has a small catchment fed largely by springs on the lake bed and as such is hydrologically different from most lakes in Ireland (Roscommon County Council, 2009). Lough Arrow has a surface area of 1266ha, with a mean depth of 9m and a maximum depth of 33m. The lake is categorised as typology class 12 (as designated by the EPA for the purposes of the Water Framework Directive), i.e. deep (>4m), greater than 50ha and high alkalinity (>100mg/l CaCO3).

Lough Arrow is of major conservation significance as it conforms to a type (hard water lake) listed in Annex I of the EU Habitats Directive. It also supports a number of important bird species and a population of otter (a Red Data Book species which is legally protected under the 1976 Wildlife Act and is listed on Annex II of the EU Habitats Directive) (NPWS, 1999). The shores of the lake are, for the most part, stony, although the common club-rush (*Scirpus lacustris*) and common reed (*Phragmites australis*) occur abundantly in several bays (NPWS, 1999). Two comprehensive surveys of submerged vegetation in the lake were undertaken in 1984 and 2001, during which the open water aquatic flora was found to be dominated by species of *Chara*, *Potamogeton* and *Elodea canadensis*, whilst the shallow (<0.5m) areas commonly contained *Litorella sp*., *Potamogeton filiformis* and *Myriophyllum alterniflorum* (King, 2002).

Plate 1.1. Lough Arrow, looking west over the lake (Photo courtesy of CFB and No. 3 Operational Wing, Irish Air Corps [Aer Chór na hÉireann])

Lough Arrow is an important game fishery, managed by the North Western Regional Fisheries Board, with good stocks of brown trout and eels. The lake was once stocked with brown trout but this practice has now been discontinued (O'Reilly, 2007). Wild brown trout average 0.45kg in weight, with fish up to 2.7kg having been taken on the fly. The lake has previously been surveyed by the Central Fisheries Board (CFB) and the North Western Regional Fisheries Board (NWRFB) in 1979, 1980 (O'Grady, 1986), 1994, 2002 (O'Grady and Delanty, 2003) and 2007 (O'Grady and Delanty, 2007). In 1994, only perch, pike and brown trout were recorded, although three-spined stickleback were also recorded in the stomachs of pike. Rudd were encountered for the first time in 2002 and were captured again in the 2007 survey. Lough Arrow has been included in the CFB's long term water quality monitoring programme of lake ecosystems since 1975. A fisheries enhancement programme to increase spawning and nursery area for trout was initiated in the Lough Arrow catchment over the period 1998 to 2000 involving re-creation of pools and a natural meander pattern, fencing of streams from livestock and placing of additional spawning gravels in streams where appropriate (O'Grady, 2004).

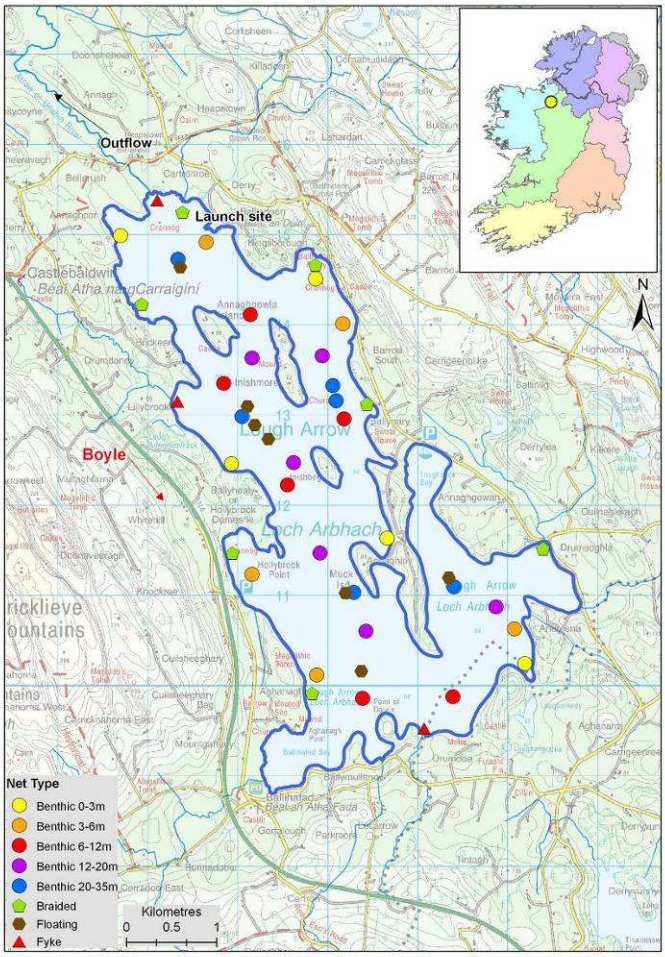

Fig. 1.1. Location map of Lough Arrow showing locations and depths of each net (outflow is indicated on map)

1.2 Methods

Lough Arrow was surveyed over four nights from the 20th to the 24th of July 2009. A total of three sets of Dutch fyke nets, 28 benthic monofilament multi-mesh (12 panel, 5-55mm mesh size) CEN standard survey gill nets (5 @ 0-2.9m, 5 @ 3-5.9m, 6 @ 6-11.9m, 6 @ 12-19.9 and 6 @ 20-34.9m) and seven surface floating monofilament multi-mesh (12 panel, 5-55mm mesh size) CEN standard survey gill nets were deployed randomly in the lake (38 sites). The netting effort was supplemented using seven benthic braided survey gill nets (62.5mm mesh knot to knot) at seven additional sites. Survey locations were randomly selected within each depth zone using a grid placed over a map of the lake. A handheld GPS was used to mark the precise location of each net. The angle of each gill net in relation to the shoreline was randomised.

All fish apart from perch were measured and weighed on site and scales were removed from all trout, pike and roach. Live fish were returned to the water whenever possible (i.e. when the likelihood of their survival was considered to be good). Samples of fish were returned to the laboratory for further analysis.

1.3 Results

1.3.1 Species Richness

A total of eight fish species were recorded on Lough Arrow in July 2009, with 836 fish being captured (Table 1.1). Perch was by far the most abundant fish species recorded. Small numbers of brown trout were captured in the gill nets. Eels were captured in fyke nets only.

Table 1.1. List of fish species recorded (including numbers captured) during the survey on Lough Arrow, July 2009

Scientific name	Common name	Number of fish captured				
		Benthic mono multimesh gill nets	Benthic braided gill nets	Surface mono multimesh gill nets	Fyke nets	Total
Perca fluviatilis	Perch	732	1	5	0	738
Gasterosteus aculeatus	Three-spined stickleback	27	0	0	22	49
Salmo trutta	Brown trout	6	5	11	0	20
Scardinius erythropthalmus	Rudd	18	2	0	0	20
Abramis brama	Bream	2	0	0	0	2
Rutilus rutilus	Roach	1	0	0	0	1
Esox lucius	Pike	0	1	0	0	1
Anguilla anguilla	European eel	0	0	0	5	5

1.3.2 Fish abundance

Fish abundance (mean CPUE) and biomass (mean BPUE) were calculated as the mean number/weight of fish caught per metre of net. For all fish species except eel, CPUE/BPUE is based on all nets, whereas eel CPUE/BPUE is based on fyke nets only. Mean CPUE and BPUE for all fish species are summarised in Table 1.2. The differences in mean brown trout CPUE and mean perch CPUE between Lough Arrow and four other similar lakes were assessed and no significant differences were found (Fig. 1.2 and 1.3).

Table 1.2. Mean (S.E.) CPUE and BPUE of all fish species captured on Lough Arrow, July 2009

Scientific name	Common name	
		Mean CPUE
Perca fluviatilis	Perch	0.547 (0.168)
Gasterosteus aculeatus	Three-spined stickleback	0.028 (0.018)
Salmo trutta	Brown trout	0.015 (0.005)
Scardinius erythropthalmus	Rudd	0.015 (0.013)
Abramis brama	Bream	0.001 (0.001)
Rutilus rutilus	Roach	0.001 (0.001)
Esox lucius	Pike	0.001 (0.001)
Anghuilla anguilla	European eel	0.028 (0.020)
		Mean BPUE
Perca fluviatilis	Perch	16.090 (5.032)
Salmo trutta	Brown trout	11.616 (4.259)
Scardinius erythropthalmus	Rudd	4.018 (3.090)
Esox lucius	Pike	2.008 (2.008)
Abramis brama	Bream	0.286 (0.286)
Gasterosteus aculeatus	Three-spined stickleback	0.026 (0.018)
Rutilus rutilus	Roach	0.024 (0.024)
Anghuilla anguilla	European eel	6.156 (3.813)

* On the rare occasion where biomass data was unavailable for an individual fish, this was determined from a length/weight regression for that species.

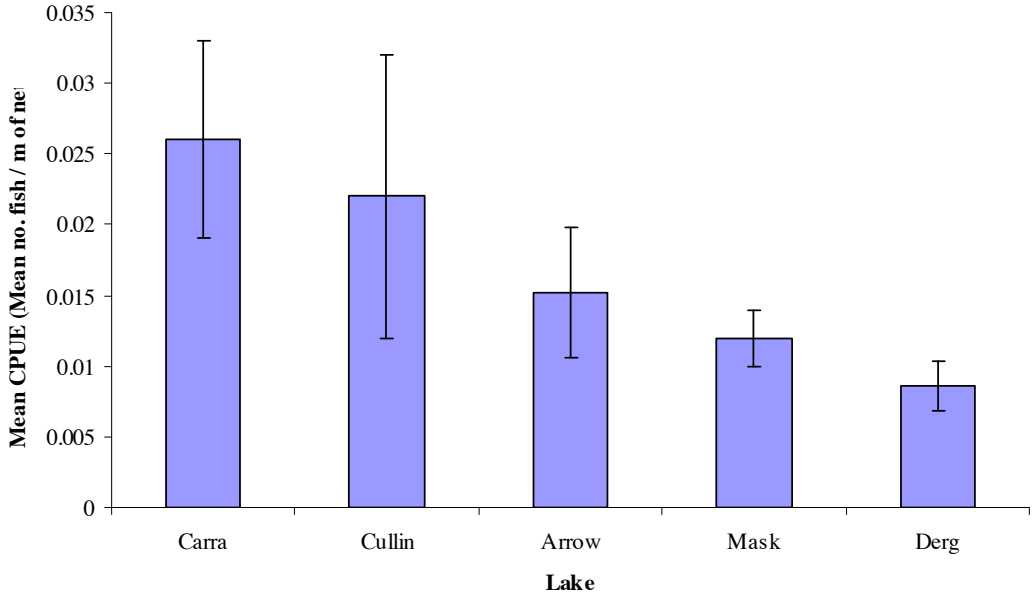

Fig. 1.2. Mean (±S.E.) brown trout CPUE in five lakes surveyed during 2009

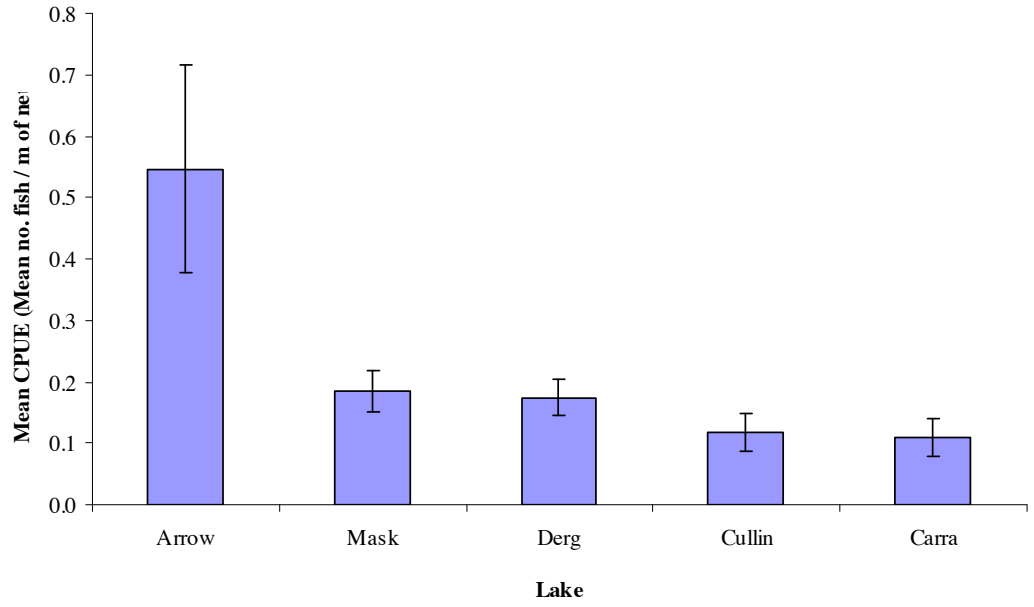

Fig. 1.3. Mean (±S.E.) perch CPUE in five lakes surveyed during 2009

1.3.3 Length frequency distributions

Perch ranged in length from 3.5cm to 30.9cm (mean = 7.8cm) (Fig.1.4). Brown trout ranged in length from 17.5cm to 59.0cm (mean = 33.0cm) (Fig. 1.5). Three-spined stickleback ranged in length from 2.1cm to 4.9cm. Rudd ranged in length from 13.4cm to 32.6cm. Eels ranged from 43.0cm to 56.0cm. Two bream were recorded, measuring 15.6cm and 26.0cm in length. One pike and one roach were also captured, measuring 57.0cm and 13.0cm in length respectively.

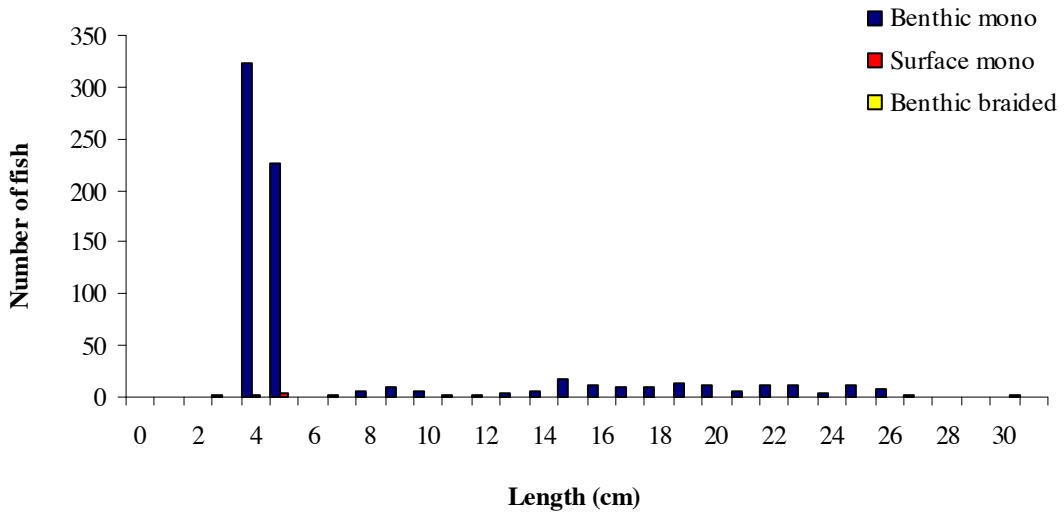

Fig. 1.4. Length frequency of perch (n=714) captured on Lough Arrow, July 2009

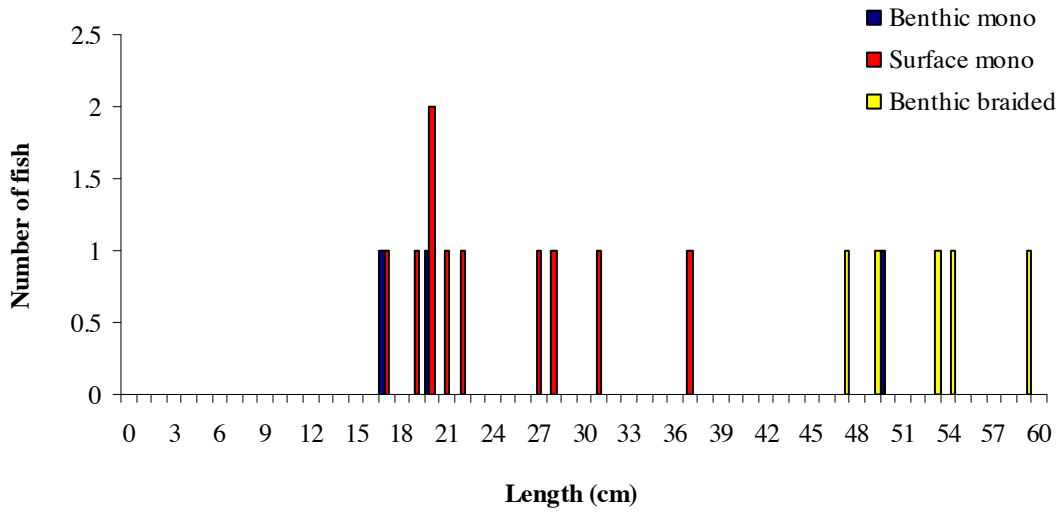

Fig. 1.5. Length frequency of brown trout (n=18) captured on Lough Arrow, July 2009

1.3.4 Fish age and growth

Ten age classes of perch were present, ranging from 0+ to 9+, with a mean L1 of 5.9cm (Table 1.2). The dominant age class was 0+ corresponding to the 2cm to 5cm length class (Fig. 1.4).

Five age classes of brown trout were present, ranging from 1+ to 5+, with a mean L1 of 8.0cm (Table 1.4). Mean brown trout L4 was 43.4cm indicating a very fast rate of growth for brown trout in this lake according to the classification scheme of Kennedy and Fitzmaurice (1971).

Seven age classes of rudd were present, ranging from 2+ to 9+ and the two bream captured were aged 4+ and 7+.

Table 1.3. Mean (±SE) perch length (cm) at age for Lough Arrow, July 2009

	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9
Mean	5.9 (0.1)	11.0 (0.2)	15.5 (0.3)	19.3 (0.3)	22.2 (0.3)	23.9 (0.4)	24.4 (1.1)	26.8 (1.4)	27.8 (2.4)
N	114	91	61	41	32	19	4	3	2
Range	3.5-8.2	6.8-16.3	10.7-19.7	14.1-24.6	18.8-24.8	21.0-26.2	22.6-26.9	24.6-29.5	25.4-30.2

Table 1.4. Mean (±SE) brown trout length (cm) at age for Lough Arrow, July 2009

	L_1	L_2	L_3	L_4	L_5
Mean	8.0 (0.4)	15.9 (1.4)	28.5 (2.2)	43.4 (2.2)	52.1 (5.0)
N	14	6	5	3	2
Range	5.6-10.0	11.2-19.1	22.0-34.5	40.5-47.7	47.1-57.1

1.4 Summary

Perch was the dominant species in terms of both abundance (CPUE) and biomass (BPUE).

The mean perch CPUE in Lough Arrow was relatively high when compared to other similar lake types; however, these differences were not statistically significant. The dominant age class of perch was 0+ which corresponded to the 2cm to 5cm length class. Perch ages ranged from 0+ to 9+, indicating reproductive success in each of the previous number of years.

The mean brown trout CPUE in Lough Arrow was similar to other high alkalinity lakes surveyed. Although Lough Arrow exhibited a lower mean brown trout CPUE than Lough Carra and Lough Cullin and a higher mean CPUE than Lough Mask and Lough Derg these differences were not statistically significant. Brown trout ranged in age from 1+ to 5+ indicating reproductive success in the last number of years. Length at age analyses revealed that brown trout in the lake exhibit a very fast rate of growth according to the classification scheme of Kennedy and Fitzmaurice (1971).

Classification and assigning lakes with an ecological status is a critical part of the WFD monitoring programme. It allows River Basin District managers to identify and prioritise lakes that currently fall short of the minimum "Good Ecological Status" that is required by 2015 if Ireland is not to incur penalties.

A WFD multimetric fish classification tool has been developed for the island of Ireland (Ecoregion 17) using CFB and Agri-Food and Biosciences Northern Ireland (AFBINI) data generated during the NSSHARE Fish in Lakes project (Kelly *et al*., 2008). Using this tool, Lough Arrow has been assigned an ecological status classification of Good based on the fish populations present.

The EPA has assigned an overall status of Good to Lough Arrow in an interim draft classification. This is based on physico-chemical parameters and biotic elements such as macroinvertebrates, macrophytes and fish.

1.5 References

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The Central and Regional
Fisheries Boards

IFI/2013/1-4131

Sampling Fish for the Water Framework Directive

Lakes 2012

Lough Arrow

Iascach Intíre Éireann
Inland Fisheries Ireland

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Water Framework Directive Fish Stock Survey of Lough Arrow, July 2012

Fiona L. Kelly, Lynda Connor, Emma Morrissey, Ciara Wogerbauer, Ronan Matson, Rory Feeney and Kieran Rocks

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Cover photo: Netting survey on Dromore Lough © Inland Fisheries Ireland

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The authors wish to gratefully acknowledge the help and co-operation of the regional director Dr. John Connelly and the staff from IFI, Galway. The authors would also like to gratefully acknowledge the help and cooperation of all their colleagues in IFI, Swords.

The authors would also like to acknowledge the funding provided for the project from the Department of Communications, Energy and Natural Resources for 2012.

We would also like to thank Dr. Martin O' Grady (IFI) and No. 3 Operational Wing, Irish Air Corps (Aer Chór na hÉireann) for the aerial photographs.

