Article (refereed) - postprint

Winfield, Ian J.; Berry, Richard; Iddon, Henry. 2019. **The cultural importance and international recognition of the Arctic charr *Salvelinus alpinus* populations of Windermere, UK.**

# The cultural importance and international recognition of the Arctic charr *Salvelinus alpinus* populations of Windermere, UK

Winfield, Ian J. [1] *, Berry, Richard [2] & Iddon, Henry [3]

* Author for correspondence

[1] Lake Ecosystems Group, Centre for Ecology & Hydrology, Lancaster Environment Centre, Library Avenue, Bailrigg, Lancaster LA1 4AP, U.K. (e-mail ijw@ceh.ac.uk)

[2] Richard Berry Film & Photography, Kendal, Cumbria, UK

[3] Henry Iddon Photography, Thornton-Cleveleys, Lancashire, UK

## Abstract

The Arctic charr *Salvelinus alpinus* populations of Windermere, England's largest natural lake in the Lake District of north-west England, have been studied since the 1940s. However, the species' cultural importance has a much longer history and these populations have been fished since 1223. As early as 1660, Arctic charr were exploited in a high-profile commercial net fishery and greatly enjoyed by locals and in a 'potted' form by wealthier members of UK society. However, overfishing led to substantially decreased catches and commercial netting was stopped in 1921. Local fishing for

Arctic charr persists to the present as a small recreational plumb-line fishery using artificial lures. These fishing activities and resulting catches have long held great cultural interest for the local community and visiting national and international tourists. The cultural importance of the Arctic charr populations of Windermere has recently been the subject of national media interest that culminated in a 2017 documentary film highlighting environmental issues facing the Arctic charr and also celebrating the role of this iconic species in the cultural life of Windermere. In addition, international recognition of the Arctic charr populations of Windermere also contributed to the Lake District becoming a UNESCO World Heritage Site in 2017.

**Key words**

conservation; ecosystem services; environmental management; fisheries; overfishing; public profile

**Acknowledgements**

We thank many CEH colleagues including Janice Fletcher and Ben James for their work in the field and laboratory over recent decades within numerous scientific projects which have advanced our understanding, management and appreciation of the Arctic charr populations of Windermere. Graeme McKee of the Environment Agency and the Arctic charr anglers of Windermere have also made substantial contributions through their operation of the Windermere Arctic Charr Anglers' Log Book Scheme and we thank them for allowing us to use their data. Liz Davey of the Environment Agency kindly provided useful information in relation to Windermere Reflections. We are also grateful to the Freshwater Biological Association for their joint stewardship of the Windermere long-term data sets and to Carol Davies, Rachel Roberts and Brian Fell of Kendal Museum, Museum of

Lakeland Life & Industry and Brian Fell Sculpture & Metalwork, respectively, for helping us into the world of cultural importance and recognition. Finally, we thank Steven Barber for his kind permission to use his photograph of the magnificent Arctic charr sculpture at Ambleside. Components of the research and other activities underpinning this story were funded by Environment Agency, Lake District National Park Authority, Natural England, Natural Environment Research Council, United Utilities and Wildsmith Hotels.

## Introduction

The Arctic charr *Salvelinus alpinus* (Linnaeus, 1758) is one of the most widely researched fish species in the world (Klemetsen, this volume), with much of this long and detailed study being driven ultimately by the cultural importance of this highly edible salmonid for the many human communities with which it shares extensive circumpolar northern habitats. These communities include some in the UK, where the Arctic charr is relatively widespread in Scotland but extremely restricted in distribution in England, Northern Ireland and Wales. In England, all native populations are restricted to the Lake District where they persist in just eight lakes including Windermere (Maitland et al., 2007; Ferguson et al., in press). Given this relatively limited national distribution and a range of environmental threats facing the species, the Arctic charr is listed as a UK Biodiversity Action Plan Priority Species which affords its populations some degree of protection from direct and indirect impacts. Nevertheless, the Arctic charr is also fished recreationally with a low intensity in a small number of UK water bodies (Winfield, 2016).

