Some observations on the behaviour of lake dwelling brown trout in Lough Erne.

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ABSTRACT

Acoustic telemetry was utilised to track a sample of 80 adult wild brown trout across an extensive array of 30 receivers in Lower Lough Erne during 2016 and 2017. The mean detection duration across the array was 142 days and the majority of tagged fish were detected consistently in the northern basin of the lake. One year after tagging c. 40% of larger fish (>45 cm L_F) were still actively detected whilst only 5-10% of smaller fish (<45 cm L_F) were detected on the array. In total 9 trout were re-captured by anglers between 2-1152 days post-tagging, with a mean liberty time of 152 days, and a minimum angling exploitation rate of 11.25%. A high proportion of tagged trout (>50%) did not undertake spawning migrations into an influent tributary and remained active within the lake during the reproductive period in November. In total 14 tagged trout undertook spawning migrations into a range of tributaries, the mean spawning sojourn was 54 days and 5 fish (36%) did not return to the lake post-spawning.

INTRODUCTION

Brown trout (*Salmo trutta*) can display marked plasticity in their life history, morphology and behaviour (Ferguson, 1989). The species is highly adaptable with a wide-scale distribution through-out Ireland, inhabiting rivers, lakes and estuaries in addition to fully saline coastal waters. Many brown trout stocks, particularly in Ireland, exhibit a potamodromous life history tendency through which spawning and juvenile production occur in influent riverine tributaries (could this be just "rivers"?) >whilst maturation is largely undertaken in the lake environment. Potamodromous trout stocks support important recreational fisheries in Ireland with local and tourist anglers regularly travelling to fish key trout lakes, of which Loughs Corrib, Lower Erne, Ree, Derg, Mask, Sheelin, Mask, and Melvin are the largest.

Previous research work on Irish lake trout has focused primarily on several discrete aspects of fundamental biology including: growth (Kennedy & Fitzmaurice, 1971; Went, 1979; O'Grady, 1984; Hanvey & Ankatell, 2001) diet (O'Grady, 1983; Crozier, 1985; Byrne *et al*., 2000), parasitology (Molloy *et al.*, 1995; Byrne *et al*., 2004) and genetic population structure (Ferguson & Mason, 1981; Crozier & Ferguson, 1986; McVeigh *et al*., 1995; Massa-Gallucci *et al*., 2010). Relatively few studies have reported on the survival, exploitation rates, habitat preferences or spawning behaviour of wild brown trout in natural lake environments (Thorpe, 1974; Haraldstad & Jonsson, 1983; Sculz & Berg, 1992; DeDual *et al*., 2000) with virtually no information available in an Irish context. Understanding of survival, exploitation, spawning and behaviour patterns in natural habitats is critically important for conservation given the extensive list of potential pressures facing Irish trout stocks. Threats may vary from wide-scale process such as climate change (O'Briain, 2019) to more localised issues like depressed water quality or over-exploitation (Fahy, 1989). Despite the importance of recreational trout fishing through-out Ireland, few data are currently available documenting some key management metrics such as the angling exploitation rate of wild brown trout in Irish lakes.

The current work used acoustic telemetry to monitor samples of wild brown trout during two years in Lower Lough Erne, Co Fermanagh in order to ascertain;

1) Spawning behaviours within the Erne catchment, including which tributaries were used for spawning, the duration of spawning tributary sojourn and the relative proportions of fish that spawn and that overwinter in the lake.
2) The long term detection rate of different size fractions of tagged brown trout (as a proxy for survival).
3) The spatial usage of the Lough by trout during the year.
4) The potential exploitation rate of tagged brown trout by anglers.

METHODS

Study Area

Lower Lough Erne is located in North West Ireland, has a wetted area of 109.5 km^2 and maximum depth of 65m. The catchment rises on Slieve Glah mountain in County Cavan and discharges into the Atlantic Ocean at Ballyshannon, Co. Donegal. The underlying geology is dominated by carboniferous limestones. Upper and Lower Lough Erne form major lakes on the system which host over 150 islands. The lakes have several feeder tributaries including the Garvary, Kesh, Ballinamallard and Colebrooke rivers, all of which support populations of brown trout (Fig. 1). The outflow from the lake has an average daily discharge of c. 100 m^3s^{-1} and supports two run of river hydro-electric stations at Cliff and Ballyshannon. Lower Lough Erne is an important recreational fishery which attracts many brown trout anglers, particularly in the late spring during the mayfly hatch.