1.1 Introduction

Lough Arrow is a large limestone lake situated in Co. Sligo, approximately 24km south-east of Sligo town and 6.4km north-west of Boyle, Co. Roscommon (Plate 1.1, Fig. 1.1). The lake is sheltered on three sides by hills and is the source of the Unshin River. It has a small catchment fed largely by springs on the lake bed and as such is hydrologically different from most lakes in Ireland (Roscommon County Council, 2009). Lough Arrow has a surface area of 1266ha, with a mean depth of 9m and a maximum depth of 33m. The lake is categorised as typology class 12 (as designated by the EPA for the purposes of the Water Framework Directive), i.e. deep (>4m), greater than 50ha and high alkalinity (>100mg/l CaCO3).

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Lough Arrow is an important game fishery, managed by Inland Fisheries Ireland (WRBD), with good stocks of brown trout and eels. The lake was once stocked with brown trout but this practice has now been discontinued (O' Reilly, 2007). Wild brown trout average 0.45kg in weight, with fish up to 2.7kg having been taken on the fly. The lake has previously been surveyed by Inland Fisheries Ireland (previously the Central Fisheries Board and the North Western Regional Fisheries Board) in 1979, 1980 (O' Grady, 1986), 1994, 2002 (O' Grady and Delanty, 2003) and 2007 (O' Grady and Delanty, 2007). In 1994, only perch, pike and brown trout were recorded, although three-spined stickleback were also recorded in the stomachs of pike. Rudd were encountered for the first time in 2002 and were captured again in the 2007 survey. Lough Arrow has been included in the IFI's long term water quality monitoring programme of lake ecosystems since 1975. A fisheries enhancement programme to increase spawning and nursery area for trout was initiated in the Lough Arrow catchment over the period 1998 to 2000 involving re-creation of pools and a natural meander pattern, fencing of streams from livestock and placing of additional spawning gravels in streams where appropriate (O' Grady, 2004).

The lake was also previously surveyed in July 2009 as part of the Water Framework Directive surveillance monitoring programme (Kelly *et al*., 2010). During this survey, perch were found to be the dominant species present in the lake. Brown trout, roach, three-spined stickleback, bream, rudd, pike and eels were also captured during the survey.

Plate 1.1. Lough Arrow, looking west over the lake (Photo courtesy of CFB and No. 3 Operational Wing, Irish Air Corps [Aer Chór na hÉireann])

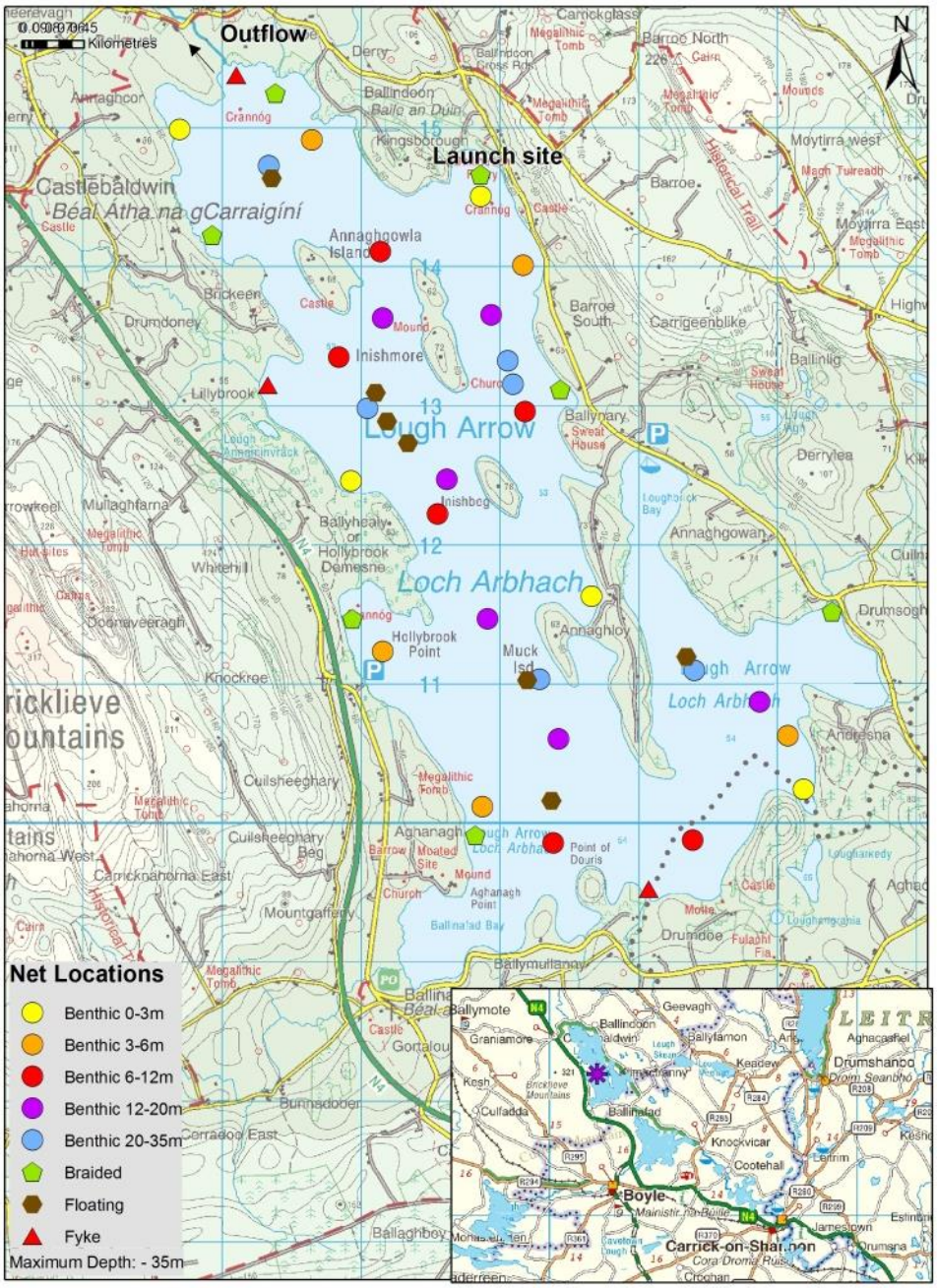

Fig. 1.1. Location map of Lough Arrow showing locations and depths of each net (outflow is indicated on map)

1.2 Methods

Lough Arrow was surveyed over four nights from the 23rd to the 27th of July 2012. A total of three sets of Dutch fyke nets, 28 benthic monofilament multi-mesh (12 panel, 5-55mm mesh size) CEN standard survey gill nets (5 @ 0-2.9m, 5 @ 3-5.9m, 6 @ 6-11.9m, 6 @ 12-19.9m and 6 @ 20-34.9m) and seven surface floating monofilament multi-mesh (12 panel, 5-55mm mesh size) CEN standard survey gill nets were deployed randomly in the lake (38 sites). The netting effort was supplemented using seven benthic braided survey gill nets (62.5mm mesh knot to knot) at seven additional sites. Nets were deployed in the same locations as were randomly selected in the previous survey in 2009. A handheld GPS was used to mark the precise location of each net. The angle of each gill net in relation to the shoreline was randomised.

All fish apart from perch were measured and weighed on site and scales were removed from all brown trout, roach, pike, bream, hybrids and rudd. Live fish were returned to the water whenever possible (i.e. when the likelihood of their survival was considered to be good). Samples of fish were retained for further analysis.

1.3 Results

1.3.1 Species Richness

A total of eight fish species and one type of hybrid were recorded on Lough Arrow in July 2012, with 695 fish being captured. The number of each species captured by each gear type is shown in Table 1.1. Perch was the most abundant fish species recorded, followed by roach, three-spined stickleback, brown trout, rudd, roach x bream hybrids, bream, eels and pike. During the previous survey in 2009 the same species composition was recorded with the exception of roach x bream hybrids, which were present during the 2012 survey but were not captured in 2009 (Kelly *et al*., 2010).

Table 1.1. Number of each fish species captured by each gear type during the survey on Lough Arrow, July 2012

Scientific name	Common name	Number of fish captured				
		Benthic mono multimesh gill nets	Benthic braided gill nets	Surface mono multimesh gill nets	Fyke nets	Total
Salmo trutta	Brown trout	8	4	7	0	19
Perca fluviatilis	Perch	461	0	0	1	462
Rutilus rutilus	Roach	101	0	0	0	101
Gasterosteus aculeatus	Three-spined stickleback	74	0	0	6	80
Esox Lucius	Pike	1	3	0	0	4
Scardinius erythropthalmus	Rudd	4	0	0	0	4
Rutilus rutilus x Abramis brama	Roach x bream hybrid	2	0	0	0	2
Abramis brama	Bream	1	0	0	0	1
Anguilla Anguilla	European eel	0	0	0	22	22

1.3.2 Fish abundance

Fish abundance (mean CPUE) and biomass (mean BPUE) were calculated as the mean number/weight of fish caught per metre of net. For all fish species except eel, CPUE/BPUE is based on all nets, whereas eel CPUE/BPUE is based on fyke nets only. Mean CPUE and BPUE for all fish species captured in 2009 and 2012 are summarised in Table 1.2. Mean CPUE and BPUE for all fish species is illustrated in Figures 1.2 and 1.3.

Although the mean brown trout CPUE and BPUE appeared slightly lower in 2012 than in 2009, these differences were not statistically significant (Fig. 1.2 and Fig. 1.3).

The differences in the mean brown trout CPUE and BPUE between Lough Arrow and six similar lakes were assessed, with an overall significant difference being found (Kruskal-Wallis, $P<0.05$) (Fig. 1.4 and Fig 1.5). However, Independent-Samples Mann-Whitney U tests between each lake showed that the mean brown trout CPUE and BPUE for Lough Arrow was not significantly different from the other similar lakes surveyed (Fig. 1.4 and Fig 1.5).

Although the mean perch CPUE appeared lower in 2012 than in 2009, this difference was not statistically significant (Fig. 1.2).

The differences in the mean perch CPUE and BPUE between Lough Arrow and six similar lakes were also assessed, with overall significant differences being found (Kruskal-Wallis, $P<0.05$) (Fig. 1.6 and Fig. 1.7). Independent-Samples Mann-Whitney U tests between each lake showed that Lough Arrow had a

significantly higher mean perch CPUE and BPUE than Lough Mask (Mann-Whitney, $z = 3.277$, $P<0.05$ and $z = 3.021$, $P<0.05$) (Fig. 1.6 and Fig. 1.7).

Although the mean perch BPUE appeared higher in 2012 than in 2009, this difference was also not statistically significant (Fig. 1.3).

Table 1.2. Mean (S.E.) CPUE and BPUE for all fish species captured on Lough Arrow, 2009 and 2012

Scientific name	Common name	2009	2012
		Mean CPUE	
Salmo trutta	Brown trout	0.015 (0.005)	0.014 (0.005)
Perca fluviatilis	Perch	0.547 (0.168)	0.342 (0.072)
Rutilus rutilus	Roach	0.001 (0.001)	0.075 (0.071)
Gasterosteus aculeatus	Three-spined stickleback	0.028 (0.018)	0.057 (0.024)
Esox Lucius	Pike	0.001 (0.001)	0.003 (0.002)
Scardinius erythropthalmus	Rudd	0.015 (0.013)	0.003 (0.003)
Rutilus rutilus x Abramis brama	Roach x bream hybrid	-	0.001 (0.001)
Abramis brama	Bream	0.001 (0.001)	0.001 (0.001)
Anguilla Anguilla	European eel	0.028 (0.020)	0.122 (0.048)
Salmo trutta		**Mean BPUE**	
Salmo trutta	Brown trout	11.616 (4.259)	8.501 (4.267)
Perca fluviatilis	Perch	16.090 (5.032)	24.680 (6.037)
Rutilus rutilus	Roach	0.024 (0.024)	3.637 (3.279)
Gasterosteus aculeatus	Three-spined stickleback	0.026 (0.018)	0.047 (0.021)
Esox Lucius	Pike	2.008 (2.008)	6.051 (3.272)
Scardinius erythropthalmus	Rudd	4.018 (3.090)	1.651 (1.651)
Rutilus rutilus x Abramis brama	Roach x bream hybrid	-	0.008 (0.006)
Abramis brama	Bream	0.286 (0.286)	0.380 (0.380)
Anguilla Anguilla	European eel	6.156 (3.813)	29.228 (11.082)

* On the rare occasion where biomass data was unavailable for an individual fish, this was determined from a length/weight regression for that species.

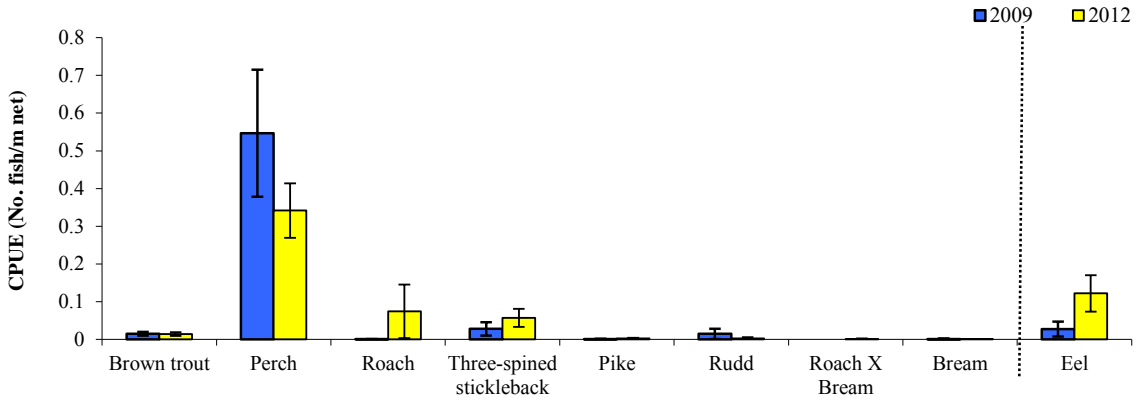

Fig. 1.2. Mean (±S.E.) CPUE for all fish species captured in Lough Arrow (Eel CPUE based on fyke nets only), 2009 and 2012

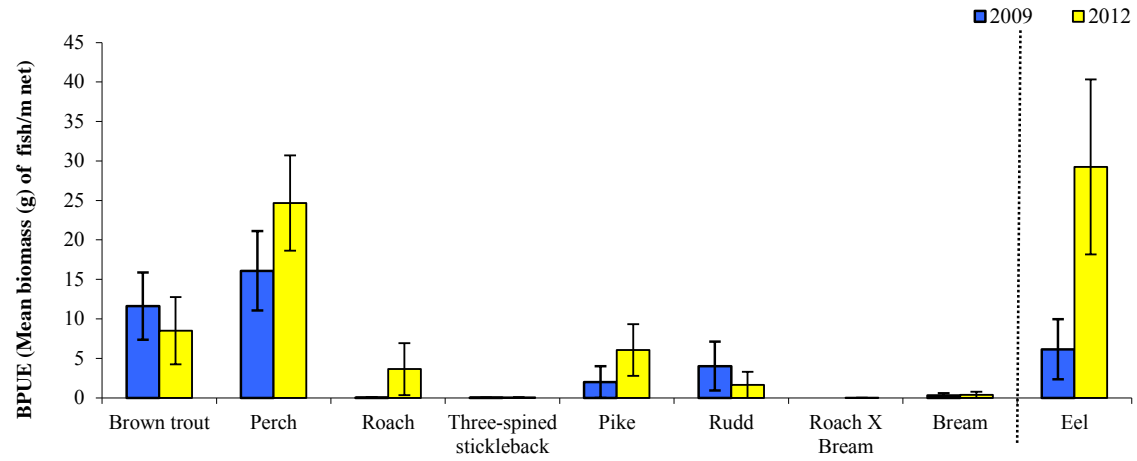

Fig. 1.3. Mean (±S.E.) BPUE for all fish species captured in Lough Arrow (Eel BPUE based on fyke nets only), 2009 and 2012

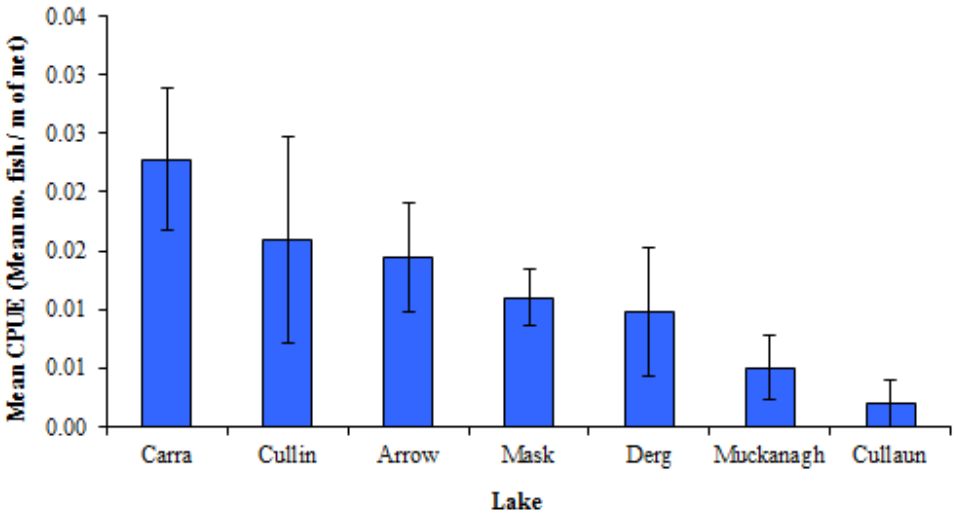

Fig. 1.4. Mean (±S.E.) brown trout CPUE in seven lakes surveyed during 2012

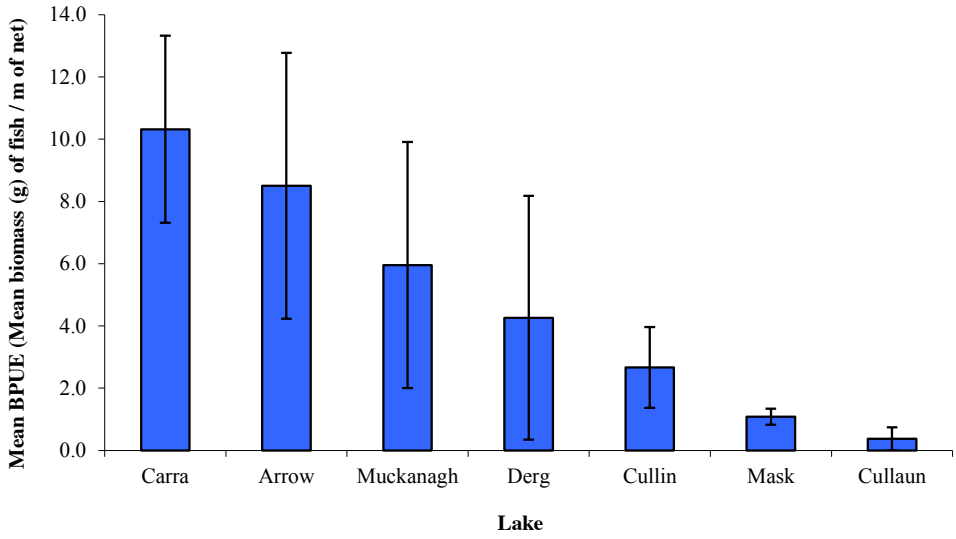

Fig. 1.5. Mean (±S.E.) brown trout BPUE in seven lakes surveyed during 2012

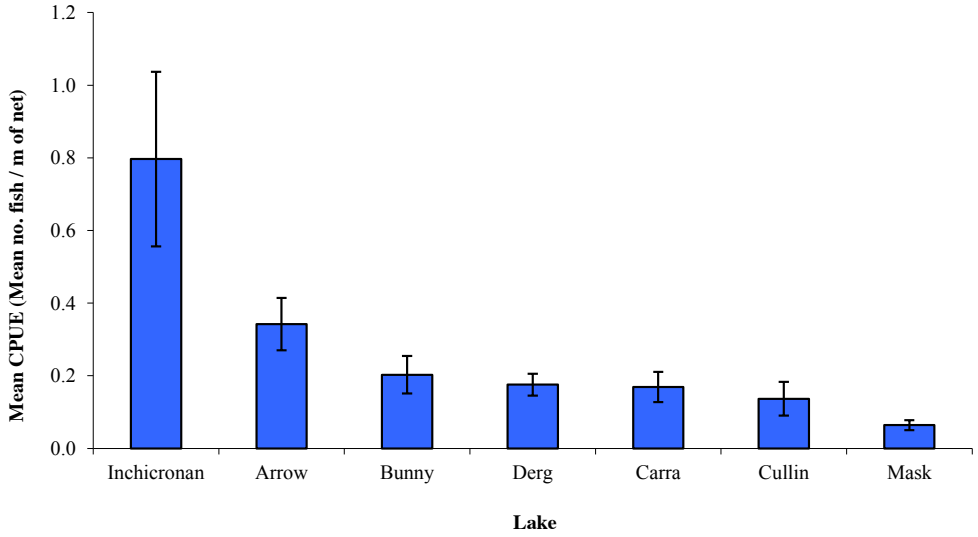

Fig. 1.6. Mean (±S.E.) perch CPUE in seven lakes surveyed during 2012

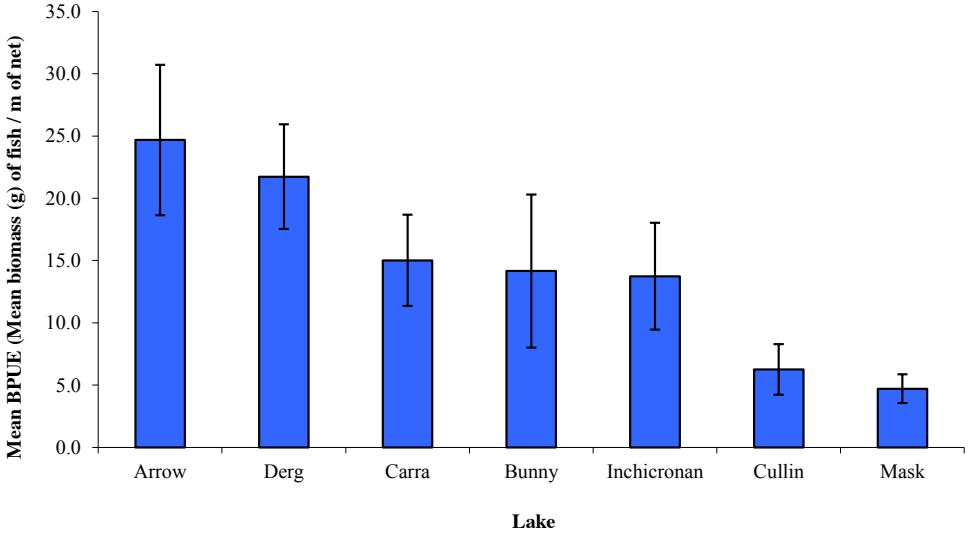

Fig. 1.7. Mean (±S.E.) perch BPUE in seven lakes surveyed during 2012

1.3.3 Length frequency distributions

Brown trout captured during the 2012 survey ranged in length from 7.2cm to 55.0cm (mean = 30.3cm) (Fig. 1.6). Brown trout captured during the 2009 survey ranged in length from 17.5cm to 59.0cm (Fig. 1.6).