The lake of Windermere in the Lake District National Park of north-west England (Fig. 1) provides a range of ecosystem services to approximately 17,500 individuals resident in its local communities

and to many of the approximately 16M national and international tourists that visit this National Park each year (Clarke & Anteric, 2014). Nevertheless, like many temperate lakes around the world, Windermere also faces significant pressures from eutrophication, climate change, sedimentation, and species introductions (Maberly & Elliott, 2012). Harnessing such cultural importance to deliver improved environmental management was recently a major driving philosophy behind Windermere Reflections, a GBP1.7M Landscape Partnership Scheme funded by the UK Heritage Lottery Fund running from 2010 to 2014. This ambitious project sought to conserve and enhance the Windermere catchment by both direct, practical, short-term interventions, and by promoting longer-term attitudinal and behavioural changes in residents, businesses and visitors, encouraging engagement and a sense of responsibility through interpretation, education and training (Clarke & Anteric, 2014). The Arctic charr played an important role throughout this innovative project by offering an excellent and highly relatable example of the ways in which environmental threats can impact lake ecosystems. Consequently, 'Albert the Arctic charr' played a visible role in promotional literature and other activities used during the lifetime of Windermere Reflections that still persists in the form of two cameo appearances illustrating effects of eutrophication and sedimentation within the entertaining and educational 'Windermere Song' (www.youtube.com/watch?v=X_VAMHJjQJU, accessed 11 June 2018).

From a global perspective, the fundamental and applied scientific literature on members of the *Salvelinus* genus is immense in terms of both historical duration and volume as considered by Klemetsen (this volume). However, specific considerations of the interactions of such fishes with human societies are remarkably rare. It is now over 30 years since Johnson (1984) provided a novel philosophical perspective on such interactions, but the vast majority of subsequent *Salvelinus* studies have remained firmly focussed on either fundamental biology and ecology or fisheries management. The persistence of this approach is despite an increasing need for scientists to

96 communicate their findings to wider society and to demonstrate their tangible benefits (Winfield,
97 2010; Kuehne & Olden, 2015). In contrast, many of the recent activities at Windermere described
98 above have embraced a more society-orientated approach and here we present an overview of the
99 cultural importance of the Arctic charr populations of this iconic lake and the ways in which they
100 have recently contributed to its management and international recognition. Before these wider
101 issues are covered, however, it is appropriate first to review briefly the considerable scientific
102 studies of the Arctic charr populations of this lake.

103

104 **Scientific studies**

105

106 Windermere has been subjected to over 75 years of continuous scientific study, with much of the
107 ecosystem aspects of this work up to 2012 being described by Maberly & Elliott (2012). In terms of
108 the lake's fish populations, work on Arctic charr by Winifred E. Frost undertaken from the 1950s to
109 the 1980s has been widely and repeatedly recognised as ground-breaking by authors from around
110 the world (e.g. Klemetsen, 2010). The present review purposefully does not cover all of Frost's work
111 because it has already been reviewed in detail by Baroudy (1995). However, it is appropriate to
112 emphasise here that Frost's work on Arctic charr spawning grounds, spring- and autumn-spawning
113 biology, and the existence of races or sub-populations as exemplified by Frost (1965) has both
114 advanced fundamental biological understanding and simultaneously informed local conservation
115 management of this iconic species.

116

117 Since Frost's prolific studies, research has continued on the fundamental biology and ecology of
118 Arctic charr in Windermere, exemplified by Mills (1989), Mills & Hurley (1990), and Elliott & Baroudy
119 (1995). However, partly in response to the local cultural importance of Arctic charr, numerous more

applied studies have also been undertaken in response to the observed eutrophication of Windermere, which has been evident in both of its north and south basins but more marked in the latter. Le Cren et al. (1972) reported an early examination of the effects of exploitation and eutrophication on the salmonid community of the lake, while Mills et al. (1990) developed this theme with specific reference to its Arctic charr populations. Subsequently, Jones et al. (2008) used detailed long-term dissolved oxygen and hydroacoustic survey data to examine eutrophication impacts on habitat availability for Arctic charr, while Winfield et al. (2008) expanded their treatment of environmental threats to this species to include climate change and fish species introductions. More recently, Winfield et al. (2015) returned to one of the original topics of Frost (1965) and used a novel hydroacoustics system to quantify and assess the condition of Arctic charr spawning grounds in the lake's two basins.