Tagging

Brown trout were sampled by rod and line angling during the fishing season on Lower Lough Erne (1st March – 30th September) during 2016 and 2017. The two angling methods employed were fly fishing and trolling with small lures from boats, this combination of methods ensured sampling could occur during different weather conditions. On sampling days several volunteer anglers fished a specific portion of the lake and were equipped with large 50 l plastic tanks in which to retain any captured fish. The tagging crew remained mobile in a boat amongst the angling fleet and were alerted upon capture of a suitable fish which was immediately translocated to a larger 100 l holding tank and shipped to the nearest suitable shoreline for tagging. Any fish that were injured (including previous predation scars), damaged, were deeply hooked or showed signs of bleeding were not used for tagging. Fish were anaesthetised individually in a 50 l plastic tank using a solution of oil of cloves of concentration 0.03 - 0.04 ml^{-1}. The emersion time averaged around 2 minutes before fish were sufficiently anaesthetised. The fish were measured for L_F (cm) and weighed (g) before being placed, belly up, on a wetted supportive foam girdle. A scalpel was used to make a c. 1cm long incision anterior of the pelvic girdle and slightly off centre, through which the acoustic tag was gently inserted into the peritoneal cavity parallel to the body wall. The tags used were 69 kHz VEMCO V9 coded acoustic transmitters (9 mm diameter, 27 mm long, 4.5 g weight) with a delay of 40-80 s and battery life of >400 days. The wound was then closed using a single 4/0 polyglycolic acid suture. After tagging each fish was pan-jet marked with a blue ink tattoo between the pectoral fins to effect a long term external mark and provide a basis for identification of tagged individuals in future angling catches. The care and use of experimental animals complied with UK welfare laws, guidelines and policies as approved by ASPA (Animals Scientific Procedures Act) licence PPL 2761. After tagging the fish were allowed to fully recover in a 100 l plastic tank for 30 mins before release back into the lake.

Tracking

The tagged fish were detected by a stationary network of 13 VR2W submersible acoustic receivers which were deployed in 6 discrete arrays (A – F) with groups of 2-3 receivers composing each array and located in specific regions within the lake (Figure 1). The receiver network did not facilitate a complete detection field across the entire lake but it did provide good coverage at key pinch points and known trout holding bays through-out the lake. Array A and F were arranged to detect fish exiting/re-entering Lower Lough Erne, array B separated the northern and southern basins of the lake and the remaining arrays covered the western, center and eastern portions of the extensive northern basin (Figure 1). An additional 17 units were placed in potential spawning tributaries draining into the lake with most of the larger tributaries hosting at 2-3 receivers (Figure 1). The arrays were deployed in Jan-Feb 2016 were downloaded regularly and maintained until November 2019.

The detections for each tagged fish were logged across all the receivers and an individual profile was assembled of the times when each fish was present at a particular array or tributary. The duration that each tagged fish was detected across the receiver network was also tabulated to provide a measure of the persistence time within the catchment. Any fish which were not actively moving between receivers, became static and did not move again from a particular receiver or any fish that disappeared from the network were considered to have died or shed their tag. The spawning period for brown trout in Lough Erne is during November and the location of each active fish was logged during this period to determine which spawning tributaries were used, how many fish were engaged in spawning behaviour and how many fish remained active in the lake. Trout anglers were notified about the tagging project and asked to report any pan-jet marked fish and return tags from any fish that were killed.

Data Analysis

The main telemetry metrics included duration of detection in the array, whether a fish spawned or was caught and the number of lake zones in which each fish was detected. These data were tabulated across 3 size classes of tagged fish (<40 cm, 40-45 cm & >45 cm L_F). Detection duration across size categories was compared using single factor Analysis of Variance (ANOVA). Tag detection persistence with increasing time and across the three size categories were arranged as cumulative frequency plots (% tags available vs time) and were compared using 2 sample Kolmogorov-Smirnoff tests. A General Linear Mixed Model (GLMM) was applied to investigate the spawning behaviour of tagged fish in which a binomial response for spawning behaviour (spawned; did not spawn) was investigated against a range of potential exploratory variables including L_F, the number of lake zones used and detection duration with tag year pooled.