Perch captured during the 2012 survey ranged in length from 3.5cm to 29.8cm (mean = 12.6cm) (Fig. 1.7). Perch captured during the 2009 survey ranged in length from 3.5cm to 30.9cm (Fig. 1.7).

Roach captured during the 2012 survey ranged in length from 6.0cm to 30.0cm, eels had lengths ranging from 34.5cm to 65.8cm, pike ranged in length from 36.5cm to 70.1cm, rudd ranged in length from 26.7cm to 31.9cm and three-spined stickleback ranged in length from 3.4cm to 5.0cm. Two roach x bream hybrids were recorded at 7.5cm and one bream was recorded at 29.8cm.

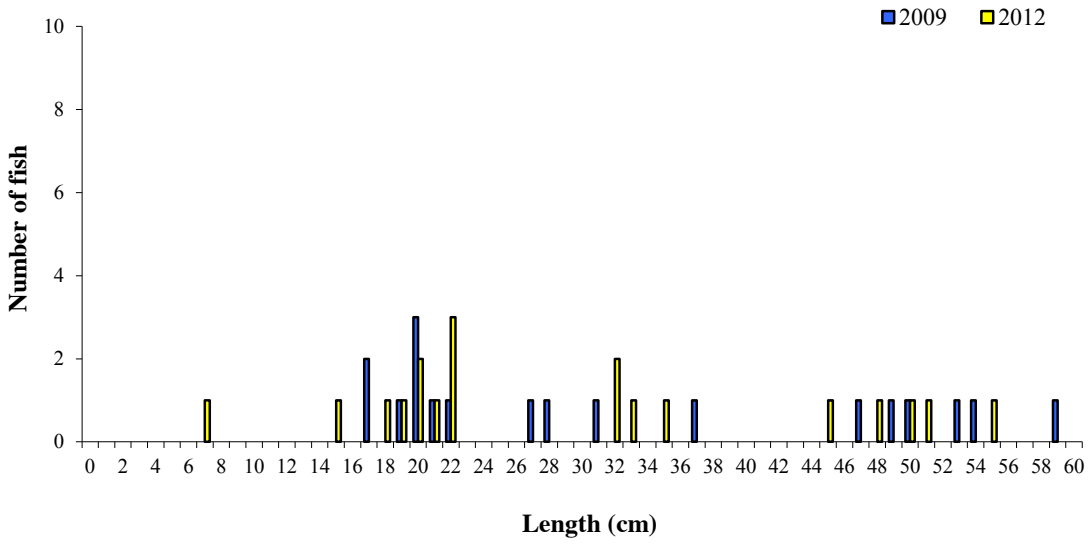

Fig. 1.6. Length frequency of brown trout captured on Lough Arrow, 2009 and 2012

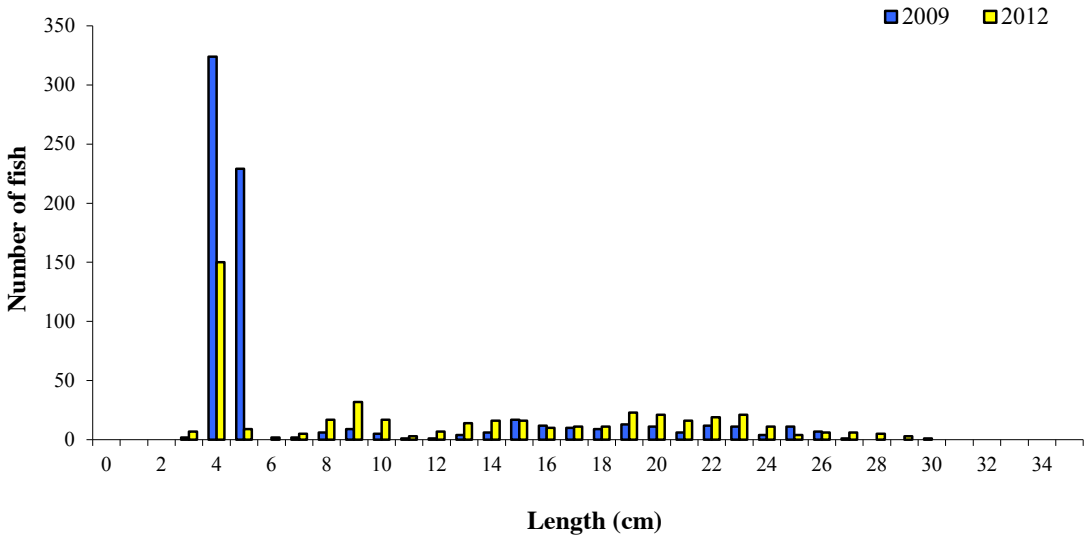

Fig. 1.7. Length frequency of perch captured on Lough Arrow, 2009 and 2012

1.3.4 Fish age and growth

Seven age classes of brown trout were present, ranging from 0+ to 6+, with a mean L1 of 7.8cm (Table 1.3). In the 2009 survey, brown trout ranged from 0+ to 5+ with a mean L1 of 8.0cm. Mean brown trout L4 in 2012 was 38.4cm indicating a very fast rate of growth for brown trout in this lake according to the classification scheme of Kennedy and Fitzmaurice (1971).

Ten age classes of perch were present, ranging from 0+ to 9+, with a mean L1 of 5.9cm (Table 1.4). The dominant age class was 0+ (Fig 1.7). In the 2009 survey, perch also ranged from 0+ to 9+ with a mean L1 of 5.9cm.

The roach captured ranged in age from 1+ to 8+.

Table 1.3. Mean (±SE) brown trout length (cm) at age for Lough Arrow, July 2012

	L_1	L_2	L_3	L_4	L_5	L_6
Mean	7.8 (0.4)	19.0 (1.4)	30.7 (1.9)	38.4 (2.8)	45.5 (0.4)	50.6 (0)
N	17	13	8	8	4	1
Range	5.7-10.7	11.6-27.9	20.5-39.2	24.6-51.8	44.7-46.4	50.6-50.6

Table 1.4. Mean (±SE) perch length (cm) at age for Lough Arrow, July 2012

	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9
Mean	5.9 (0.1)	10.9 (0.1)	16.8 (0.3)	21.1 (0.3)	24.2 (0.4)	24.7 (0.7)	25.4 (0.4)	26.5 (0.7)	27.0 (1.1)
N	149	120	82	43	27	7	5	4	2
Range	3.9-7.8	7.7-14.9	10.5-21.3	16.2-25.3	19.8-28.5	22.0-27.4	24.3-26.3	25.1-28.4	25.9-28.1

1.4 Summary

Perch was the dominant species in terms of abundance (CPUE) and biomass (BPUE) captured in the survey gill nets.

Although the mean brown trout CPUE and BPUE in Lough Arrow appeared slightly different in 2012 than in the 2009 survey, these differences were not statistically significant. The mean brown trout CPUE and BPUE in Lough Arrow was similar to the other lakes assessed during 2012, with no statistically significant differences being found between lakes. Brown trout ranged in age from 0+ to 6+, indicating reproductive success in the previous seven years. Length at age analyses revealed that brown trout in the lake exhibit a very fast rate of growth according to the classification scheme of Kennedy and Fitzmaurice (1971).

Although the mean perch CPUE and BPUE in Lough Arrow appeared slightly different in 2012 than in the 2009 survey, these differences were not statistically significant. The mean perch CPUE and BPUE in Lough Arrow was significantly higher than Lough Mask, another similar lake surveyed. Perch ranged in age from 0+ to 9+, indicating reproductive success in the previous ten years.

Classification and assigning lakes with an ecological status is a critical part of the WFD monitoring programme. It allows River Basin District managers to identify and prioritise lakes that currently fall short of the minimum "Good Ecological Status" that is required by 2015 if Ireland is not to incur penalties.

A multimetric fish ecological classification tool (Fish in Lakes – 'FIL') was developed for the island of Ireland (Ecoregion 17) using IFI and Agri-Food and Biosciences Institute Northern Ireland (AFBINI) data

generated during the NSSHARE Fish in Lakes project (Kelly *et al*., 2008). This tool was further developed during 2010 (FIL2) in order to make it fully WFD compliant, including producing EQR values for each lake and associated confidence in classification (Kelly *et al*., 2012). Using the FIL2 classification tool, Lough Arrow has been assigned an ecological status of Good based on the fish populations present in 2012. The ecological status assigned to the lake based on the 2009 survey data was High.

In the 2007 to 2009 surveillance monitoring reporting period, the EPA assigned Lough Arrow an overall ecological status of Good, based on all monitored physico-chemical and biological elements, including fish. This status classification will be revised at the end of 2012.

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IFI/2016/1-4303

National Research Survey Programme

Lakes 2015

Lough Arrow

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INLAND FISHERIES IRELAND

Inland Fisheries Ireland

National Research Survey Programme

Fish Stock Survey of Lough Arrow, July 2015

Fiona L. Kelly, Lynda Connor, Karen Delanty, Paul McLoone, John Coyne, Emma Morrissey, William Corcoran, Daniel Cierpial, Ronan Matson, Paul Gordon, Rossa O' Briain, Kieran Rocks, Laura Walsh, Sinead O' Reilly, Roisin O' Callaghan, Ronan Cooney and Dave Timbs.

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Cover photo: Netting survey on Lough Dan © Inland Fisheries Ireland

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1.1 Introduction

Lough Arrow is a large limestone lake situated in Co. Sligo, approximately 24km south-east of Sligo town and 6.4km north-west of Boyle, Co. Roscommon (Plate 1.1, Fig. 1.1). The lake is sheltered on three sides by hills and is the source of the Unshin River. It has a small catchment fed largely by springs on the lake bed and as such is hydrologically different from most lakes in Ireland (Roscommon County Council, 2009). Lough Arrow has a surface area of 1266ha, with a mean depth of 9m and a maximum depth of 33m. The lake is categorised as typology class 12 (as designated by the EPA for the purposes of the Water Framework Directive), i.e. deep (>4m), greater than 50ha and high alkalinity (>100mg/l CaCO3).

Lough Arrow is of major conservation significance as it conforms to a type (hard water lake) listed in Annex I of the EU Habitats Directive. It also supports a number of important bird species and a population of otter (a Red Data Book species which is legally protected under the 1976 Wildlife Act and is listed on Annex II of the EU Habitats Directive) (NPWS, 1999). The shores of the lake are, for the most part, stony, although the common club-rush (*Scirpus lacustris*) and common reed (*Phragmites australis*) occur abundantly in several bays (NPWS, 1999). Two comprehensive surveys of submerged vegetation in the lake were undertaken in 1984 and 2001, during which the open water aquatic flora was found to be dominated by species of *Chara*, *Potamogeton* and *Elodea canadensis*, whilst the shallow (<0.5m) areas commonly contained *Litorella sp*., *Potamogeton filiformis* and *Myriophyllum alterniflorum* (King, 2002).

Lough Arrow is an important game fishery, managed by Inland Fisheries Ireland (WRBD), with good stocks of brown trout and eels. The lake was once stocked with brown trout but this practice has now been discontinued (O' Reilly, 2007). Wild brown trout average 0.45kg in weight, with fish up to 2.7kg having been taken on the fly. Lough Arrow has been included in the IFI's long term water quality monitoring programme of lake ecosystems since 1975. A fisheries enhancement programme to increase spawning and nursery area for trout was initiated in the Lough Arrow catchment over the period 1998 to 2000 involving re-creation of pools and a natural meander pattern, fencing of streams from livestock and placing of additional spawning gravels in streams where appropriate (O' Grady, 2004).

The lake was previously surveyed in 1979, 1980, 1981 (O' Grady, 1986), 1994, 2002 (O' Grady and Delanty, 2003), 2006 and 2007 (O' Grady and Delanty, 2007) as part of a fish stock assessment by IFI's research section using seven-panel benthic braided survey gill nets. Up to 1994, only perch, pike and brown trout were recorded, although three-spined stickleback were also recorded in the stomachs of pike. Rudd were encountered for the first time in 2002 and were captured again in the 2007 survey.

The lake was also previously surveyed by IFI for the WFD fish monitoring programme in 2009 and 2012 (Kelly *et al*., 2010 and 2013). During both of these surveys, perch were found to be the dominant species present in the lake. Brown trout, roach, three-spined stickleback, bream, rudd, pike and eels were also captured during the survey.

The survey had two objectives:

1. Assess the status of the fish stocks in the lake as part of IFIs WFD surveillance monitoring programme and also the national brown trout and coarse fish research programmes.

2. Undertake a method intercalibration exercise using the existing WFD multi method approach (benthic and floating multimesh monofilament survey gill nets, fyke nets, but adding supplementary two panel braided survey gill nets instead of one panel braided survey gill nets (WFD+)) and the method established by IFI in the late 1970s to assess the status of brown trout in lakes (seven panel braided survey gill nets), but adding an additional 88.90mm panel to these latter nets (8-PBB).

This report summarises the results of the 2015 fish stock survey (e.g. species composition, abundance and age structure) on Lough Arrow using both methods above, while the method intercalibration results will be dealt with in a separate report.

Plate 1.1. Lough Arrow, looking west over the lake (Photo courtesy of CFB and No. 3 Operational Wing, Irish Air Corps [Aer Chór na hÉireann])

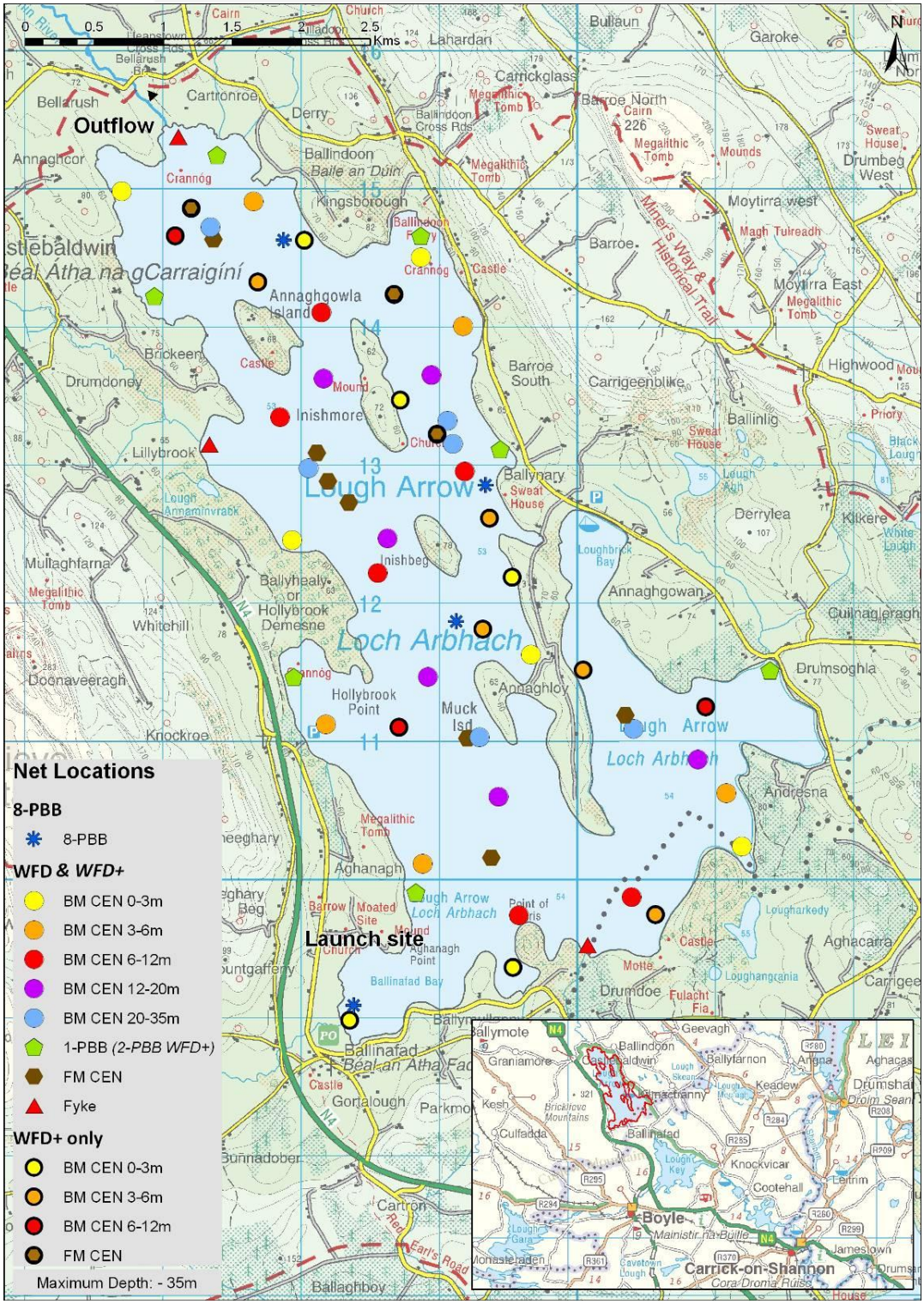

Fig. 1.1. Location map of Lough Arrow showing locations and depths of each net (outflow is indicated on map)

1.2 Methods

1.2.2 Netting methods

Lough Arrow was surveyed over four nights from the 13th and the 17th of July 2015. A total of 3 Dutch fyke nets (Fyke), 41 benthic monofilament multi-mesh (12 panel, 5-55mm mesh knot to knot) CEN standard survey gill nets (BM CEN) and 7 surface floating monofilament multi-mesh (FM CEN) (12 panel, 5-55mm mesh knot to knot) CEN standard survey gill nets were deployed in the lake. The netting effort was supplemented using two-panel benthic braided (63.5mm and 88.9mm mesh knot to knot) survey gill nets (2-PBB).

Four eight-panel benthic braided survey gill nets (8-PBB) were also deployed on the lake. They were composed of eight 27.5m long panels each a different mesh size, tied together randomly. The panels ranged from 2" (50.8mm stretched mesh, 25.4mm mesh knot to knot) to 5" (127mm stretched mesh, 63.5mm mesh knot to knot) in half inch (12.7mm) increments (O'Grady, 1981) with the addition of a 7" (177.8mm stretched mesh, 88.9mm mesh knot to knot) panel.

The nets were deployed in the same locations as randomly chosen in the previous surveys. Site locations for additional nets (WFD+) were chosen randomly within fixed depth zones. A handheld GPS was used to mark the precise location of each net. The angle of each gill net in relation to the shoreline was also randomised.

All fish apart from perch were measured and weighed on site and scales were removed from all brown trout, pike, roach, bream, hybrids and rudd. Live fish were returned to the water whenever possible (i.e. when the likelihood of their survival was considered to be good). Samples of fish were returned to the laboratory for further analysis.

1.2.2 Biosecurity - disinfection and decontamination procedures

Procedures are required for disinfection of equipment in order to prevent dispersal of alien species and other organisms to uninfected waters. A standard operating procedure was compiled by Inland Fisheries Ireland for this purpose (Caffrey, 2010) and is followed by staff on the IFI NRSP team when moving between water bodies.

1.3 Results

1.3.1 Species Richness

A total of eight fish species and one type of hybrid were recorded on Lough Arrow in July 2015, with 548 fish being captured. The number of each species captured by each gear type is shown in Table 1.1. Perch was the most abundant fish species recorded, followed by three-spined stickleback, roach, brown trout, eels, roach x bream hybrids, rudd, pike and bream (Table 1.1). During the previous WFD surveys in 2009 and 2012 the same species composition was recorded with the exception of roach x bream hybrids, which were present during the 2012 and 2015 surveys but were not captured in 2009 (Kelly *et al*., 2010 and 2013). The IFI surveys conducted from 1979 to 2007 captured the same species composition, with the exception of roach (O' Grady, 1986) and bream (O' Grady and Delanty, 2003 and 2007).