Finally, in terms of advances in applied science that have been made from research at Windermere, an exhaustive and semi-popular account of the restoration of Windermere provided by Pickering (2001) included specific sections on Arctic charr in the initial description of the lake's ecology and within chapters on historic deterioration of water quality and its restoration. Such incidences attest to both this species' value as an indicator species and to its local cultural importance.

**Fisheries**

The island nature of the UK has given this geographical area a long history of commercial marine fisheries. In contrast, its abundant fresh waters support very few commercial fisheries, although they do provide extensive recreational opportunities (Winfield, 2016). Windermere is a notable exception to this scant history of freshwater commercial fisheries, possibly as a result of the

combination of this lake's large size and its once relative geographical isolation from major sea fishing ports.

Kipling (1973) described 113 commercial netting sites used historically on Windermere, but the lake's commercial fisheries were most extensively documented by Kipling (1972). The latter noted that in addition to Arctic charr, fisheries also existed for brown trout *Salmo trutta* Linnaeus, 1758, European eel *Anguilla Anguilla* (Linnaeus, 1758), perch *Perca fluviatilis* Linnaeus, 1758, pike *Esox lucius* Linnaeus, 1758 and migratory Atlantic salmon *Salmo salar* Linnaeus, 1758. The first written mention of the fisheries of Windermere was in a court case of 1223 between William de Lancaster 4th Baron of Kendal and the Abbot of Furness as reported in Curia Regis Rolls (1955). Historically, the main fishing technique for Arctic charr was seine nets operating within commercial fisheries. Apparently, little or no historical recreational fishing targeted Arctic charr on Windermere, although the famous angler Izaak Walton wondered about the species' sporting potential in his classic recreational fishing book *The Compleat Angler* first published in 1653 (Walton & Cotton, 2008). A full historical record of commercial catches is unavailable, but Kipling (1972) indicated that the amount of Arctic charr caught became unsustainable in the middle of the 19th century, with temporarily disastrous results. This precipitous decline came at a time when trade in this species was flourishing and both the local population and the tourist trade were increasing. Restrictions on the most efficient fishing methods were swiftly imposed by the lake's proprietors. Soon afterwards, and as the result of a Royal Commission addressing concerns over national fisheries issues, Boards of Conservators were established for fishery districts in 1865, and at Windermere the policy from 1880 onwards was to rent all net fisheries with a view to closing them down. Watson (1899) cited Nicholson & Burn (1777), who noted the existence and importance of the Arctic charr fishery on Windermere and even commented that the lake contains three sorts of 'chars'. Watson (1899) also cited a Mr Berrington's Report on Salmon and Freshwater Fisheries in 1890, which stated that recent

protective measures for Arctic charr in Windermere had borne excellent results. By 1915, the Board of Conservators responsible for Windermere had amassed complete control over netting activities and the last commercial netting took place in 1921.

As the above commercial netting story was unfolding, in 1840 a Mr Spencer from Manchester first introduced to Windermere a way of fishing for Arctic charr from a row boat using a plumb-line technique involving a small number of artificial lures deployed by a purpose-built rod, or more usually by a pair of rods (Day, 1887). This technique persists today virtually unchanged as the sole means by which Arctic charr are fished in Windermere, where this practice is undertaken by a few tens of anglers as a recreational fishery (Fig. 2). The fishery is now regulated by the Environment Agency with a fishing season running from 15 March to 30 September and a minimum takeable size of 200 mm, with no other restrictions on the catch or effort of this very small-scale fishery (Environment Agency, 2009). Further details of this unusual fishery may be found online (www.fishingmuseum.org.uk, accessed 11 June 2018).

Variations in catch-per-unit-effort (CPUE) recorded by two Windermere Arctic charr anglers over the period 1966 to 1991 were found by Elliott & Baroudy (1992) to agree with corresponding variations in CPUE of non-destructive gill nets operated on a north basin spawning ground over the same or similar periods as far as data availability permitted. Subsequently, Winfield et al. (2008) showed that these agreements persisted from 1990 to 2005 with an angler catch dataset that had been expanded from 2004 onwards to include catches of additional anglers recorded under the Environment Agency's Windermere Arctic Charr Anglers' Log Book Scheme, which persists to the present as the best monitoring metric for Arctic charr populations of the lake's north and south basins (Fig. 3). Unfortunately, this metric also reveals a declining trend of CPUE in both basins, with the decline in the more-eutrophicated south basin being particularly severe.