RESULTS

A total of 80 brown trout were tagged during the study with 50 tagged in 2016 and 30 tagged in 2017 (Table I). The tagged fish ranged in size from 29.0 cm – 52.9 cm L_F (Figure 2) and based on scale readings undertaken on similar sized Erne fish reflected an age range of around 3 - 6+ years (R. Rosell *pers. com.*). All fish were sampled by rod and line angling (28 fly angling, 50 trolling) except for 2 specimens captured in good condition by a survey net in April and July 2016 (Table I). Seven fish were never detected on any receiver during the study whilst the remaining 73 were detected on one or more receivers during the course of the study. No detected tags became static at a particular receiver or location. The mean duration over which tagged fish were detected on the lake arrays was 143 days. No significant difference was evident in the mean detection duration between different size categories of tagged fish with <40 cm, 40-45 cm & >45 cm L_F fish picked up across 158, 116 & 156 days respectively (ANOVA, F=0.68, *P*=0.51). The rate at which tagged fish disappeared from the array was considered a proxy for survival and was compared between three size categories <40 cm, 40-45 cm & >45 cm $L_{F.}$ Tag loss rates were similar during the first 3 months but thereafter was lower for the largest fish (> 45 cm) and higher for smaller size categories (<40, 40-45 cm) (Figure 3). Tag loss over time was significantly higher for small fish < 40cms than for larger fish >45 cms (K-S test; D=0.41; $P < 0.05$) and after 12 months 40% of larger fish were still actively detected on the array whilst only 5-10% of the smaller size categories remained active (Figure 3).

A total of 9 tags (11.25%) were returned by anglers who had either noticed the tattoo mark or discovered the tag whilst cleaning the fish. Eight of these angler recaptures ~~In total 8 fish~~ were ~~recaptured~~ in the lake and 1 individual was caught in a spawning tributary. Of the 9 recaptured fish 5 had initially been caught trolling and were recaptured by fly angling (3) and trolling (2), 4 others had initially been caught fly angling and were recaptured by fly (2), troll (1) and worm fishing in a tributary (1). It is highly likely that other fish were caught but not reported and therefore the 11.25% angling exploitation rate should be considered as a *minimum* estimate. There was little difference in the exploitation rate amongst different size classes of fish (Table II) possibly because 79 of the 80 tagged fish were above the minimum landing size for brown trout on Lower Lough Erne (30 cm) and subject to a similar likelihood of harvest. The time duration between tagging and angling recapture ranged from 2 – 1151 days with a mean liberty time of 152 days.

In total 53 tagged fish were active for >1 month during the study and around 60% of this group were detected on 4 or more or more arrays within the lake (Figure 4a). Tagged fish moved extensively within Lower Lough Erne but were most commonly detected on arrays in the northern basin with around 85% and 83% of fish recorded located on arrays C and D respectively (Figure 4b).

A number of trout (14) were detected in the lake tributaries during October – December in 2016 and 2017. Two trout entered a different river before navigating to their final spawning stream later in the year. The movement into tributaries was associated with spawning behaviour and around 39%, 42% and 44% of <40cm, 40-45cm and >45cm trout were detected in rivers during the spawning period (Figure 5). A high proportion of trout remained active in the lake during the entire spawning period and it was assumed that these individuals did not contribute to reproduction in these years (Figure 5). Most spawning fish used tributaries draining into Lower Lough Erne whilst around 12% moved into tributaries draining the adjacent Upper Lough Erne (Figure 6). The most commonly used spawning channel was the Ballinamallard river which accommodated c. 41% of the tagged spawners (Figure 6). The mean duration of river residence at spawning time was c. 54 days but varied from 29 days (Garvary river) to 114 days (Ballinamallard river). The mean date on which tagged trout exited the lake to enter spawning channels was 7th October and the mean date when kelts re-entered the lake was 30th November. GLMM analysis of spawning behaviour indicated that neither L_F or the number of lake zones utilised by an individual significantly predicted whether a trout would spawn or not ($P > 0.05$).