Table 1.1. Number of each fish species captured by each gear type during the survey on Lough Arrow, July 2015

Scientific name	Common name	Number of fish captured					
		8-PBB	2-PBB	BM CEN	FM CEN	Fyke	Total
Salmo trutta	Brown trout	25	9	34	3	0	71
Perca fluviatilis	Perch	44	6	235	7	0	292
Rutilus rutilus	Roach	10	0	60	0	0	70
Gasterosteus aculeatus	Three-spined stickleback	0	0	70	0	28	98
Esox Lucius	Pike	1	1	1	0	0	3
Scardinius erythropthalmus	Rudd	0	0	2	0	0	2
Rutilus rutilus x Abramis brama	Roach x bream hybrid	0	0	3	0	0	3
Abramis brama	Bream	0	0	1	0	0	1
Anguilla Anguilla	European eel	0	0	0	0	8	8

1.3.2 Fish abundance

Fish abundance (mean CPUE) and biomass (mean BPUE) were calculated as the mean number/weight of fish caught per metre of net. For all fish species except eel, CPUE/BPUE is based on all nets, whereas eel CPUE/BPUE is based on fyke nets only. Mean CPUE and BPUE for all fish species captured are summarised in Table 1.2.

Perch was the dominant fish species in terms of abundance and biomass (Table 1.3).

Table 1.2. Mean (S.E.) CPUE and BPUE (per metre of net) for all fish species captured on Lough Arrow, 2015

Scientific name	Common name	8-PBB	WFD+**
		Mean CPUE (±S.E.)	
Salmo trutta	Brown trout	0.028 (0.008)	0.023 (0.004)
Perca fluviatilis	Perch	0.050 (0.023)	0.136 (0.024)
Rutilus rutilus	Roach	0.011 (0.006)	0.033 (0.011)
Gasterosteus aculeatus	Three-spined stickleback	-	0.046 (0.029)
Esox Lucius	Pike	0.001 (0.001)	0.001 (0.001)
Scardinius erythropthalmus	Rudd	-	0.001 (0.001)
Rutilus rutilus x Abramis brama	Roach x bream hybrid	-	0.002 (0.001)
Abramis brama	Bream	-	0.001 (0.001)
Anguilla Anguilla	European eel	-	0.033 (0.016)*
		Mean BPUE (±S.E.)	
Salmo trutta	Brown trout	-	11.127 (2.636)
Perca fluviatilis	Perch	-	13.271 (2.369)
Rutilus rutilus	Roach	-	6.719 (2.794)
Gasterosteus aculeatus	Three-spined stickleback	-	0.036 (0.023)
Esox Lucius	Pike	-	0.878 (0.749)
Scardinius erythropthalmus	Rudd	-	0.874 (0.874)
Rutilus rutilus x Abramis brama	Roach x bream hybrid	-	0.669 (0.532)
Abramis brama	Bream	-	0.546 (0.546)
Anguilla Anguilla	European eel	-	7.428 (6.966)*

Note: On the rare occasion where biomass data was unavailable for an individual fish, this was determined from a length/weight regression for that species.

*Eel CPUE and BPUE based on fyke nets only

**CPUE and BPUE data above for all fish species except eels are not comparable to earlier surveys as an extra panel was added to the supplementary nets (now 2-PBB) to provide additional information on large coarse fish.

1.3.3 Length frequency distributions and growth

Brown trout

Brown trout captured during the 2015 survey ranged in length from 14.8cm to 56.0cm (mean = 30.8cm) (Fig. 1.2). Seven age classes were present, ranging from 1+ to 7+, with a mean L1 of 7.5cm (Table 1.3). The dominant age class was 4+ (Fig. 1.2). Mean brown trout L4 in 2015 was 36.4cm indicating a very fast rate of growth for brown trout in this lake according to the classification scheme of Kennedy and Fitzmaurice (1971) (Table 1.3).

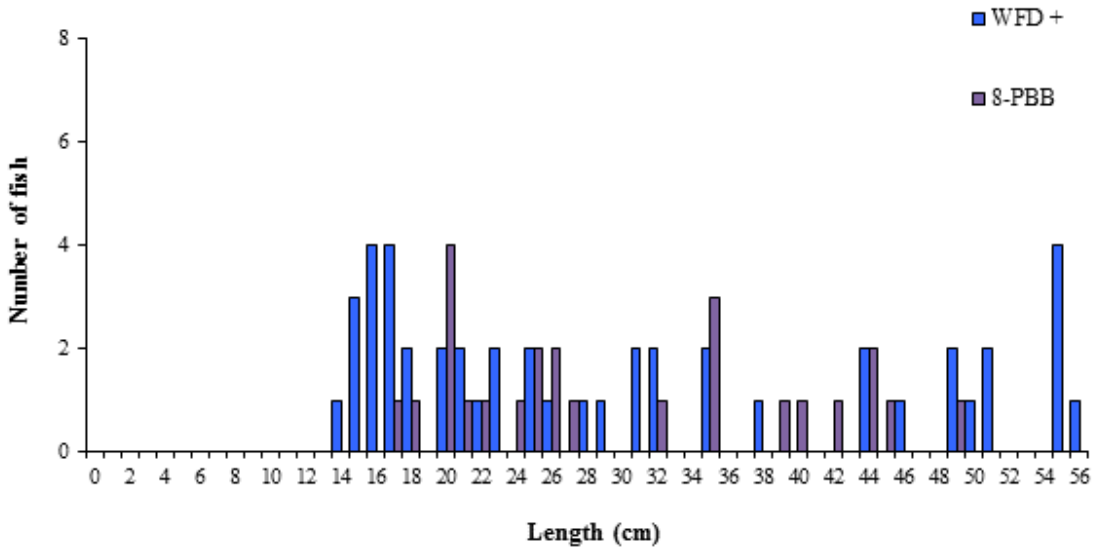

Fig. 1.2. Length frequency of brown trout captured on Lough Arrow, 2015

Table 1.3. Mean (±S.E.) brown trout length (cm) at age for Lough Arrow, July 2015

	L_1	L_2	L_3	L_4	L_5	L_6	L7	Growth Category
Mean (±S.E.)	7.5 (0.1)	17.1 (0.4)	27.4 (0.6)	36.4 (0.9)	42.6 (1.0)	48.3 (1.8)	51.6	Very fast
N	59	49	35	24	17	7	1	
Range	5.7-9.9	12.1-24.3	20.1-35.0	28.1-43.9	36.2-49.4	41.9-52.9	51.6-51.6	

Perch

Perch captured during the 2015 survey ranged in length from 3.5cm to 31.6cm (mean = 17.4cm) (Fig.1.3) with seven age classes present, ranging from 0+ to 8+ with a mean L1 of 6.6cm (Table 1.4). The dominant age class was 3+ (Fig.1.3).

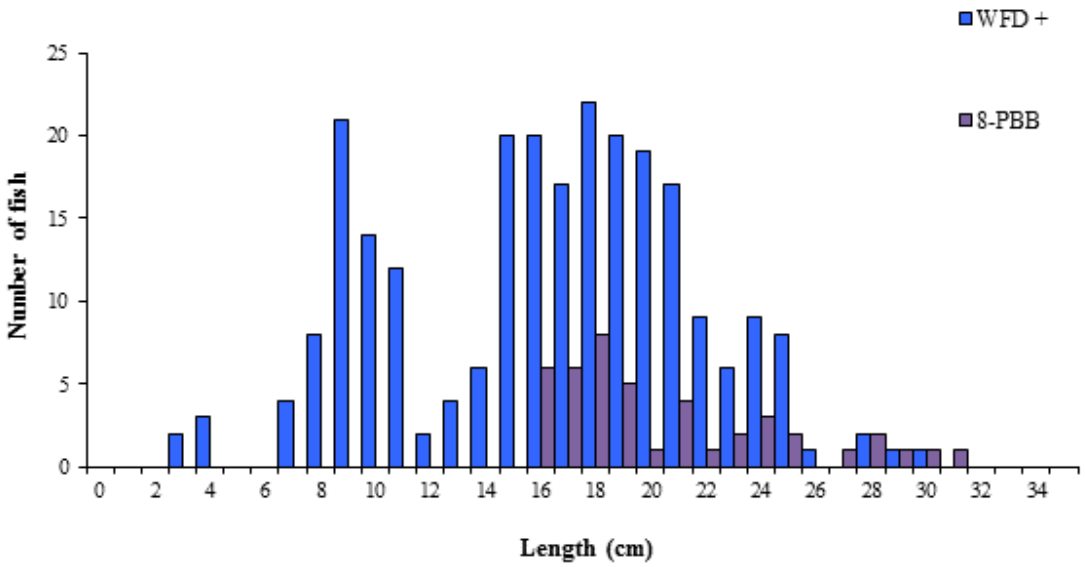

Fig. 1.3. Length frequency of perch captured on Lough Arrow, 2015

Table 1.4. Mean (±S.E.) perch length (cm) at age for Lough Arrow, July 2015

	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8
Mean (± S.E.)	6.6 (0.2)	12.0 (0.3)	17.7 (0.3)	22.2 (0.4)	24.8 (0.8)	26.8	28.9	30.2
N	60	44	33	17	10	1	1	1
Range	4.9-10.3	8.3-16.1	13.3-21.4	19.9-24.9	21.6-28.5	26.8-26.8	28.9-28.9	30.2-30.2

Roach

Roach captured during the 2015 survey ranged in length from 7.4cm to 34.9cm (mean = 21.0cm) (Fig.1.4) with eight age classes present, ranging from 1+ to 8+ with a mean L1 of 3.3cm (Table 1.5). The dominant age class was 3+ (Fig.1.4).

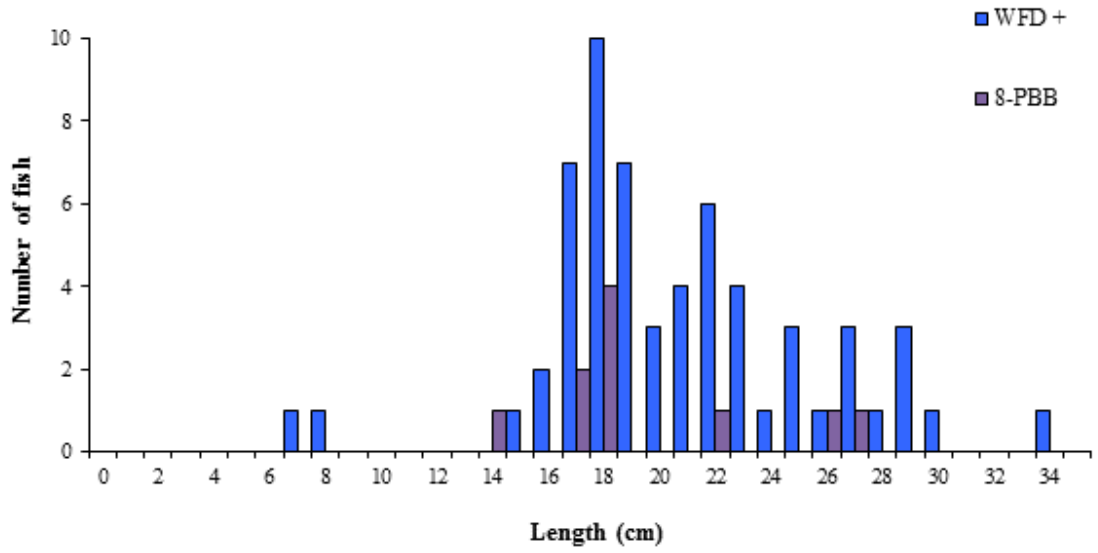

Fig. 1.4. Length frequency of roach captured on Lough Arrow, 2015

Table 1.5. Mean (±S.E.) roach length (cm) at age for Lough Arrow, July 2015

	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8
Mean (± S.E.)	3.3 (0.1)	7.8 (0.2)	12.7 (0.4)	16.6 (0.4)	20.6 (0.5)	24.0 (0.6)	26.5 (1.0)	30.9 (3.1)
N	39	38	37	28	21	14	8	2
Range	2.2-4.2	6.0-11.1	9.3-18.7	13.7-21.3	17.1-26.7	20.6-28.2	23.2-32.0	27.7-34.0

Other fish

Eels captured during the 2015 survey ranged in length from 37.5cm to 56.0cm, three-spined stickleback ranged in length from 2.9cm to 4.8cm, pike ranged from 31.4cm to 73.0cm, roach x bream hybrids ranged 25.0cm to 31.7cm and one bream was 41.4cm. Two rudd were measured at 33.9cm.

1.3.4 Stomach and diet analysis

Feeding studies provide a good indication of the availability of food items and the angling methods that are likely to be successful. However, the value of stomach content analysis is limited unless undertaken over a long period as diet may change on a daily basis depending on the availability of food items.

Perch

Perch initially start to feed on pelagic zooplankton. Once they reach an intermediate size they start feeding on benthic resources eventually moving on to feed on fish once they are large enough (Hjelm *et al*., 2000). The food items recorded in perch stomachs during the survey were dominated by *Gammarus* sp. (Fig 1.5).

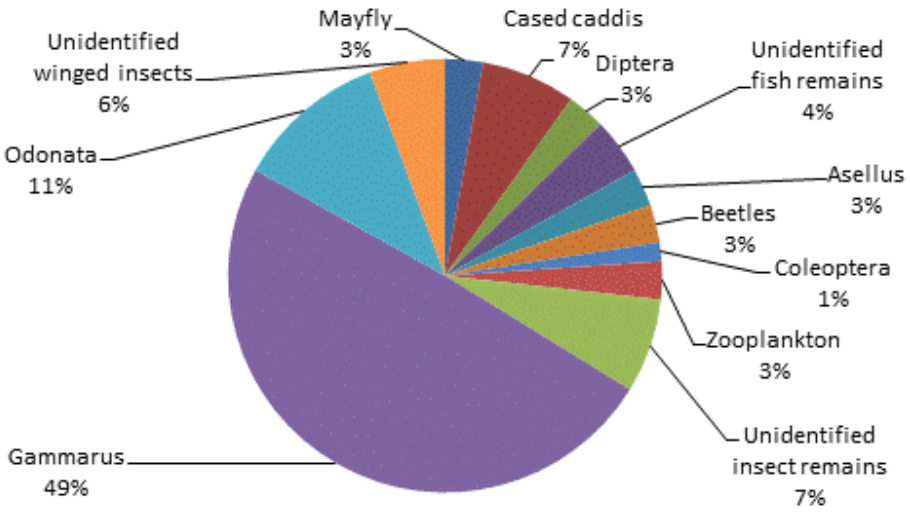

Fig. 1.5. Diet of perch captured on Lough Arrow 2015 (% occurrence) n=52

1.4 Summary and ecological status

Perch was the dominant species in terms of abundance (CPUE) captured in the survey gill nets during the 2015 survey.

Perch ranged in length from 3.5cm to 39.1cm and ranged in age from 0+ to 8+, indicating reproductive success in each of the previous nine years. The dominant age class was 3+.

Roach ranged in length from 7.4cm to 34.9cm ranging in age from 1+ to 8+ indicating reproductive success in eight of the previous nine years. The dominant age class was 3+.

Brown trout captured ranged in length from 14.8cm to 56.0cm and ranged in age from 1+ to 7+, indicating reproductive success in seven of the previous eight years. The dominant age class was 4+. Length at age analyses revealed that brown trout in the lake exhibit a very fast rate of growth according to the classification scheme of Kennedy and Fitzmaurice (1971).

Classification and assigning lakes with an ecological status is a critical part of the WFD monitoring programme. It allows River Basin District managers to identify and prioritise lakes that currently fall short of the minimum "Good Ecological Status" that is required by 2015 if Ireland is not to incur penalties.

A multimetric fish ecological classification tool (Fish in Lakes – 'FIL') was developed for the island of Ireland (Ecoregion 17) using IFI and Agri-Food and Biosciences Institute Northern Ireland (AFBINI) data generated during the NSSHARE Fish in Lakes project (Kelly *et al*., 2008). This tool was further developed during 2010 (FIL2) in order to make it fully WFD compliant, including producing EQR values for each lake and associated confidence in classification (Kelly *et al*., 2012b). Using the FIL2 classification tool Lough Arrow has been assigned an ecological status of Good for 2009, 2012 and 2015 based on the fish populations present.

In the 2010 to 2012 surveillance monitoring reporting period, the EPA assigned Lough Arrow an overall draft ecological status of Good, based on all monitored physico-chemical and biological elements, including fish. This status classification will be revised during 2016.

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National Research Survey Programme

Lakes 2018

Lough Arrow

IFI/2019/1-4450

Iascach Intíre Éireann
Inland Fisheries Ireland

Inland Fisheries Ireland

National Research Survey Programme

Fish Stock Survey of Lough Arrow, August 2018

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

CITATION: Connor, L., Morrissey, E., Coyne, J., Corcoran, W., Cierpial, D., Gavin A., Brett A., McLoone, P., Delanty, K., Rocks, K., Gordon, P., O' Briain, R., Matson, R., McCarthy E. and Kelly, F.L. (2018) Fish Stock Survey of Lough Arrow, August 2018. National Research Survey Programme, Inland Fisheries Ireland, 3044 Lake Drive, Citywest Business Caumpus, Dublin 24.

Cover photo: Netting survey on Lough Gur © Inland Fisheries Ireland

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1.1 Introduction

Lough Arrow is a large limestone lake situated in Co. Sligo, approximately 24km south-east of Sligo town and 6.4km north-west of Boyle, Co. Roscommon (Plate 1.1, Fig. 1.1). The lake is sheltered on three sides by hills and is the source of the Unshin River. It has a small catchment fed largely by springs on the lake bed and as such is hydrologically different from most lakes in Ireland (Roscommon County Council, 2009). Lough Arrow has a surface area of 1266ha, with a mean depth of 9m and a maximum depth of 33m. The lake is categorised as typology class 12 (as designated by the EPA for the purposes of the Water Framework Directive), i.e. deep (>4m), greater than 50ha and high alkalinity (>100mg/l CaCO3).

Lough Arrow is of major conservation significance as it conforms to a type (hard water lake) listed in Annex I of the EU Habitats Directive. It also supports a number of important bird species and a population of otter (a Red Data Book species which is legally protected under the 1976 Wildlife Act and is listed on Annex II of the EU Habitats Directive) (NPWS, 1999). The shores of the lake are, for the most part, stony, although the common club-rush (*Scirpus lacustris*) and common reed (*Phragmites australis*) occur abundantly in several bays (NPWS, 1999). Two comprehensive surveys of submerged vegetation in the lake were undertaken in 1984 and 2001, during which the open water aquatic flora was found to be dominated by species of *Chara* sp., *Potamogeton* sp. and *Elodea canadensis*, whilst the shallow (<0.5m) areas commonly contained *Litorella sp.*, *Potamogeton filiformis* and *Myriophyllum alterniflorum* (King, 2002).

Lough Arrow is an important game fishery, managed by Inland Fisheries Ireland (WRBD), with good stocks of brown trout and eels. The lake was once stocked with brown trout but this practice has now been discontinued (O' Reilly, 2007). Wild brown trout average 0.45kg in weight, with fish up to 2.7kg having been taken on the fly. A fisheries enhancement programme to increase spawning and nursery area for brown trout was initiated in the Lough Arrow catchment over the period 1998 to 2000 involving re-creation of pools and a natural meander pattern, fencing of streams from livestock and placing of additional spawning gravels in streams where appropriate (O' Grady, 2004).

The lake was previously surveyed in 1979, 1980, 1981 (O' Grady, 1986), 1994, 2002 (O' Grady and Delanty, 2003), 2006 and 2007 (O' Grady and Delanty, 2007) as part of a fish stock assessment by IFI's research section using seven-panel benthic braided survey gill nets. Up to 1994, only perch, pike and

brown trout were recorded, although three-spined stickleback were also recorded in the stomachs of pike. Rudd were encountered for the first time in 2002 and were captured again in the 2007 survey.

The lake was also previously surveyed by IFI for the WFD fish monitoring programme in 2009, 2012 and 2015 (Kelly *et al*., 2010, 2013 and 2016). During the 2015 survey, perch were found to be the dominant species present in the lake. Brown trout, roach, three-spined stickleback, roach x bream hybrids, bream, rudd, pike and eels were also captured during the survey.

This report summarises the results of the 2018 fish stock survey carried out on the lake.

Plate 1.1. Lough Arrow, looking west over the lake (Photo courtesy of IFI and No. 3 Operational Wing, Irish Air Corps [Aer Chór na hÉireann])

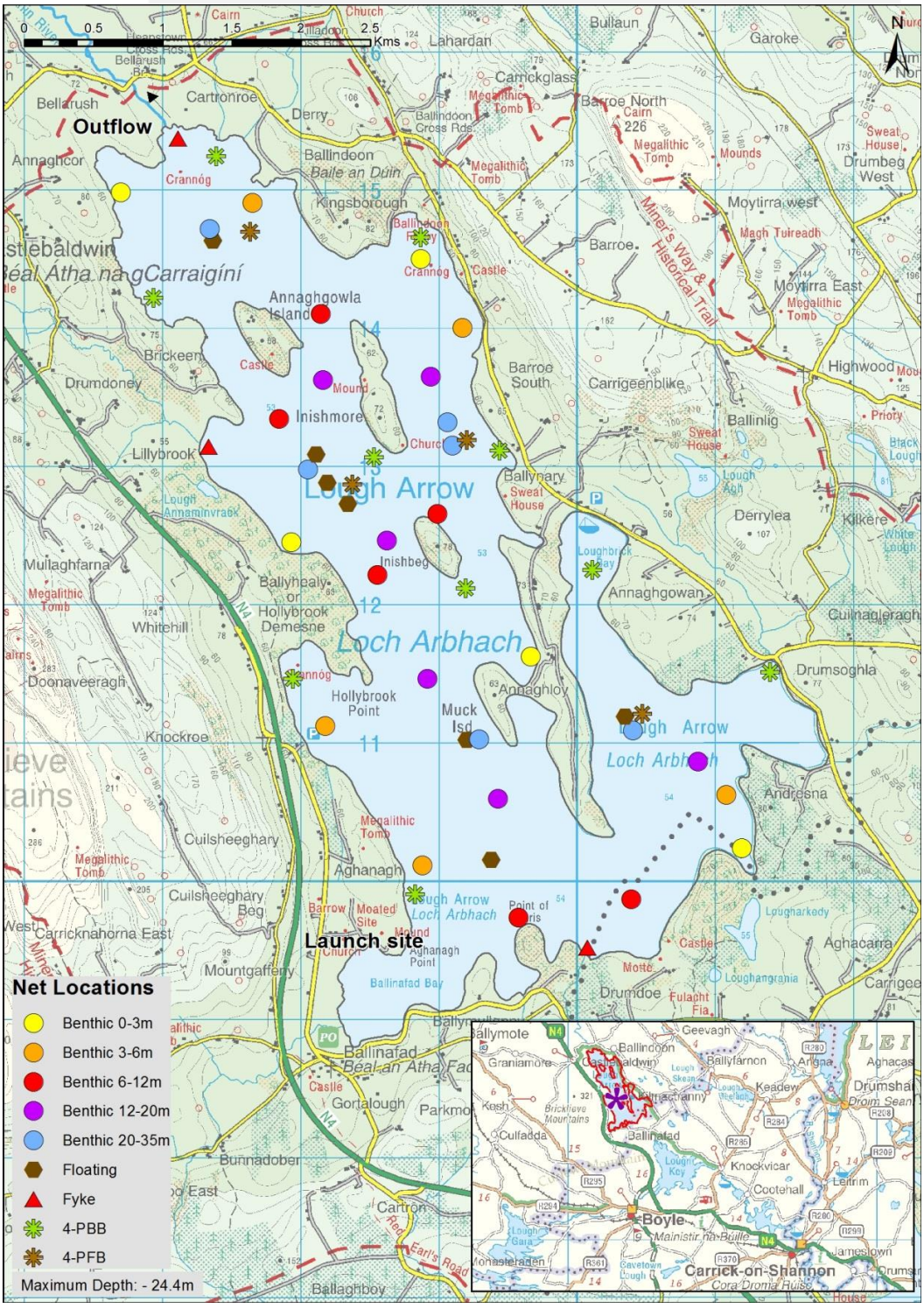

Fig. 1.1. Location map of Lough Arrow showing locations and depths of each net (outflow is indicated on map)

1.2 Methods

1.2.1 Netting methods

Lough Arrow was surveyed over four nights from the 13th to the 17th of August 2018. A total of three sets of Dutch fyke nets (Fyke), 28 benthic monofilament multi-mesh (BM CEN) (12 panel, 5-55mm mesh size) CEN standard survey gill nets (5 @ 0-2.9m, 5 @ 3.0-5.9m, 6 @ 6.0-11.9m, 6 @ 12.0-19.9m and 6 @ 20.0-34.9m) and seven floating monofilament multi-mesh (FM CEN) (12 panel, 5-55mm mesh size) CEN standard survey gill nets were deployed in the lake (38 sites). The netting effort was supplemented using eleven four-panel benthic braided survey gill nets (4-PBB) and three four-panel floating braided survey gill nets (4-PFB) at 14 additional sites. The 4-panel nets are composed of four 27.5m long panels each a different mesh size (55mm, 60mm, 70mm and 90mm knot to knot) tied together randomly. Nets were deployed in the same locations as were randomly selected in the previous survey. A handheld GPS was used to mark the precise location of each net. The angle of each gill net in relation to the shoreline was randomised.

All fish apart from perch were measured and weighed on site and scales were removed from all brown trout, pike, roach, hybrids and rudd. Live fish were returned to the water whenever practical or when the likelihood of their survival was considered to be good. Samples of fish were retained for further analysis. Fish were frozen immediately after the survey and transported back to the IFI laboratory for later dissection.

1.2.2 Fish diet

Total stomach contents were inspected and individual items were counted and identified to the lowest taxonomic level possible. The percentage frequency occurrence (%FO) of prey items were then calculated to identify key prey items (Amundsen *et al.*, 1996).

$$\%FO_i = (N_i / N) \times 100$$

Where:

$\%FO_i$ is the percentage frequency of prey item i,
N_i is the number of a particular species with prey i in their stomach,
N is total number of a particular species with stomach contents.

1.2.3 Biosecurity - disinfection and decontamination procedures

Procedures are required for disinfection of equipment in order to prevent dispersal of alien species and other organisms to uninfected waters. A standard operating procedure was compiled by Inland Fisheries Ireland for this purpose (Caffrey, 2010) and is followed by staff in IFI when moving between water bodies.

1.3 Results

1.3.1 Species Richness

A total of six fish species and two types of hybrid were recorded on Lough Arrow in August 2018, with 1763 fish being captured. The number of each species captured by each gear type is shown in Table 1.1. Perch was the most abundant fish species recorded, followed by roach. Brown trout, roach x rudd hybrids, roach x bream hybrids, rudd, pike and eels were also recorded. During the previous surveys in 2009, 2012 and 2015 the same species composition was recorded, with the exception of roach x bream hybrids, which were present during the 2012, 2015 and 2018 surveys but were not captured in 2009. No bream or three-spined stickleback were recorded in the 2018 survey (Kelly *et al*., 2010, 2013 and 2016). The IFI surveys conducted from 1979 to 2007 captured the same species composition, with the exception of roach (O' Grady, 1986) and bream (O' Grady and Delanty, 2003 and 2007).

Table 1.1. Number of each fish species captured by each gear type during the survey on Lough Arrow, August 2018

Scientific name	Common name	Number of fish captured				
		BM CEN	FM CEN	4-Panel	Fyke	Total
Perca fluviatilis	Perch	1428	1	0	1	1430
Rutilus rutilus	Roach	265	1	2	0	268
Salmo trutta	Brown trout	19	5	4	0	28
Scardinius erythropthalmus	Roach x rudd hybrid	20	0	4	0	24
Rutilus rutilus x Abramis brama	Roach x bream hybrid	8	0	0	0	8
Scardinius erythropthalmus	Rudd	2	0	0	0	2
Esox lucius	Pike	1	0	0	0	1
Anguilla anguilla	European eel	0	0	0	2	2

1.3.2 Fish abundance

Fish abundance (mean CPUE) and biomass (mean BPUE) were calculated as the mean number/weight of fish caught per metre of net. For all fish species except eel, CPUE/BPUE is based on all nets, whereas eel CPUE/BPUE is based on fyke nets only. Mean CPUE and BPUE for all fish species captured in the 2018 survey are summarised in Table 1.2.

Perch was the dominant fish species in terms of abundance (CPUE) and biomass (BPUE) captured during the 2018 survey (Table 1.2).

The mean CPUE and BPUE (excluding the 55mm, 70mm and 90mm mesh panels of each 4-PBB survey net) for all species captured in the 2009, 2012, 2015 and 2018 surveys are illustrated in Figures 1.2 and 1.3. Mean perch, roach and brown trout CPUE and BPUE fluctuated slightly over the four sampling occasions. These differences were most apparent in 2018 where perch and roach had the highest CPUE and BPUE of all the sampling years (Table 1.2; Fig 1.2 and 1.3).

Table 1.2. Mean (S.E.) CPUE and BPUE for all fish species captured on Lough Arrow, 2018

Scientific name	Common name	Mean CPUE (± S.E) **
Perca fluviatilis	Perch	0.914 (0.280)
Rutilus rutilus	Roach	0.174 (0.049)
Salmo trutta	Brown trout	0.016 (0.004)
Scardinius erythropthalmus	Roach x rudd hybrid	0.014 (0.004)
Rutilus rutilus x Abramis brama	Roach x bream hybrid	0.005 (0.003)
Scardinius erythropthalmus	Rudd	0.001 (0.001)
Esox lucius	Pike	0.001 (0.001)
*Anguilla anguilla**	European eel*	0.011 (0.011)*
		**Mean BPUE (± S.E) ** **
Perca fluviatilis	Perch	36.495 (9.525)
Rutilus rutilus	Roach	13.639 (3.561)
Salmo trutta	Brown trout	7.317 (2.218)
Scardinius erythropthalmus	Roach x rudd hybrid	5.516 (1.779)
Rutilus rutilus x Abramis brama	Roach x bream hybrid	1.179 (0.588)
Scardinius erythropthalmus	Rudd	0.415 (0.415)
Esox lucius	Pike	0.017 (0.017)
*Anguilla anguilla**	European eel*	3.400 (3.400)*

Note: On the rare occasion where biomass data was unavailable for an individual fish, this was determined from a length/weight regression for that species (Connor *et al*., 2017).

*Eel CPUE and BPUE based on fyke nets only

**CPUE and BPUE data above for all fish species except eels are not comparable to earlier surveys as extra panels were added to the 1-PBB to provide additional information on large fish.

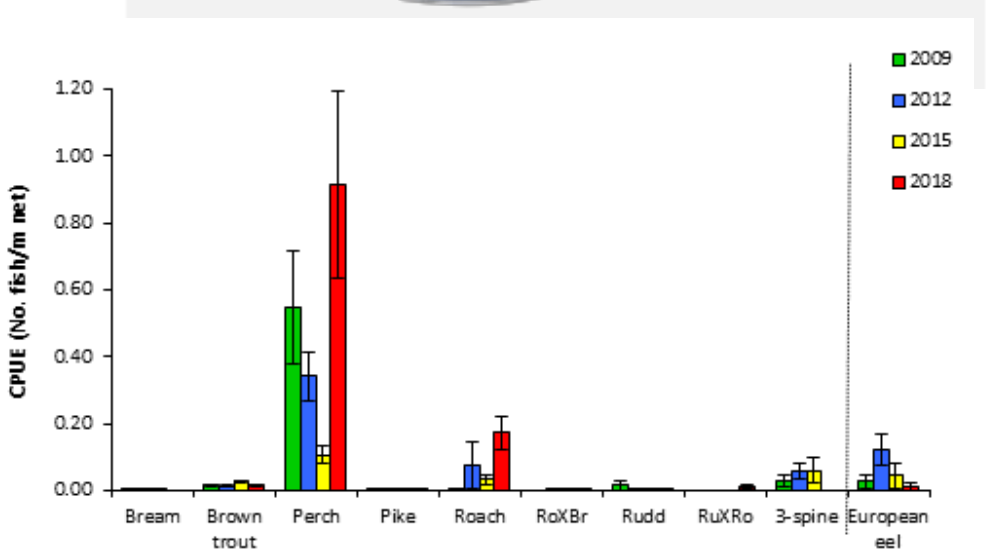

Fig. 1.2. Mean (±S.E.) CPUE for all fish species captured in Lough Arrow (Eel CPUE based on fyke nets only), 2009, 2012, 2015 and 2018

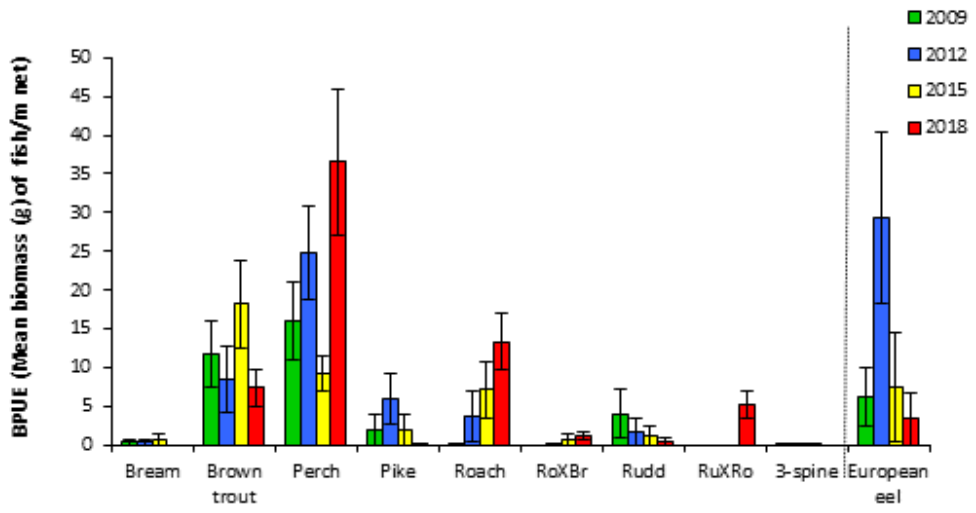

Fig. 1.3. Mean (±S.E.) BPUE for all fish species captured in Lough Arrow (Eel BPUE based on fyke nets only), 2009, 2012, 2015 and 2018

1.3.3 Length frequency distributions and growth

Perch

Perch captured during the 2018 survey ranged in length from 3.5cm to 35.6cm (mean = 9.8cm) (Fig.1.4) with nine age classes present, ranging from 0+ to 8+ with a mean L1 of 6.3cm (Table 1.3). The dominant age class was 1+ (Fig. 1.4). Perch captured during the 2009, 2012 and 2015 surveys had a similar length and age range with some smaller fish recorded in 2009 and 2012 (Fig.1.4).

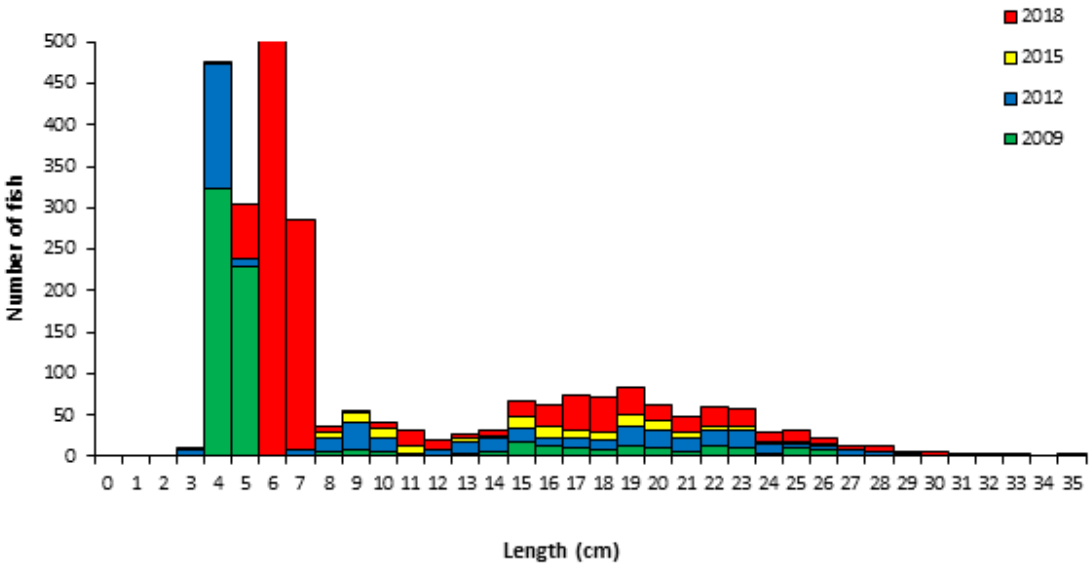

Fig. 1.4. Length frequency of perch captured on Lough Arrow, 2009, 2012, 2015 and 2018

Table 1.3. Mean (±S.E.) perch length (cm) at age for Lough Arrow, August 2018

	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8
Mean (±S.E.)	6.3 (0.1)	11.8 (0.2)	17.4 (0.2)	21.2 (0.3)	23.8 (0.4)	25.4 (0.6)	29.1 (1.3)	33.2
N	104	76	54	49	32	21	5	1
Range	4.1-11.5	9.1-15.1	12.9-21.3	16.0-25.5	18.2-27.1	19.2-29.2	24.1-31.2	33.2-33.2

Roach

Roach captured during the 2018 survey ranged in length from 4.0cm to 33.2cm (mean = 13.2cm) (Fig.1.5) with twelve age classes present, ranging from 0+ to 11+ (Table 1.4). Roach captured during the 2009, 2012 and 2015 surveys had a similar length and age range with 2018 exhibiting the largest range (Fig.1.5).

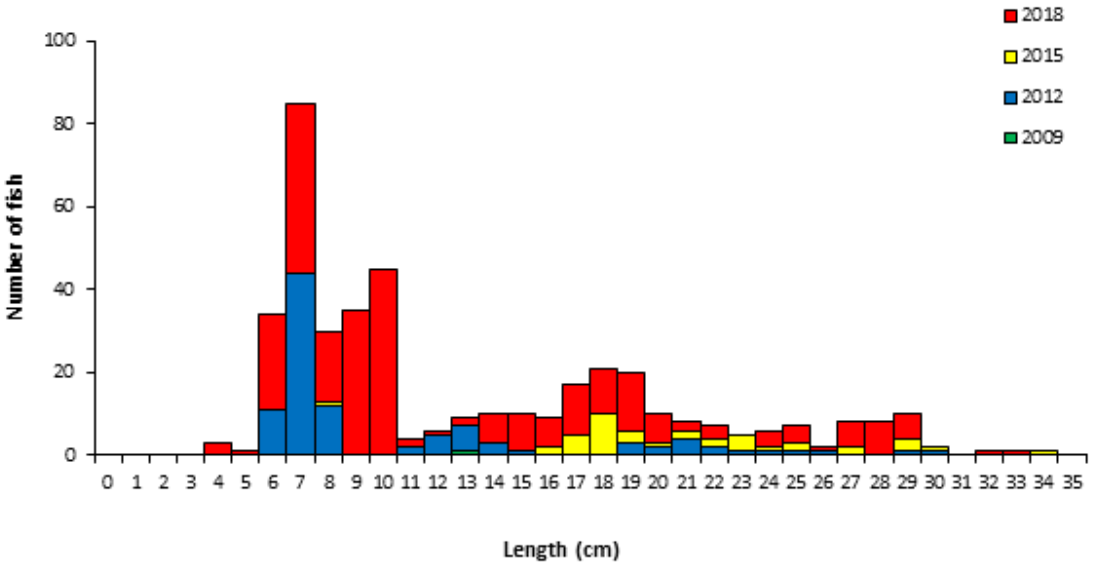

Fig. 1.5. Length frequency of roach captured on Lough Arrow, 2009, 2012, 2015 and 2018

Table 1.4. Summary age data for a sub-sample of roach captured on Lough Arrow, August 2018. Number of fish and length ranges of all fish aged in the sample is presented (N=105)

	Age class											
	0+	**1+**	**2+**	**3+**	**4+**	**5+**	**6+**	**7+**	**8+**	**9+**	**10+**	**11+**
Mean (cm)	5.0	7.3	9.5	15.7	17.8	19.8	22.7	24.9	26.8	28.5	29.9	33.2
N	3	6	24	17	14	8	5	4	7	12	4	1
Range (cm)	4.9-5.3	6.2-10.3	7.3-16.0	12.5-19.2	14.2-20.2	18.5-21.1	21.0-24.4	24.1-25.5	25.0-28.8	27.0-29	29.0-32.3	33.2-33.2

Brown trout

Brown trout captured during the 2018 survey ranged in length from 15.5cm to 54.5cm (mean = 31.5cm) (Fig.1.5) with six age classes present, ranging from 1+ to 6+ (Table 1.5). Brown trout captured during the 2009, 2012 and 2015 surveys had a similar length and age range (Fig.1.5).