DISCUSSION

The interpretation of fish telemetry data relies on several key assumptions including a negligible impact of the tagging on subsequent survival and behaviour plus good long term retention of surgically implanted tags (Jepsen *et al.*, 2002). An increasing realisation amongst researchers, however, is that surgically implanted fish can shed tags, sometimes in significant quantities, over the longer term. In brown trout, shedding rates of around 23% have been documented for peritoneal implanted tags after 5 months (Jepsen *et al.*, 2008). Kennedy *et al* 2020). documented 33% annual tag loss rates in hatchery brown trout of similar size to those tagged in Lough Erne, a study which was designed as a direct calibration exercise for the Erne work. In the current study around 10% of smaller trout (<45 cm) and 40% of larger trout (>45cm) were still active on lake receiver arrays after 1 year, implying minimal annual survival levels of 10-40%. The true survival rates for these fish would almost certainly have been higher, depending on the extent of tag shedding, perhaps as high as 43-73% according to Kennedy *et al*., (2020). The better relative persistence of larger fish in comparison to smaller fish over the longer term could also be due to differential tag retention. This was considered to be unlikely in the present situation, however, given that higher tag expulsion has been associated with increased tag burdens >7.5% tag weight :body weight in salmonids (Brunsdon *et al.,* 2019) and the tag burden on all the experimental fish used in the Erne study was very low <1%. A more likely explanation for the implied better survival of larger trout is that the larger body size provided a survival advantage, perhaps facilitating a 'refugia in size' against predation within the lake (Nilsson & Bronmark, 2000). Shephard *et al.*, (2019) for example, suggested that Northern pike (*Esox lucius* L.), a potential predator of trout in Irish lakes, limited prey selection to items that fitted their mouth gape with larger prey less vulnerable to all but the largest, least abundant pike.

The return of 9 tags from the angling community was an unexpected result and was suggestive of at least 11.25% exploitation rate on the tagged fish. This result was surprising to the authors given the modest numbers of trout tagged during the study (80) and the huge surface area of Lower Lough Erne (109.5 km^2) which made it seem unlikely that many fish would be re-encountered by anglers. Millane *et al*., (2017) documented mean exploitation rates of 6.7 –

9.3% for returning anadromous *S. trutta* based on fish counter data and angling catch returns from Western Irish Loughs. The final exploitation rate on potamodromous trout in Lough Erne, however, was likely higher than the reported 11.25% which represented a minimum estimate. Swales (1986) monitored trout production and angling catch from an upland reservoir and found that anglers removed 62.6 kg of *S. trutta* from a standing stock of around 250.8 kg, suggestive of a 25% harvest level. Further research into brown trout exploitation in lakes is needed to ascertain if such high harvest levels are common in these fisheries, given the intrinsic implications for conservation and management. The relatively high re-capture rate of *S. trutta* in Lough Erne may also be partially explained by individual behaviour patterns. Previous research has suggested that individual-level behavioural traits such as aggression or activity level, might influence the overall likelihood of capture by angling techniques (Biro & Post, 2008; Wilson *et al.*, 2011). The fact that 97.5% of the tagged Erne trout were initially captured by angling may have produced a sample that was more susceptible to rod-catchability.

In total 14 tagged fish undertook classic upstream spawning migrations into various feeder tributaries through-out the Erne catchment. Spawning migrations were relatively short duration behaviours with several fish residing for less than a month in their spawning channel before returning to the lake. Some of the Erne spawning tributaries are relatively small channels, for example the Garvary river is only c. 7.5 km long, rarely exceeds 5 m width and has limited deeper resting pools for larger fish. Residence in such smaller waterways can expose larger salmonids to increased predation risk from piscivorous species such as otters (*Lutra lutra* L.) (Carss *et al.*, 1990) and may explain the relatively short residence window around spawning habitats. Around 36% of kelts did not return to the lake after the reproductive period, implying a significant mortality cost associated with upstream spawning migration and potential losses due to predation or angling. A novel finding from the current study was that a relatively high proportion of tagged fish did not enter the influent tributaries during the spawning season and actively overwintered in the lake. Brabrand *et al*., (2002) documented lake spawning by *S. trutta* when groundwater influx and suitable spawning gravels were available. It may be possible that some of the Erne fish engaged in spawning activities within the lake, perhaps on the gravel shores around Islands, although such behaviour has never previously been observed in the Erne. A more likely explanation for the partial spawning behaviour in Lough Erne could be due to the inherent mortality risk associated with migration into the tributaries. Wysujack *et al*., (2009) demonstrated high plasticity in migratory tactics between *S. trutta* from the same gene pool which were subject to different feeding conditions. It is possible that various selective pressures influence the annual reproductive strategy of individual fish, with some trout overwintering in the lake to minimise the mortality risk and energy losses associated with spawning in order to maximise potential reproductive investment in a future year. Jonsson & Jonsson (1993) suggested that partial migration in anadromous salmonid populations was partly developmental, depending on environmental conditions, and partly genetic, inherited as a quantitative trait. This intriguing biological question requires further research on potamodromous trout stocks to examine the extent of partial spawning behaviour in other lakes, possibly through the use of longer term telemetry transmitters.

The ability of migratory salmonids to return to natal habitats promotes genetic differentiation among stocks and Crozier & Ferguson (1986) demonstrated the existence of multiple brown trout populations between different tributaries of Lough Neagh in N. Ireland. Most of the tagged Erne fish migrated directly to, and remained within, a single spawning tributary suggestive of migratory fidelity. In the Erne study >40% of spawners migrated into a single lake tributary (Ballinamallard river) which is indicative of a high contribution from that river to the overall lake stock. Studies on other lacustrine salmonid stocks have often indicated highly variable contributions between various spawning tributaries in Atlantic salmon, *Salmo salar* L., (Kennedy *et al*., 2016), brook trout *Salvelinus fontinalis*, Mitchill, 1814, (D'Amelio

& Wilson, 2008) and rainbow trout Oncorhynchus mykiss, Waulbaum 1792, (McKenna & Johnson, 2005). The identification of key spawning tributaries is a useful finding but the effective management of these source river populations will now be critical to future conservation and enhancement efforts for the Erne trout fishery.

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References

Biro, P. & Post J. (2008). Rapid depletion of genotypes with fast growth and bold personality traits from harvested fish populations. *Proceeding of the National Acadamy of Science USA*, **105**, 2919–22.

Brabrand, Å., Koestler, A.G. & Borgstrøm, R. (2002). Lake spawning of brown trout related to groundwater influx. *Journal of Fish Biology*, **60**, 751-763.

Brunsdon, E., Daniels, J., Hanke, A., & Carr, J. (2019). Tag retention and survival of Atlantic salmon (*Salmo salar*) smolts surgically implanted with dummy acoustic transmitters during the transition from fresh to saltwater. *ICES Journal of Marine Science*, **76**, 2471–2480.

Byrne, C., Poole R. & McGinnity, P. (2000) Food consumed by wild and stocked brown trout, *Salmo trutta* L., and salmon, *Salmo salar* L., in an Irish lake. *Internationale Vereinigung fur Theoretische und Angewandte Limnologie Verhandlungen*, **27**, 185-188

Byrne, C., Holland, C., Walsh, E., Mulligan, C., Kennedy, C., & Poole, W. (2004). Utilization of brown trout Salmo trutta by Acanthocephalus clavula in an Irish lake: Is this evidence of a host shift? *Journal of Helminthology, 78*(3), 201-206.

Carss, D.N., Kruuk, H. & Conroy, J.W.H. (1990). Predation on adult Atlantic salmon, Salmo salar L., by otters, *Lutra lutra* (L.), within the River Dee system, Aberdeenshire, Scotland. *Journal of Fish Biology*, **37**, 935-944.

Crozier, W. (1985). Observations on the Food of Two Sympatric Populations of Brown Trout (Salmo trutta) in Lough Neagh, Northern Ireland. *Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science,* **85B**, 57-71.

Crozier, W.W. & Ferguson, A. (1986). Electrophoretic examination of the population structure of brown trout, *Salmo trutta* L., from the Lough Neagh catchment, Northern Ireland. *Journal of Fish Biology*, **28**, 459-477.

D'Amelio, S. & Wilson, C. (2008). Genetic Population Structure among Source Populations for Coaster Brook Trout in Nipigon Bay, Lake Superior. *Transactions of the American Fisheries Society*, **137**, 1213-1228.

Dedual, M., Maxwell, I., Hayes, J. & Strickland. R. (2000). Distribution and movements of brown (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) in Lake Otamangakau, central North Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, **34**, 615-627.

Fahy, E. (1989). Conservation and management of brown trout, *Salmo trutta*, in Ireland. *Freshwater Biology*, **21**, 99-109.

Ferguson, A. & Mason, F.M. (1981), Allozyme evidence for reproductively isolated sympatric populations of brown trout *Salmo trutta* L. in Lough Melvin, Ireland. *Journal of Fish Biology*, **18**, 629-642.

Ferguson, A. (1989). Genetic differences among brown trout, *Salmo trutta*, stocks and their importance for the conservation and management of the species. *Freshwater Biology*, **21**, 35-46.

Hanvey W. & Anketell, M. (2001). A Review of Growth in Brown Trout *Salmo trutta* (L.) from Lough Neagh and the River Main, Co Antrim, Northern Ireland. *The Irish Naturalists Journal*, **26**, 351-362

Haraldstad, Ø. & Jonsson, B. (1983). Age and Sex Segregation in Habitat Utilization by Brown Trout in a Norwegian Lake. *Transactions of the American Fisheries Society*, **112**, 27-37.

Jepsen, N., Koed, A., Thorstad, E.B. & Baras, E. (2002). Surgical implantation of telemetry transmitters in fish: how much have we learned? *Hydrobiologia* **483,** 239–248.