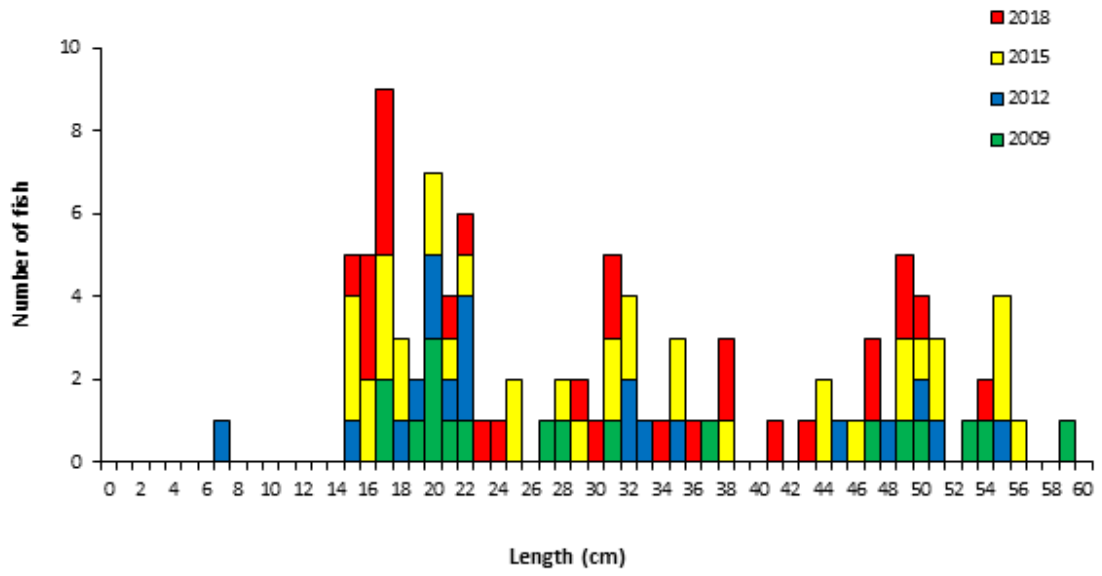

Fig. 1.6. Length frequency of brown trout captured on Lough Arrow, 2009, 2012, 2015 and 2018

Table 1.5. Summary age data from a sub-sample of brown trout captured on Lough Arrow, August 2018. Number of fish and length ranges of all fish aged in the sample is presented

	Age class					
	1+	**2+**	**3+**	**4+**	**5+**	**6+**
Mean (cm)	16.6	20.8	26.9	36.2	42.3	49.5
N	5	5	5	2	8	3
Range (cm)	15.5-17.4	17.5-24.9	16.5-34.5	31.4-41.0	31.8-54.5	49.0-50.1

Other fish species

Two eels were captured during the 2018 survey and were measured at 48.0cm and 63.0cm. One pike at 26.5cm was recorded, aged 1+ and two rudd ranged in length from 25.0cm to 26.0cm (5+ and 6+ respectively). Roach x bream hybrids ranged in length from 16.5cm to 30.1cm (five age classes ranging

from 3+ to 11+) and roach x rudd hybrids ranged in length from 20.1cm to 32.6cm, with seven age classes present ranging from 6+ to 12+.

1.3.4 Stomach and diet analysis

Dietary analysis studies provide a good indication of the availability of food items and the angling methods that are likely to be successful. However, the value of stomach content analysis is limited unless undertaken over a long period as diet may change on a daily basis depending on the availability of food items. The stomach contents of a subsample of perch captured during the survey were examined and are presented below.

Perch

Perch initially start to feed on pelagic zooplankton. Once they reach an intermediate size they start feeding on benthic resources eventually moving on to feed on fish once they are large enough (Hjelm *et al*., 2000). A total of 116 stomachs were examined. Sixty two were empty and of the remaining 54 stomachs containing food, 55% contained unidentified digested material, 24% fish, 17% zooplankton and 4% invertebrates (Fig. 1.7).

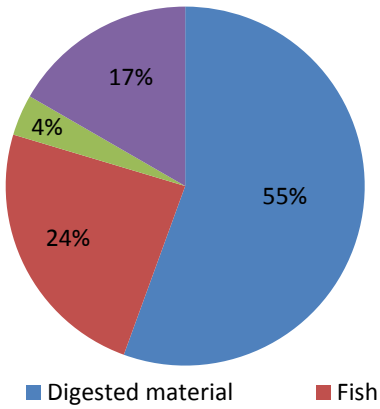

Fig 1.7. Diet of perch (n=54) captured on Lough Arrow, 2018 (% frequency occurrence)

Brown trout

Adult trout usually feed principally on crustaceans (*Asellus* sp. and *Gammarus* sp.), insects (principally chironomid larvae and pupae) and molluscs (snails) (Kennedy and Fitzmaurice, 1971, O'Grady, 1981). Lough Arrow had total of 16 stomachs were examined. Of these nine were found to contain no prey items. Of the remaining seven stomachs containing food, 43% contained fish, 43% unidentified digested material and 14% zooplankton (Fig. 1.8).

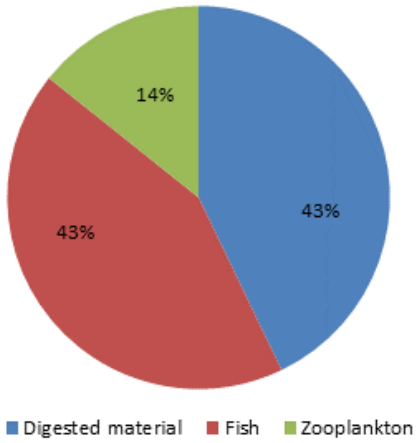

Fig 1.8. Diet of brown trout (n=7) captured on Lough Arrow, 2018 (% frequency occurrence)

1.4 Summary and ecological status

A total of six fish species and two types of hybrid were recorded on Lough Arrow in August 2018. Perch was the dominant fish species in terms of abundance and biomass captured during the 2018 survey.

Perch captured during the 2018 survey ranged in length from 3.5cm to 35.6cm, with nine age classes present, ranging from 0+ to 8+, indicating reproductive success in each of the previous nine years. The dominant age class was 1+.

Roach captured during the 2018 survey ranged in length from 4.0cm to 33.2cm, with twelve age classes present, ranging from 0+ to 11+, indicating reproductive success in all of the previous twelve years.

Brown trout ranged in length from 15.5cm to 54.5cm and ranged in age from 1+ to 6+, indicating reproductive success in six of the previous seven years.

Classification and assigning lakes with an ecological status is a critical part of the WFD monitoring programme. It allows River Basin District managers to identify and prioritise lakes that currently fall short of the minimum "Good Ecological Status" that is required if Ireland is not to incur penalties. A multimetric fish ecological classification tool (Fish in Lakes – 'FIL') was developed for the island of Ireland (Ecoregion 17) using IFI and Agri-Food and Biosciences Institute Northern Ireland (AFBINI) data generated during the NSSHARE Fish in Lakes project (Kelly *et al.*, 2008). This tool was further developed during 2010 (FIL2) in order to make it fully WFD compliant, including producing EQR values for each lake and associated confidence in classification (Kelly *et al*., 2012). Using the FIL2 classification tool, Lough Arrow has been assigned an ecological status of Good for 2018 based on the fish populations present. In previous years the lake was assigned a similar status based on the fish populations present.

In the 2010 to 2015 surveillance monitoring reporting period, the EPA assigned Lough Arrow an overall ecological status of Good.

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APPENDIX IV

A Fish Stock Assessment of Lough Arrow, 2002

Management Proposals for this Resource

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February, 2003

Survey Methodology and Results

A total of 30 sampling locations where selected from the original 40 sites surveyed in 1994 (Figure 1). The sampling procedure involved setting gangs of gill nets over-night and servicing them the following day. Each set consisted of 7 nets of differing mesh size ranging from 2 inch to 5 inch (at half inch intervals). The type of survey nets used are capable of capturing all trout >= 19.8 cm in proportion to their presence and a cross-section of all other fish species present. Fifteen gangs of nets were set on each of two days. The majority of fish taken in the nets were retained for processing. This involved taking length, weight, scale samples and dietary analyses of all fish.

As a method for comparing numbers of fish caught in different lake surveys "catch per unit effort" (CPUE) is more commonly used. CPUE reflects the relative density of that species present in the lake. CPUE values, for any species, are obtained by dividing the total number of fish, for that species, by the number of net gangs set. It has proved to be a very effective management tool in illustrating the fluctuations in fish stocks over time (O'Grady, 1983).

The present survey yielded 271 perch, 39 pike, 23 brown trout (11 of which were returned to the lake) and 6 rudd. Details of numbers of fish caught per square are summarised in Table 1.

Length frequency distributions for the brown trout (Figure 2) taken in this survey show an absence of younger fish, in the 19 – 39 cm length range (or in the 2 – 3 year old range). More than 80% of the population were greater than 40cm and 3+ or older. Of the 11 trout stomachs examined contained large amounts of asellus, and in some samples other invertebrates were also found.

Pike numbers, in relation to the trout catch, were significant. A length frequency distribution for pike showed the majority of fish to be in the 35 to 80 cm range, with over 50% of the catch greater than 65cm (Figure 3). Dietary analysis found that fish were encountered in 8 of the stomachs examined, another seven contained invertebrates and 25 stomachs were empty. The large number of empty stomachs is characteristic of fish in

their spawning season. The majority of pike were ripe fish with a 2.88 to 1 female to male ratio.

A substantial number of perch were encountered during this survey. The stock were dominated by fish in the 22 to 27 cm length range, though fish as small as 12 cm and as big as 32 cm were also taken (Figure 4). Nets with the greatest number of perch in them were those that had been set in the deeper areas of the lake. The majority of fish were mature, with the female to male ratio being 4 to 3.

Rudd are also present in the lake, with a small number being taken in the survey. These few samples were between 21 and 24 cm in length.

Discussion

Total numbers of fish caught, during the netting operation, were with the exception of trout, relatively similar to the 1994 survey for pike and perch (Table 2) even though fewer nets were set. Trout numbers have continued to decline since the 1980 study. When CPUE values, for the three main species present, are compared across 4 separate surveys (1979 - 1980 – 1944 – 2002), it shows that trout have been in decline since 1980 while pike have been increasing since around that period (Figure 5). Perch numbers appear to fluctuate throughout the survey periods with a high in 1980.

When length frequency distributions for trout from previous surveys (1980 and 1994) are compared this lack of younger fish is even more obvious (Figure 2). Though the gaps in the different length ranges were starting to appear even in the earlier 1994 survey. Changes observed in the pike stock structure, since the 1994 survey, show the presence of pike from 35cm right up to 82.5cm with no age group missing (Figure 3).

Earlier data available for perch (1994) when compared with the 2002 data indicate the size structure of the population has shifted slightly with a greater proportion of the stock at greater lengths than before (Figure 4).

No rudd were captured in previous surveys.

Summary Comments and Management Recommendations

The decline in the trout stock in Lough Arrow over the period 1979 to date (2002) is of concern in fisheries management terms – a fall in trout C.P.U.E values from a figure of 2.83 in 1979 to 0.766 in 2002 suggests that the current trout population is now only circa 27% of the stock density present in 1979 (Table 2). This trend is also reflected in poor angling catches from the lough in recent years.

A comparison of the length frequency distribution of the trout population captured in samples in 1980 and 1994 indicates the presence of a balanced population on both sampling occasions. However in comparison the stock structure currently (2002) in Lough Arrow is very unbalanced – it is largely composed of bigger older fish ≥ 41cm in length. These data suggest that either:

a- recruitment of year-classes, currently 2, 3 and 4 year old fish, in 2002, was exceptionally poor, or
b- the survival of 2, 3 and 4 year old fish (in 2002), following their recruitment to the lake, was very poor.

There is substantial evidence to suggest that the latter (b) is the case. A major stream enhancement programme was undertaken on all of the Lough Arrow feeder streams in the late 1990's. The effectiveness of this programme was monitored carefully since, in all streams, on a annual basis. Data indicate that, post-works, there has been a very substantial increase in the production of juvenile trout in these streams – estimates suggest an increased annual production of circa 58,000 fry and 1,500 1+ year old trout in these streams, which is almost an eight fold increase in numerical terms in trout production, post-works. This would have resulted in a greatly increased stock density of young fish in Lough Arrow in 2002 if these fish all survived.

The significant failure of these fish to survive in Lough Arrow to adulthood in repeated years may well be as a consequence of the greatly increased population of adult pike in the lake in 2002, compared to previous years. A comparison of fish numbers in the 1979 and 2002 surveys suggests a 4.5 fold increase in the pike stock over this period. Research has shown that the pike in question (predominately fish in the 50 to 80cm length range) specifically target trout, 25 to 40cm in length, as prey items. It is therefore hardly coincidental that it is this size range of trout which are most poorly represented in the 2002 survey (Figure 2).

The authors would recommend the following management initiatives:-

1- Purchase the finest mesh braided nylon gill-nets available to increase pike capture efficiency rates.
2- Increase the number of crews gill-netting for pike to three if possible for the next three years – thereafter a smaller number of staff would suffice.
3- Use the lake electrofishing equipment regularly on Lough Arrow once every few weeks for a year to see if there are specific times and/or locations where pike can be harvested efficiently - on Lough Corrib, over the last year up to 900 0+ and 1+ pike per day have been removed using this equipment. The pike in Lough Corrib were living in the charaphyte beds at depths of 3 to 3.5m. On Lough Corrib the most critical factor limiting the success of this technique would appear to be weather conditions, ie small stunned pike in circa 3m of water can only be seen and captured efficiently during very calm sunny periods (M. Butler, pers com.)

Acknowledgments

The authors are most grateful to the staff of the NorthWestern Regional Fisheries Board who provided them with every assistance in carrying out this survey.

APPENDIX V

W/E 1-3-'24

Iascach Intíre Éireann
Inland Fisheries Ireland

Appendix iv: Standard Catch Record Form

Iascach Intíre Éireann
Inland Fisheries Ireland

SM3

Removed Fish

Date 27/2/24	Watercourse ARROW	Catchment
Method	Number	Crew/Club

	Species	Length (cm)	Weight (kg)	Scale Env. No.	Sex	Stomach contents
1	Pike	49	1·5		F	Empty
2	"	30	·75 kg		M	Empty
3	"	31	·75 kg		M	Empty
4						
5						
6						
7						
8	28/2/24					
9						
10	Pike	53	2·5		F	Trout.
11	"	46	0·5		F	empty
12	"	53	0·75		M	empty
13						
14						
15						
16						
17						
18	1/3/24					
19						
20	Pike					
21	"	76	3		F	Trout
22	"	57	1·25		M	Roach
23	"	72	3		M	empty
24	"	71	3		M	empty
25	"	61	2		F	empty
26	"	41	1		F	empty
27						
28	Trout	47	1			
29						
30						

Pike 12 Total Weight 21

Bycatch 6 Trout Released. Rudd/Roach Released

1 Trout Dead.

W/E 8/3/24

Iascach Intire Éireann
Inland Fisheries Ireland

Appendix iv: Standard Catch Record Form

Iascach Intire Éireann
Inland Fisheries Ireland

SM3

Removed Fish

Date	Watercourse	Catchment
Method	Number	Crew/Club

	Species	Length (cm)	Weight (kg)	Scale Env. No.	Sex	Stomach contents
5-3 1	Pike	55 ~~55~~	1		M	empty
2	"	61	2		M	empty
3						
4						
5						
6-3 6	Pike	76	5		F	empty
7	"	78	7		F	empty
8	"	1.2 m	12½	dead in net	F	empty
9	"	79	7¼		F	empty
10	"	69	4		F	empty
11	"	63	2½		F	empty
12	"	56	2		M	empty
13	"	67	2½		M	empty
14	"	57	1¾		M	empty.
15						
16						
17						
7/3 18	Pike	67	2.5		M	empty
19	"	66	2		F	empty
20	"	69	3.25		F	empty
21	"	69	3.5		F	empty.
22						
9/3 23	Pike	62	2½		M	empty
24	"	69	2¾		F	empty
25	"	71	3		F	empty
26	"	82	6½	Pike	F	roach.
27	"	30	¼		M	empty
28	"	43	½		M	empty.
29	"	44	¾		M	empty.
30						

Pike	22	Total Weight	74
Bycatch	9 Trout released.	Rudd/Roach released.	

W/E 15/3

Iascach Intire Éireann
Inland Fisheries Ireland

Appendix iv: Standard Catch Record Form

Iascach Intire Éireann
Inland Fisheries Ireland

SM3

Removed Fish

Date	Watercourse Lough Arrow.	Catchment
Method Gill Netting.	Number	Crew/Club

	Species	Length (cm)	Weight (kg)	Scale Env. No.	Sex	Stomach contents
13/3 1	Pike	90	6 Pike		F	Empty.
2	Pike	84	7 Pike.		F	" "
3	"	66	2		M	" "
4	"	62	3		F	" "
5	"	130	14 dead in net.		F	Roache
6	"	52	2		M	Empty.
7	"	76	5		F	Empty
8	"	81	8		F	" "
9	"	58	2		M	" "
10	"	61	2		M	" "
11	"	60	2		M	" "
12	"	45	1		M	" "
13	"	53	2		M	" "
14	"	62	2		M	" "
15	"	49.	2		M	" "
16						
17						
18						
19						
14/3 20						
21		1 M	9 dead in net.		F	—
22		78	5		F	T
23		80	7		F	—
24		77	5		F	—
25		61	2		M	—
26						
27						
28						
29						
30						

Pike	20	Total Weight	88
Bycatch	5 Trout Released.		Rudd/Roach Released.

Iascach Intíre Éireann
Inland Fisheries Ireland

Appendix iv: Standard Catch Record Form

Iascach Intíre Éireann
Inland Fisheries Ireland

SM3

Removed Fish

Date	Watercourse	Catchment
Method	Number	Crew/Club

	Species	Length (cm)	Weight (kg)	Scale Env. No.	Sex	Stomach contents
1	Pike	58	2		F	Empty.
2	Pike	100	10·5 dead in net.		F	Empty.
3	Pike	62	1·5		F	Empty.
4	Pike	80	5·5		F	Roach.
5	Pike	64	4		F.	Trout.
6	Pike	65	2·6		F	Empty.
7	Pike	69	4·25		F	Trout.
8	Pike	77	6		F	Empty.
9	Pike	78	7		F	Trout.
10	Pike	73	4 Stent.		F	Empty
11	Pike	37	0·5		M	Empty.
12	Trout	47	1·5			
13						
14		2 Pike	released over 85 cm.			
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

Pike	11	Total Weight	46·25	
Bycatch	3 Trout Released. 1 Trout Dead.			Rudd/Roach.

16/3

Iascach Intíre Éireann
Inland Fisheries Ireland

Appendix iv: Standard Catch Record Form

Iascach Intíre Éireann
Inland Fisheries Ireland

SM3

Removed Fish

Date 20-3-24	Watercourse CARROW	Catchment
Method	Number	Crew/Club

	Species	Length (cm)	Weight (kg)	Scale Env. No.	Sex	Stomach contents
1	Pike	60	2		M	empty
2	"	58	3		F	empty
3	"	64	2		F	empty
4	"	70	3		F	Roach
5	"	61	2·25 spent		F	Trout
6	"	80	8		F	empty
7	"	71	4·5		F	empty
8	"	81	6		F	empty
9	"	74	5		F	empty
10	"	79	5		F	empty
11	"	64	3		F	Roach
12	"	75	5		F	Trout
13	"	59	1·5		M	Roach.
14	"	59	1·5		M	empty
15	"	49	1		F	empty
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
Pike	15	Total Weight	52·25			
Bycatch	1 Trout Released. Rudd/Roach Released.					

W/E 22-3-24

Iascach Intíre Éireann
Inland Fisheries Ireland

Appendix iv: Standard Catch Record Form

Iascach Intíre Éireann
Inland Fisheries Ireland

SM3

Removed Fish

Date 21-3-24	Watercourse ARROW.	Catchment
Method	Number	Crew/Club

	Species	Length (cm)	Weight (kg)	Scale Env. No.	Sex	Stomach contents
1	Pike	71	4 Rifle		F	empty
2		74	5		F	empty
3		70	3.25		F	empty
4		80	6		F	Roach.
5		65	2.75		F	empty
6		68	2.75		F	Roach.
7		84	8		F	empty
8		79	4.5		F	empty
9		74	4.5		M	empty
10		69	4.75		F	Trout.
11						
12		3 Pike over 85 cm		Released.		
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
Pike	10	Total Weight	45.5			
Bycatch	2 Trout Released	Rudd/Roach, Perch				

Iascach Intíre Éireann
Inland Fisheries Ireland

Appendix iv: Standard Catch Record Form

Iascach Intíre Éireann
Inland Fisheries Ireland

SM3

Removed Fish

Date 26-3-24	Watercourse	Catchment
Method	Number	Crew/Club

	Species	Length (cm)	Weight (kg)	Scale Env. No.	Sex	Stomach contents
1	Pike	79	5·5		F	Roach
2		72	5		F	empty
3		80	7		F	empty
4		50	1·25		M	empty.
5						
6						
7						
8	27-3-24					
9						
10	Pike	74	4		F	Roach
11		76	5		F	empty
12		78	6		F	empty
13		61	1·25		M	empty
14		67	2·5		M	empty
15		74	4		F	Trout
16		72	3·75		F	Trout.
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

Pike	11	Total Weight	45·25
Bycatch	5 Trout Released. Rudd/Roach & Perch.		

Total 101 Pike
Weighing 372·25 Kg

APPENDIX VI

north western international river basin district

North South Shared Aquatic Resource (NS SHARE)

neagh bann international river basin district

North South Shared Aquatic Resource (NS SHARE)

north eastern river basin district

North South Shared Aquatic Resource (NS SHARE)

North South Shared Aquatic Resource (NS Share)

Task 6.9: Classification Tool for Fish in Lakes: Plan for Development/Conceptual Model

(T1 A6.9 - 1.1)

Environment & Heritage Service
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AN ROINN COMHSHAOIL, OIDHREACHTA AGUS RIALTAIS ÁITIÚIL
DEPARTMENT OF THE ENVIRONMENT, HERITAGE AND LOCAL GOVERNMENT

INTERREG IIIA

North South Shared Aquatic Resource (NS Share)

Water Framework Directive

A Directive establishing a new framework for Community action in the field of water policy (2000/60/EC) came into force in December 2000. This Water Framework Directive (WFD) rationalises and updates existing legislation and provides for water management on the basis of River Basin Districts (RBDs). The WFD was transposed into national law in Northern Ireland by the Water Environment (Water Framework Directive) Regulations (Northern Ireland) 2003 and in the Republic of Ireland by the European Communities (Water Policy) Regulations 2003. The primary objective of the WFD is to maintain the "high status" of waters where it exists, prevent deterioration in existing status of waters and to achieve at least ***"good status"*** in relation to all waters by 2015.

NS Share Study Area

NS Share is a cross border project and incorporates three River Basin Districts as set out in the joint North/South Consultation paper *Managing our Shared Waters*:

1. North Western International River Basin District (NWIRBD);
2. Neagh Bann International river Basin District (NBIRBD);
3. North Eastern River Basin District (NERBD).

The NW and NB are International River Basin Districts as they share their waters between Northern Ireland (NI) and Republic of Ireland (ROI). The NERBD is contained wholly within NI.

NS Share Project

The overall objective of the project is to strengthen inter-regional capacity for environmental monitoring and management at the river basin district level, to improve public awareness and participation in water management issues, and to protect and enhance the aquatic environment and dependent ecosystems.

The NS Share project aims to facilitate delivery of the objectives of the WFD within the project area between August 2004 and March 2008.

The NS Share project is funded by the EU INTERREG IIIA Programme for Ireland / Northern Ireland. The Department of the Environment (NI) and the Department of the Environment, Heritage and Local Government (ROI) are implementing agents for the project. Donegal County Council is the project promoter. Technical support is proivded by the Environment and Heritage Service an agency within the Department of the Environment (NI), and the Environmental Protection Agency (ROI). RPS Consulting Engineers in association with Jennings O'Donovan are the principal consultants.

Assistance was also provided by the Marine Institute, Central Fisheries Board, Geological survey Ireland, Geological survey Northern Ireland, Loughs Agency, North West Regional Fisheries Board, and Cavan, Leitrim, Longford, Louth, Meath, Monaghan, and Sligo County Councils.

Project publications are available at www.nsshare.com/publications

PREFACE

The work presented in this paper was carried out as part of the NS SHARE project, which is funded by the European Union INTERREG IIIA programme for Ireland/Northern Ireland. The implementing agents for the NS SHARE project are the Department of Environment (DOE), Northern Ireland, and the Department of Environment Heritage and Local Government (DEHLG), Republic of Ireland. Donegal County Council (DCC) is the project promoter.

All data, drawings, reports, documents, databases, software and coding, website and digital media and publicity material produced as part of this project shall be the property of the DOE/DEHLG who will use, reproduce and distribute same as they see fit.

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BY

FIONA KELLY AND TREVOR CHAMP

PROJECT PARTICIPANTS

CENTRAL FISHERIES BOARD (CFB)

AQUATIC SYSTEMS BRANCH, AGRI-FOOD AND BIOSCIENCES INSTITUTE, NORTHERN IRELAND (AFBI)

Contents

1. Underlying principles and approaches

The overall objective of the Water Framework Directive (WFD) is to maintain high and good status where it exists and to achieve good status for all other waters by December 2015. In order to assess if the overall goal of the Directive has been achieved a consistent classification of all European surface waters into status classes is necessary. In order to make the results comparable between Member States, common methods need to be developed and implemented. The respective classification systems also have to be intercalibrated (REFCOND, 2005).

Annex V of the WFD gives standard definitions for the classification of lakes into five different ecological quality classes, HIGH, GOOD, MODERATE, POOR and BAD status (CEC, 2000). The ecological status of a lake is based on its level of deviation from the reference biological condition (i.e. high status reflecting undisturbed conditions and no or only very minor evidence of distortion) and impairment is assigned according to a quality level in a 5 tiered scheme formulated in the WFD (Fig. 1). Ecological status is assessed using phytoplankton, macrophytes, phytobenthos, benthic invertebrates, fish communities and hydromorphological characteristics.

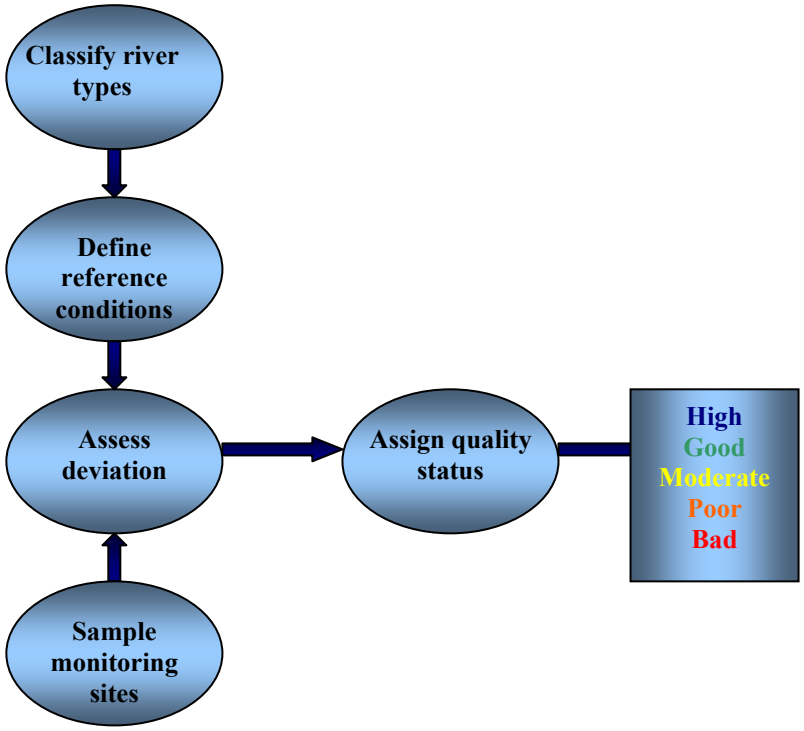


Fig. 1: Defining ecological status according to the WFD (after FAME Group, 2004)

Class boundaries must be established for each set of reference conditions. The quality elements for fish in lakes are species composition, abundance and age structure (EU, 2000). In order to facilitate comparability of ecological classification systems across Europe, Member States are required to express their monitoring as ecological quality ratios (EQRs),

(Fig. 2) "These ratios shall represent the relationship between the values of the biological parameters observed for a given body of surface water and the values for these parameters in the reference conditions applicable to that body", i.e. the observed biological values divided by the same parameter in the reference condition (Annex V:1.4ii) (REFCOND, 2005).

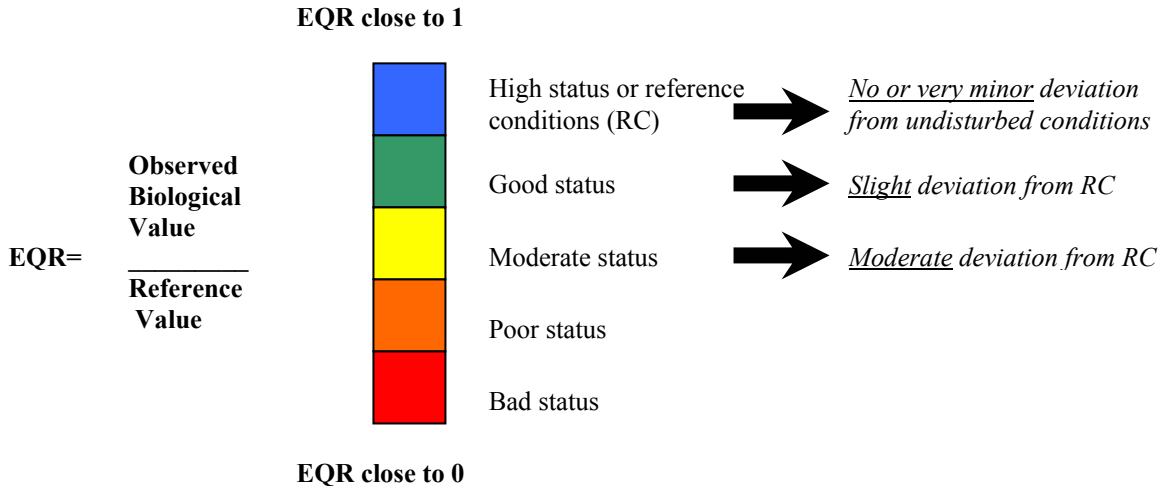


Fig. 2: Basic principles for classification of ecological status based on Ecological Quality Ratios (after REFCOND, 2005)

2. Background

The principal task of the NS Share Fish in Lakes project is to develop an ecological classification tool which will meet the requirements of Annex V of the WFD for surface waters. In order to achieve this it is necessary to develop an understanding of fish populations in lakes in a range of lake types. A fundamental hypothesis of the classification tool is that changes due to natural processes (hydrological and ecological) and anthropogenic processes alter the fish population structure in a lake. The tool should be able to detect ecological deficits of the fish community such as extinction of intolerant species and impairment of reproductive success).

2.1 *Models for fish*

Three major approaches to the biological assessment of the ecological effects of pollution and landscape alteration in freshwater ecosystems have been developed in the last two decades (Joy and Death, 2002). The most common approach is multimetric, where a number of individual indices are combined to measure biotic condition e.g. the Index of Biotic Integrity (IBI) (Karr, 1981; Gerritson, 1995), the ICI (Plafkin, 1999 for invertebrates-USEPA rapid bioassessment protocols). A second approach is predictive and compares fauna to those predicted by empirical models in the absence of human impacts e.g. RIVPACS (Wright *et al*, 1984; Clarke *et al*, 1996; Norris 1996), AUSRIVAS (Parsons and Norris, 1996), HABSCORE (Milner *et al*., 1995). The European Fish Index (EFI) is a multimetric predictive index (FAME CONSORTIUM, 2004; Pont *et al*., 2006). The third approach is the use of artificial intelligence (AI) techniques, this is a relatively new approach to river quality monitoring, i.e. Pattern recognition and Plausible reasoning (Walley and Fontama, 2000).

2.2 *The Multimetric Approach*

The classification tool for fish in lakes will follow the concept of the Index of Biotic Integrity (Fig. 3). This index combines indicators, or metrics, reflecting elements of biological integrity (e.g. number of lithophilic species) into a single index value. A metric is defined as “a characteristic (attribute) of the biota that changes in some predictable way with increases in human disturbance” (Fig.4).

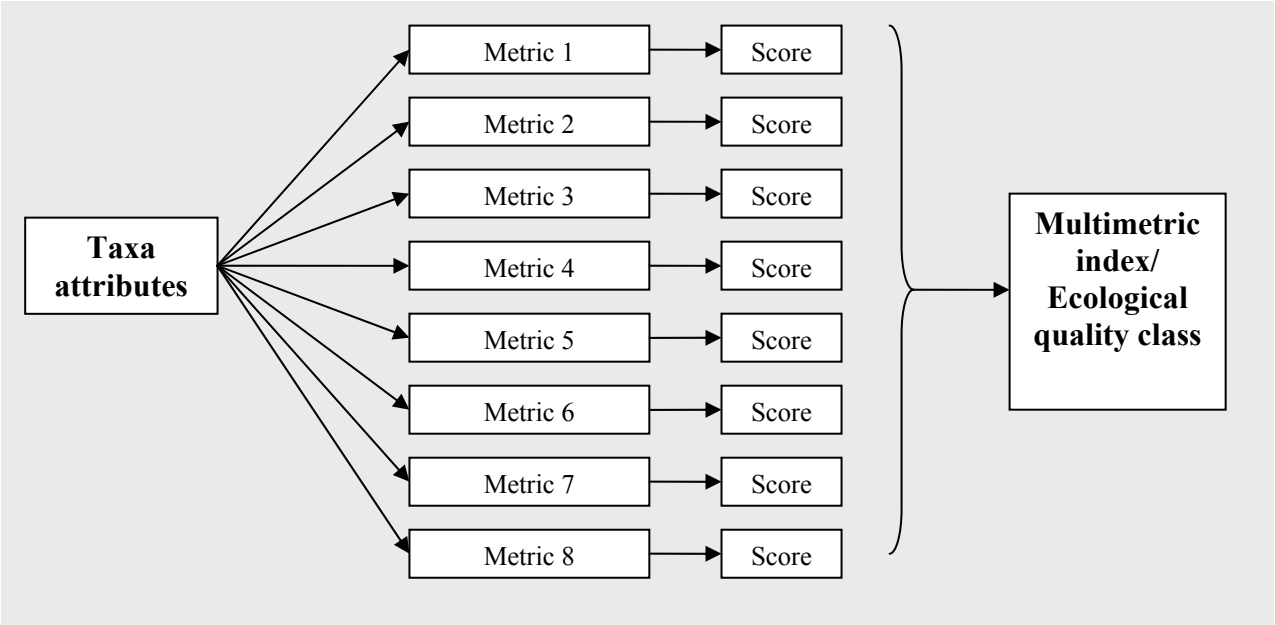


Fig. 3: Development of a multimetric index (from CEN, 2004)

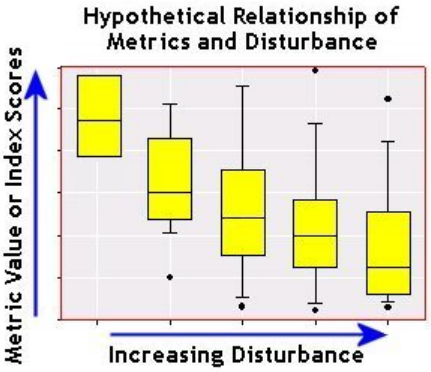


Fig. 4: Example of a correlation between a metric along a disturbance gradient (from US EPA, 2006)

The basis of the multimetric approach is the comparison of a metric (observed) to an expected (reference) distribution of values and a judgement of whether the value is within the expected range (US EPA, 2006). Each metric is tested and calibrated to a scale and transferred into a unit less score (e.g. 5, 4, 3, 2, 1, depending on whether it is similar to reference values (i.e. 5 = within the expected range, 4 = is slightly different (good status), 3 = moderately different (moderate status) and 2 and 1 = very different (poor and bad)) prior to being aggregated into a multimetric index (Fig. 3). The expected range is usually expressed as a percentile of the reference distribution. Two methods of scoring are commonly used, i.e. the first is based on a lower percentile (i.e. 25th percentile of the reference site distribution is often used as the dividing line between reference and non-reference) of a representative sample of reference sites. The second is used if predetermined reference conditions are not

definable or if there are too few reference sites available (i.e. the 95th percentile of the entire population distribution is often used as the reference mark) (Karr *et al*., 1986).

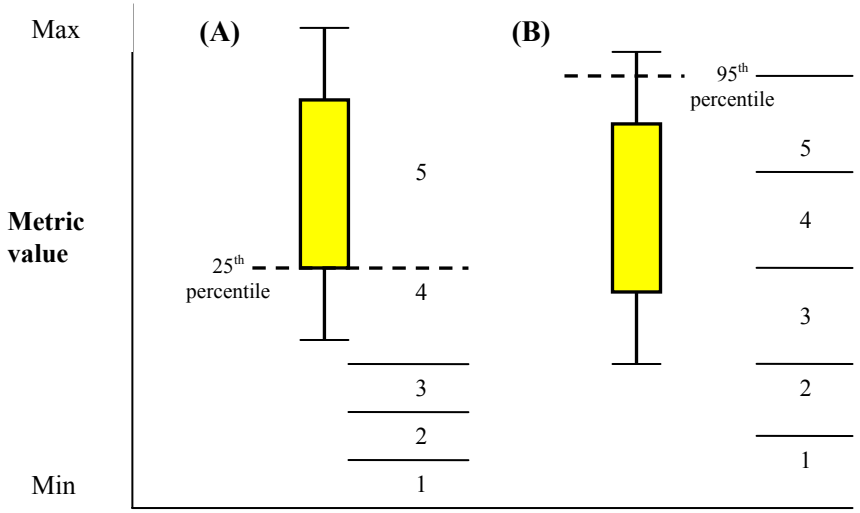


Fig. 5: Basis of the multimetric scores – (A) lower percentile of a representative sample of reference sites is used as the reference mark and (B) 95th percentile of the entire population distribution is used as the reference mark (adapted from US EPA, 2006)

The development of the classification tool will therefore involve (US EPA, 2006):

1. Characterization of reference conditions to obtain the distributions of metric values
2. Final selection of metrics based on metric responses to stressors
3. Characterization of the index distribution in reference conditions.

3. Use of the classification tool development plan/conceptual model

In addition to guiding the fish in lakes research team in the development of the classification tool the model should enable the project managers and reviewers to better evaluate the logic and underlying assumptions of the classification tool.

4. Caveats

It is important to understand what the classification tool development plan/conceptual model is and is not.

- It is a starting point toward an increased understanding, knowledge and development of an ecological classification tool for fish in lakes rather than the “final” tool for classification of fish in lakes.
- It is an evolving tool that will change with more data and knowledge
- It is a descriptive rather than a quantitative numeric tool.

5. Steps in the development of the ecological classification tool for fish in lakes

There are a number of essential steps involved in developing a multimetric index and subsequent ecological classification tool for fish in lakes (Table 1). The tool will address a broad range of ecological issues.

Table 1: Steps involved in developing the ecological classification tool for fish in lakes

1	Develop cost effective and reproducible sampling methods/protocols that ensure the biological attributes are measured accurately and precisely a. Sampling design b. Collect the fish c. Identify the fish d. Prepare and analyze data e. Present results (develop database)	Standard field sampling protocol completed (see methods manual). Data currently being processed
2	Classify ecotypes or subsets (e.g. shallow or deep lakes, low, moderate or high alkaline). Reference conditions are defined for each subset.	Completed (EPA) 12 (13) types. Identify fish types Reference condition for fish to be defined (see plan for statistical analysis)
3	Select measurable metrics using reference datasets. Before an index can be built and tested, the metrics need to be carefully selected to provide relevant and reliable signals about the biological effects of human activities.	TO BE DONE Expert opinion and correlation analysis (see plan for statistical analysis)
4	Combining metrics , index calculation and validation (EQR)	TO BE DONE (see plan for statistical analysis)
5	Communicate results to different users	TO BE DONE

Step 1. Develop cost effective and reproducible methods

One of the aims of the NS Share fish in lakes project was to develop and test a cost effective and reproducible standard methodology to sample fish in lakes. A standard methodology has been developed based on the CEN standard for multi-mesh gillnets (CEN, 2006). The method is supplemented with fyke nets and large mesh multifilament gillnets may also be added. The method includes information on:

a. Sampling design
b. Collecting the fish
c. Identifying the fish
d. Preparing and analyzing data
e. Presenting results

The standard methodology was tested on a range of lakes over an ecological gradient (reference to bad) for fish populations during 2005 and 2006 (Kelly *et al*., 2007). The lakes used to test the method and develop the fish index were representative of the range of conditions which prevail within the geographic area (NS Share). The dataset includes the best and worst conditions because sampling only from "reference" sites creates a problem as it does not provide a way to document which biological attributes vary with human influences (Karr and Chu, 1999).

Step 2. Classifying ecotypes and defining reference conditions

The establishment of reference conditions is crucial for the development of the ecological classification tool for fish in lakes. Reference conditions provide the baseline from which to determine human-induced lake changes over time, without which it would be impossible to evaluate the extent of human impact on a lakes current status or potential for future changes (Wallin *et al*., 2005). Biological, physico-chemical and hydromorphological variables must be taken into account when determining reference conditions. The WFD CIS Guidance recommends that reference conditions may span very minor disturbances, which means that limited human pressure is allowed as long as there are no, or only minor ecological effects (Anon, 2003).

Besides an abiotic classification of the European water bodies, the WFD requires that the reference conditions and the assessment procedure should be specific for types of water bodies (CEC, 2000 therefore the following steps will be followed in the development of the classification tool:

1. Firstly surface water bodies will be grouped into types

2. Secondly reference conditions will be estimated for the identified types before ecological status can be determined.

System B typology (Annex II) was found to be the most appropriate basis on which to define lake types in Ireland (Ecoregion 17) (Free *et al*., 2006). Twelve types have been identified using the factors, alkalinity (as a surrogate for geology), depth and size and a thirteenth type was identified to include a number of lakes at altitudes >300m (Free *et al*., 2006). Biological data (macroinvertebrates) from 60 high status lakes across several river basin districts in Ireland were used to demonstrate that the selected hydromorphological types, derived from these factors can be discriminated on a biological type (Free *et al*., 2006).

New lake classification systems based on fish assemblages have been reported for Finnish, French and German lakes (Tammi, *et a*l., 2002; Argillier *et al*., 2002 and Mehner *et al*., 2005). However, these classification systems are based on the fish communities which currently exist and therefore may not reflect natural/reference fish communities in Europe because of their degradation by human activities. This represents a tremendous scientific deficit, given the enormous importance of fish in lake and reservoir systems (Gassner *et al*., 2005). Initially lake types in Ireland should be evaluated using fish population data from reference lakes where available. Gap filling should be carried out using historical fish data and expert opinion.

At a minimum, reference conditions should be identified for each of the lake classification types (Karr and Chu, 1999). In order to achieve this the following steps are necessary:

I) Classify lakes so that comparisons can be made within, not across, classes.

II) Classification should reflect differences in the biota of the classes, for example a deep lake might have a fish assemblage different to that of a shallow lake, and classification should distinguish between the two types of systems (US EPA, 2006).

REFCOND guidance specifies that two categories are used to select reference sites in member states (ANON, 2003):

I) Pressure criteria. A table is provided in the REFCOND guidance which describes the degree of acceptable change in an anthropogenic pressure that would provide the limits of high status sites or values, pressures include diffuse pollution (such as land-use intensification: agriculture and forestry), point source pollution (specific synthetic pollutants, specific non-synthetic pollutants, other effluents), morphological alterations (structural modifications that hinder fluctuations of the water surface), water abstraction, flow regulation, riparian zone vegetation, biological pressures (introduction of alien species, fisheries and aquaculture and biomanipulation) and other pressures such as recreational use.