Jepsen, N., Mikkelsen, J.S. & Koed, A. (2008). Effects of tag and suture type on survival and growth of brown trout with surgically implanted telemetry tags in the wild. *Journal of Fish Biology*, **72**, 594-602.

Jonsson, B. & Jonsson, N. (1993). Partial migration: niche shift versus sexual maturation in fishes. *Reviews in Fish Biology & Fisheries* **3,** 348–365.

Kennedy, M., & Fitzmaurice, P. (1971). Growth and Food of Brown Trout Salmo trutta (L.) in Irish Waters. *Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science,* **71**, 269-352.

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Massa-Gallucci, A., Coscia, I., O'Grady, M., Kelly-Quinn, M. & Mariani, S. (2010). Patterns of genetic structuring in a brown trout (*Salmo trutta* L.) metapopulation. *Conservation Genetics* **11,** 1689–1699.

McKenna, J. & Johnson, J. (2005). Juvenile Rainbow Trout Production in New York Tributaries of Lake Ontario: Implications for Atlantic Salmon Restoration. *North American Journal of Fisheries Management*, **25**, 391-403.

McVeigh, H., Hynes, R. & Ferguson, A. (1995). Mitochondrial DNA differentiation of sympatric populations of brown trout, *Salmo trutta* L., from Lough Melvin, Ireland. *Canadian Journal of Fisheries and Aquatic Sciences*, **52**, 1617-1622

Millane, M., Shephard, S., White, J.,. Ó Maoliléidigh, N., O'Higgins, K., O'Malley, P., Roche, W., Poole, R., Rogan, G., Bond N. & Gargan P. (2017). Estimating salmonid angling exploitation rates from systems monitored by fish counters and their potential applications to

fisheries management in Ireland. In: *Sea Trout: Science & Management: Proceedings of the 2nd International Sea Trout Symposium*, (ed. Harris, G.), Matador, Leicestershire.
Molloy, S., Holland, C. & Poole, R. (1995). Metazoan parasite community structure in brown trout from two lakes in western Ireland. *Journal of Helminthology*, **69**, 237-242.

Nilsson, P. A. & Bronmark, C. (2000). Prey vulnerability to a gape-size limited predator: behavioural and morphological impacts on northern pike piscivory. *Oikos*, **88**, 539–546.

O'Briain, R., Coghlan, B., Shephard, S. & Kelly, F. (2019). River modification reduces climate resilience of brown trout (*Salmo trutta)* populations in Ireland. *Fisheries Management & Ecol*ogy, **26**, 512– 526.
O'Grady, M.F. (1983). Observations on the dietary habits of wild and stocked brown trout, *Salmo trutta* L., in Irish lakes. *Journal of Fish Biology*, **22**, 593-601.

O'Grady, M.F. (1984). The Effects of Fin-Clipping, Floy-Tagging and Fin-Damage on the Survival and Growth of Brown Trout (*Salmo trutta* L) Stocked in Irish Lakes. *Aquaculture Research*, **15**, 49-58.

Schulz, U. and Berg, R. (1992). Movements of ultrasonically tagged brown trout (*Sulmo trutta* L.) in Lake Constance. *Journal of Fish Biology*, **40**, 909-917.

Shephard, S., Delanty, K., O'Grady, M. & Kelly, F. (2019). Salmonid Conservation in an Invaded Lake: Changing Outcomes of Predator Removal with Introduction of Nonnative Prey. *Transactions of the American Fisheries Society*, **148**, 219-231.

Thorpe, J.E. (1974). The movements of brown trout, *Salmo trutta* (L.) in Loch Leven, Kinross, Scotland. *Journal of Fish Biology*, **6**, 153-180.

Went, A.E.J. (1979). 'Ferox' trout, *Salmo trutta* L. of Loughs Mask and Corrib. *Journal of Fish Biology*, **15**, 255-262.

Wilson, A., Binder, T., McGrath, K., Cooke, S. & Godin J. (2011). Capture technique and fish personality: angling targets timid bluegill sunfish, *Lepomis macrochirus*. *Canadian Journal of Fisheries & Aquatic Science*, **68**, 749–57.

Wysujack, K., Greenberg, L.A., Bergman, E. & Olsson, I.C. (2009). The role of the environment in partial migration: food availability affects the adoption of a migratory tactic in brown trout *Salmo trutta*. *Ecology of Freshwater Fish*, **18**, 52-59.