II) Ecological critieria must be based on fish abundance, fish species composition (includes trophic composition, reproduction and condition) and age structure.

Three fish groups have been identified and agreed for Ecoregion 17 by a panel of fishery experts (Table 1). In the absence of major human disturbance a lake fish community is considered to be in reference state (in relation to fish) if the population is dominated by salmonids (or euryhaline species with an arctic marine past) (i.e. group 1 fish species (natives) are the only species present in the lake) (Table 1).

Table 2: List of the three fish groups identified for Ecoregion 17

1. Natives	2. Non-natives influencing ecology	3. Non-natives benign (generally not influencing ecology)
Brown trout	Roach	Tench
Sea trout	Perch	Rudd
Salmon	Pike	Stoneloach
Char	Bream	Gudgeon
Pollan	Dace	
Eel	Carp	
Shad	Rainbow trout	
3-spine stickleback	Chub	
9-spine stickleback	Minnow	
Brook lamprey		
River lamprey		
Sea lamprey		
Flounder		

Data Analysis

Data analysis will involve two steps

1. Classifying lakes into fish types. Preliminary classification will be refined through graphical analysis (box plots, scatter plots-metrics vs. habitat variables such as lake size, alkalinity etc.), professional judgement and statistical tests of final classification hypotheses. The values and distribution of metrics will be compared among lake types. Lake types that appear similar (metric distributions must be similar) can be grouped together for final classification. Hierarchical cluster analysis (Ward's method) will be used to classify the lake fish types and validation of the fish end groups will be verified using the Multi Response Permutation Procedure (MRPP) in PCORD (McCune & Mefford, 1997) and other methods. MRPP is a non-parametric procedure for testing the hypothesis that there are no significant differences between two or more groups and has the advantage over ANOVA that it is not reliant on

multivariate normality and/or homogeneity of variances. Indicator species analysis will be used to determine which fish species are the most important in discriminating between fish communities in the lakes sampled. Ordination methods (e.g. PCA, correspondence analysis and multidimensional scaling) may also be used.

2. Reference conditions for each lake type will be determined by comparison with similar undisturbed lakes using a modelling approach (establishing a good stress-ecological response relationship) and by reconstruction of the reference status (historical data and expert opinion). Pressures must be identified in order to determine reference condition. The fundamental aim is to determine whether an individual lake is a member of the least-impaired reference population, if it is not then the second aim is to establish how far it has deviated from that reference status.

Step 3. Selecting metrics

Development of an IBI requires quantitative expectations of what a fish community should look like under reference or least impacted conditions (Karr *et al*., 1986). When conducting biological assessments, measurements are taken in the field and/or laboratory. Metrics for each assemblage sample are calculated from these measurements. Each metric represents an ecologically important attribute of the biological community. Every metric has its own set of expectations and metric expectations often vary with ecosystem size or location. Generating an acceptable set of expectations/metrics is perhaps the most difficult part of developing a new version of the IBI or effectively applying an existing version to a new geographic area (Simon and Lyons, 1995).

Most approaches start from a list of dozens of potential metrics and then use a systematic process to eliminate those metrics that do not meet certain criteria. The ecological classification tool must satisfy WFD normative definitions, metrics must therefore include:

1. Fish abundance (this can be expressed in a number of different ways, e.g. CPUE, total biomass etc.)
2. Fish species composition (includes trophic composition, reproduction and condition)
3. Age structure. (Age determination is time consuming and complex. Gassner *et al*., 2003 used length frequency indices as an alternative method to age determination as they enable a numeric estimation of length frequency data).

Fish species composition, abundance and age structure are generally affected by a number of factors such as (Gassner *et al*., 2003):

- Eutrophication
- Shoreline degradation

- Barriers to migration (of inflows and outflows)
- Fisheries management (angling, stocking etc.)
- Acidification

Therefore, the metrics used should assess the effects of these factors on the fish community in Irish lakes. Most IBIs contain between 8 and 12 metrics. A list of 67 metrics used in the development of fish based indices for lakes in Europe and the US was compiled (Kelly and Champ, 2006) and a group of fishery experts identified 32 (5 categories) of these metrics as being possibly suitable in the Irish context (Table 1). A systematic process will be used to eliminate those metrics which do not meet certain criteria. In order to develop an index for fish in lakes and the subsequent classification tool for ecoregion 17, metrics will be initially selected from this "pool" of existing metrics (Table 3). These metrics will be tested to ensure their precision and accuracy.

Table 3: Fish metrics identified as suitable for testing in the development of an index of biotic integrity for fish in lakes in ecoregion 17.

Ireland	Species richness and composition metrics	Response to human pressure
1	Total number of species present/current fish species composition	↓
2	Number fish species/fish species composition under three categories (see Table 2)	↓
3	Number of cyprinid species	
4	Number of fish species excluding Salmonidae	
5	Species evenness/diversity (Shannon-Wieners H' /number of native species/biomass)	
	Indicator species metrics	
6a	Number/proportion of intolerant/sensitive/indicator species (NOTE - include all salmonids, keep char etc. separate)	↓
6b	Number/proportion of char, pollan and shad	↓
7	Percent of individuals that are Salmonidae	↓
8	Age and/or size structure for populations of selected species	
9	Percent of individuals larger than a certain size for selected species (e.g. ferox, fishing pressure)	↓
10	Percent/number of individuals that are Tolerant species	↑
11	Percent of biomass as Tolerant species	↑
12	Percent of individuals that are Group 2 species	
13	Percent of biomass as Group 2 species	
14	Maximum length of the dominant fish species	

15	Maximum length of native species	↓
16	Occurrence of young stages of sensitive species (i.e. salmonids - 0+ or 1+)	
Trophic function metrics		
17	Percent of individuals that are Piscivores (trout>40cm, perch>20cm, pike>20cm)	
18	Proportion biomass of cyprinid species in relation to total biomass	
19	Proportion biomass of piscivorous species in relation to total biomass	
20	Percent biomass as Native piscivores (e.g. ferox)	
21	Proportion of intolerants by biomass	
22	Number of piscivorous species	
Reproductive function metrics		
23	Reproductive success (need a metric) Examples: scale of 1-5, 5=annually successful (80-100%) 4=missing a year class (60-79%) 3=missing year classes (2 classes missing - 40-59%) 2=missing year classes (3 classes missing - 20-39%) 1=recruitment pattern likely to threaten continuation of the species (<20%)	
24	Percent of individuals that are lithophilic	Use FAME classification
25	Percent of individuals that are rheophilic	
26	Percent of individuals that are phytophilic	
Abundance and condition metrics		
27	Abundance or catch per unit effort of native fish	↓
28	Total native fish biomass or CPUE in weight	↓
29	Current total fish biomass (BPUE)	↓
30	Pike (predators) CPUE and biomass	
31	No. species migrating over long distances	
32	No. potamodromous species (includes 3 separate species of trout in Melvin)	↓

A list of abiotic and biotic variables (i.e. indicators of human disturbance) has been compiled in Table 4. Certain physical and chemical attributes can have a strong influence on biological metrics, particularly the number of taxa metrics. The most important of these to

test are lake size, depth and alkalinity and reference expectation may need adjusting as a function of these factors (covariate analysis).

Table 4: Abiotic variables to be included in the analysis for tool development

On site	Description
Lake area	ha
Max depth	Maximum depth (m)
Mean depth	Mean depth (m)
Lake volume	m^3
Extent of littoral area ?	% (percent of lake area <4.6m in depth, Drake and Perreira (2002))
Secchi depth/ Tansparency	(W or S or mean?) If there is more than one secchi value use a mean but if only have 1 Secchi value, e.g. summer, then just have to use it (add a comment in the file in relation to this)
Stratification	Does the lake stratify?
Presence/absence of zebra mussels	Y/N
Lab	
Colour	hazen Winter samples are better rather than using secchi
Total P	Winter MAX and Mean (μg/l P)
Chlorophyll a	MAX winter or summer and mean (or single measurement where available) (μg/L)
Alkalinity	(mg/l $CaCO_3$) – any measurement available
Trophic status	OECD
GIS	
Spawning	Extent of spawning and nursery areas u/s of lake – area (m^2) or length (m) and width (m) of all tributaries
Distance from source	(m)
Distance from tidal limit	(m)
Catchment area	Area of catchment upstream (km^2)
Connectivity	Presence of a barrier to fish migration d/s

	3 types (0=none present, 1=impassable man-made barrier, 2=impassable natural barrier)
Geology	calcareous/siliceous (or all geological types)
Landuse	Dominant land use
Other pressures	Morphological/hydrological, e.g. abstraction

Selection of candidate Metrics, exclusion of Redundant Metrics and selection of Core Metrics

The available lake fish dataset will be split into two parts:

1. Reference dataset, to develop the index and calculate expected values (reference sites only)
2. Test data set (reference and non-reference/impacted sites)

Following classification and characterization of reference conditions, metrics will be evaluated for suitability in the multimetric index. Suitable metrics are those that respond in a predictable way to stressors on the system and that have low noise or variability (US EPA, 2006).

All potential metrics will be screened using the following approach:

1. Box plots for each metric distribution per five impact classes based on the sum of the impact scores (reference and test sites)
2. Spearman rank correlation analysis between metric values and impacts (hydrological, morphological, water quality, and connectivity)
3. Scatter plots of metrics versus total impact scores
4. Statistical analysis (comparison of means=t-test, not assuming equal variances, analysis of variance and various non-parametric methods, etc.) for each metric between calibration (reference) and impacted sites per fish type. Other methods include multiple regression, canonical correlation, canonical correspondence analysis and log-linear models. Metrics are judged responsive if there are significant differences in mean/median or variance values between reference and test sites
5. Logistic regression to predict calibration sites per fish type.
6. From this analysis the best/most suitable metrics (i.e. responsive to known or unknown stressors) will be selected for further statistical analysis and scoring.

7. Evaluation of redundancy: A metric that is highly correlated with another metric might not contribute new information to the assessment. Pairs of metrics with correlation coefficients greater than 0.9 should be examined carefully to determine whether both metrics are necessary. A scatter plot of correlated metrics should be examined, if there is an apparent nonlinear or curved relationship then both should be retained (US EPA, 2006).

Variability and uncertainty of metrics

Variability in values of measurements and metrics results in uncertainty of the assessment. Uncertainty can be reduced by increasing the sampling effort (repeated measurement) to obtain a better estimate of the mean/median value. This is especially important for measurements that are the most variable such as nutrients (TP and N) and chlorophyll (US EPA, 2006).

Metrics that are too variable within the reference dataset are unlikely to be effective for assessment. A measure of metric variability is the ratio of the interquartile range to the distance between the lower quartile (25th percentile) and the minimum possible value of the metric (Fig. 6). Metric values below the lower quartile range of reference conditions are typically judged as not meeting reference conditions. The larger the "scope for detection" (0 to the lower quartile) compared to the interquartile range, the easier it will be to detect deviation from the reference condition. The "interquartile coefficient" (i.e. ratio of the interquartile range to the scope for detection) is similar to the coefficient of variation (an interquartile coefficient greater than 1 indicates excessive variability of a metric) but is bidirectional. In general, an interquartile coefficient greater than 1 indicates excessive variability of a metric. This variability can be evaluated using box and whisker plots, multiple regression, canonical correlation, canonical correspondence analysis and log-linear models (US EPA, 2006).

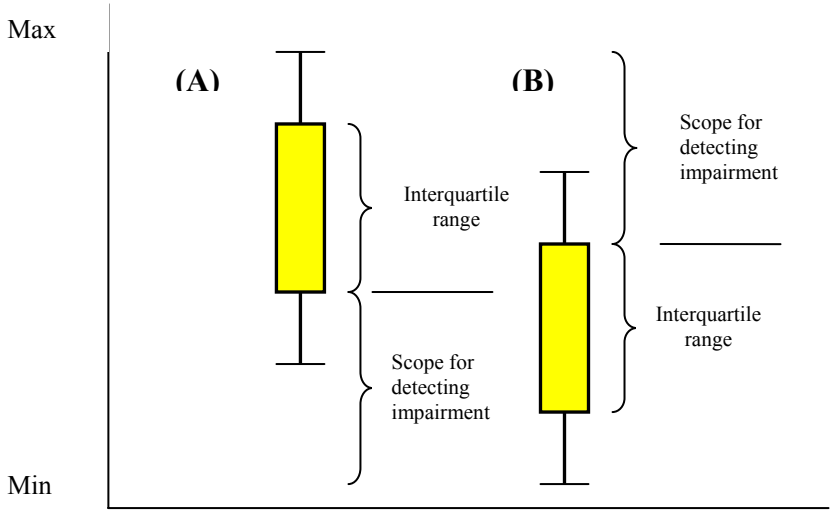


Fig. 6: Assessing candidate metrics. (A) Metrics that have high values under impaired conditions and (B) metrics that have low values under impaired conditions (adapted from US EPA, 2006).

Step 4. Combining metrics to produce a multimetric index, index calculation and validation

Combining unlike measurements is possible only when the values have been standardized by a transformation through which measurements become unit less (US EPA, 2006). Two methods have been used for scoring metrics:

Transformation of core metrics into a 0 to 1 score

Option 1: Traditional metric scoring approach

Percentile boundaries (the lower quartile-25th percentile is frequently taken as the cut off between reference and impaired conditions when reference sites are unimpaired, the 95th percentile is used as the best value when all reference sites are somewhat impacted), individual metric scoring and summation of score (Minns *et al*., 1994). If covariates such as lake size and maximum depth determine metric values then the scoring should be adjusted for these.

Option 2: FAME discriminant analysis method (Noble *et al*., 2003)

Discriminant analysis is used to assess differences between impact classes and to create a predictive biological integrity class model.

Combination of Core Metrics to a Multimetric Index

Once the metrics are scored, or normalized, they will be combined into a Multimetric index. If the same number of metrics has been selected for each metric type the Multimetric Index can be calculated as the mean of the 0 to 1 scores of all Core Metrics (CEN, 2004). The number of metrics in an index affects the variability of the index, i.e. those with more metrics tend to be less variable (Karr, 1991).

Validation and testing of the index

The Index will be subjected to testing to ensure that the index can consistently and predictably respond to a disturbance gradient (US EPA, 2006). IBI scores will be calculated for all lakes surveyed (test data - 83 lakes) and tested against IBI scores for reference lakes, human/abiotic disturbance categories/variables and trophic state using General linear models (GLMs), Tukeys multiple comparison method and Pearsons correlation analysis, etc.

The sensitivity of the IBI to each metric will be assessed for each lake by systematically removing a metric from the IBI, calculating a reduced IBI (scaled for the elimination of one metric) and then calculating the difference between the reduced and full IBI (Minns *et al*., 1994). The variances of the differences for each reduced IBI will be calculated, this will suggest the relative importance of an eliminated metric. The ratio of the variances within a disturbance category to the variance of the differences for all lakes should provide a measure of the metrics range of sensitivity. Metrics with ratios greater than the median for the disturbance category should be considered informative within the category (Drake and Perreira, 2002).

Problems identified which may hinder the development of the classification tool

1. The reliability of the classification procedure will be largely dependent on the quality of the data used in defining reference conditions.
2. There are not sufficient numbers of minimally impacted high ecological status lakes in the database that can be used to determine reference conditions in each lake type, particularly the high alkalinity groups; therefore the use of historical data is necessary.
3. Establishing reference condition and obtaining sufficient number of reference lakes is complicated/restricted by the introduction of non-native fish species to many lakes in ecoregion 17 (group 2 and 3). Therefore historical data is essential in establishing lake types and reference condition for fish communities.

4. There are limited survey data available (particularly abundance data) prior to 1960. If historical data does exist it has been collected using different methodologies (e.g. O' Grady CFB method) therefore it's not possible to assess the quality of the data. Long-term historical data exists for only a few lakes in Ireland (e.g. L. Sheelin, L. Conn, L. Melvin, L. Erne etc.), but few of these records date back to "reference" conditions. These are large high/moderate alkalinity lakes, little data exists for small lakes, particularly those in the low alkalinity category. There is also a lack of reference data/long term data for lakes where salmonids only exist (particularly mod and high alkalinity). It is necessary to establish abundance/relative abundance figures for reference fish populations (least impacted) (as we need to calculate expected values for each fish metric in the absence of human degradation for each lake type (similar sized water bodies and similar depth range). Expert opinion for reference status will only be able to draw on species composition. There are no data for abundance of species in the historical datasets.

5. Jackson and Harvey (1997) reported that estimates of relative abundance and patterns of covariation for fish species captured with a variety of sampling gears differed greatly among the gears and provided contradictory results about fish species relative abundance. They also concluded that attempts to integrate catches from gears to provide an overall estimate of species abundances in communities across lakes are compromised because of the inconsistency in estimates of abundance and covariation. Therefore it may be necessary to develop separate metrics for each gear type.

6. Three types of lake fish communities exist in ecoregion 17:

   1. salmonids dominant (group 1 only) (no coarse fish or pike introduced)

   2. salmonids and coarse fish (including pike) (all fish groups present) have been introduced (e.g. rudd in L. Meela, L. Melvin =rudd, perch & tench)

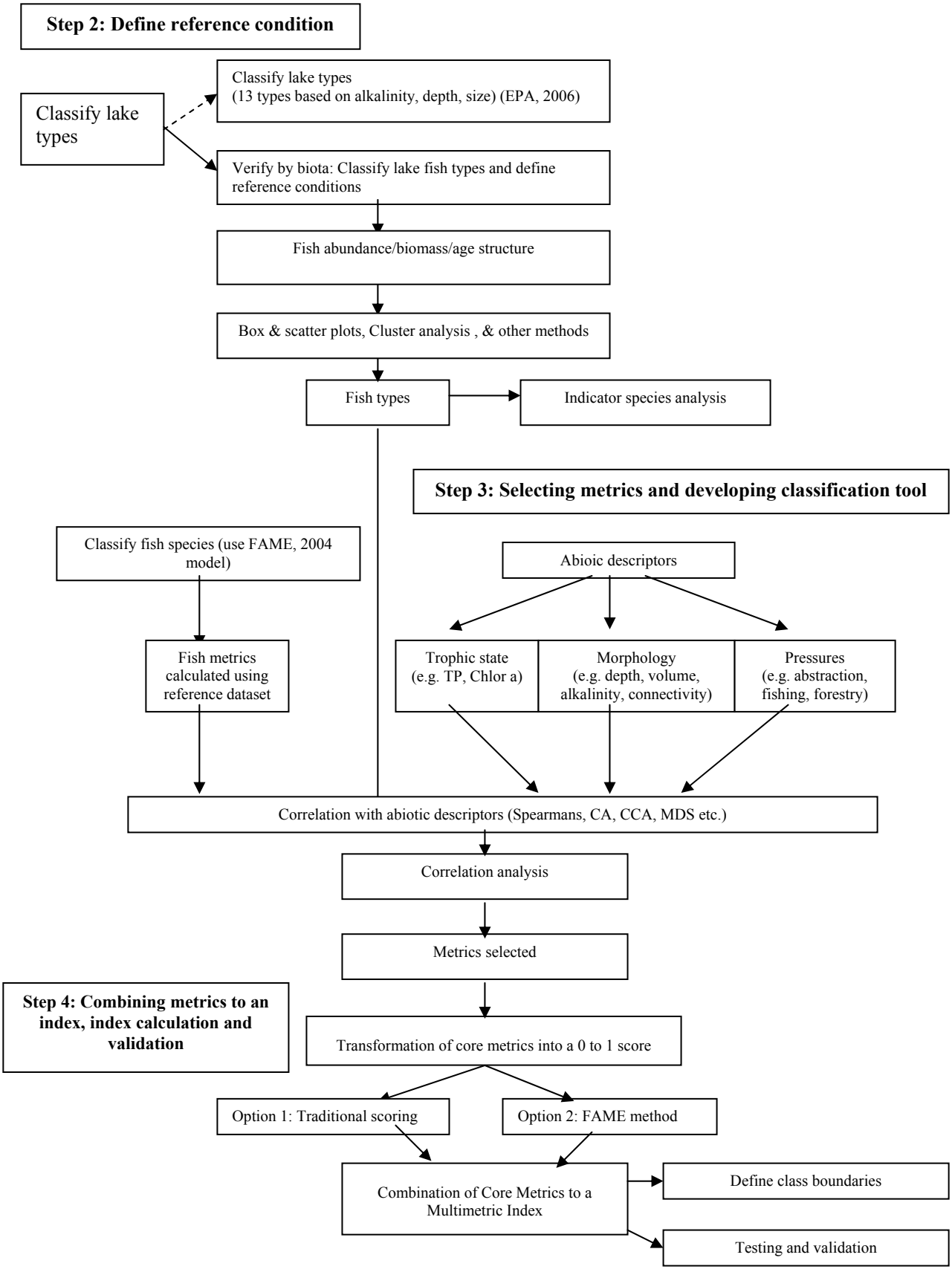
   3. coarse fish including perch, roach, rudd, bream and pike (groups 2 and 3) (native salmonids absent)

   It may be necessary to develop differing metrics for the various lake types? Or a separate index? 3 indices one for each alkalinity type.

Step 5. Communicate results to different users

The WFD requires that Member States report a considerable amount of information in the form of maps and the most suitable method for this is in the form of GIS data layers. A fish layer will be developed based on results of the classification tool.

Summary (Development of the classification tool for fish in lakes)



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