194

195 **Cultural importance and international recognition**

196

197 The historical cultural importance of the Arctic charr populations of Windermere has already been
198 alluded to above in their context of historically supporting commercial fisheries for this valued
199 species, i.e. in providing an important provisioning ecosystem service. In addition, mention of this
200 species in Izaac Walton's original 1653 edition of his classic recreational fishing book *The Compleat*
201 *Angler* suggests that the sporting value of Arctic charr may also have been appreciated as long ago
202 as several hundred years (Walton & Cotton, 2008). Similarly, in his account of his extensive travels
203 through Great Britain, the literary writer Daniel Defoe noted that the Arctic charr of Windermere
204 had a reputation not simply as a basic food fish, but as a dainty (or delicacy) that was traded near
205 and far as a gift (Defoe, 1727). Writing somewhat later, Watson (1899) also noted the high regard in
206 which the Arctic charr was held by the local community, which was such that for a short period a
207 small private hatchery was operated for this species on the banks of Windermere and as many as
208 180,000 fry were introduced to the lake each year.

209

210 In more recent decades, the Arctic charr populations of Windermere have enjoyed a consistently
211 high profile in a range of popular or semi-popular books or articles on the lake or its surrounding
212 areas such as those by Palmer (1945) and Frost (1989). Part of this persistent attraction stems from
213 the species' high culinary value, with a notable recent resurgence in the context of so-called 'slow
214 food' that is produced or prepared following local culinary traditions and usually uses high-quality,
215 locally sourced ingredients. For example, the Arctic charr is featured on the website of 'Slow Food in
216 the UK' (www.slowfood.org.uk, accessed 11 June 2018). The species also continues to feature in
217 exhibits of the local Kendal Museum and the Museum of Lakeland Life & Industry in the contexts of

218 natural history (with the species' renowned morphological plasticity amongst an angler's catches
219 evident and recognised as long ago as 1914) and fisheries, respectively. In addition, a small
220 exhibition of Arctic charr fishing tackle is planned for the Windermere Jetty Museum of Boats, Steam
221 and Stories (www.windermerejetty.org, accessed 11 June 2018), which will open soon on the lake's
222 shore (Rachel Roberts, Museum of Lakeland Life & Industry, *pers. comm.*).

223

224 The contemporary cultural importance of the Arctic charr populations of Windermere was also
225 prominent in a recent exploration and documentation of the current condition of the lake in an
226 historical context within the Clear Waters Project conducted by the Freshwater Biological
227 Association (Davy-Bowker, 2015). This volunteer-based oral history project focussed on
228 Windermere with the help of volunteers and research materials provided by the Centre for Ecology
229 & Hydrology, Kendal Oral History Group, University of Cumbria, and Wordsworth Trust. Specifically,
230 38 interviewees recalled socio-economic, climatic, and ecological changes that they had observed at
231 the lake over recent decades. The project reported on 21 May 2014, with transcripts of its
232 interviews subsequently archived and available on registration at the website of the Ambleside Oral
233 History Archive (www.aohg.org.uk, accessed 11 June 2018). The acknowledged cultural importance
234 of this work was such that a well-attended mobile exhibition then visited a number of venues
235 including the Aquarium of the Lakes, Cumbria County Council, Lakeland Arts Trust, and Lancaster
236 Maritime Museum. Similarly, a range of evening talks and other publicity was disseminated through
237 the Freshwater Biological Association, Lakeland Arts Trust, Newsletters, South Cumbria Rivers Trust,
238 and Windermere Reflections.

239

240 In the present context, 19 interviewees (50%) of the Clear Waters Proje*ct* specifically referred to
241 Arctic charr, or char as the species is frequently also known locally. Moreover, interviewees
242 demonstrated a familiarity with basic features of Arctic charr ecology, such as individuals

243 frequenting deeper areas of the lake and moving deeper when the weather is hot and sunny,
244 together with an appreciation of observable differences between Arctic charr from the lake's north
245 and south basins. Interviewees were also well aware of the history of the local Arctic charr fishery,
246 including that its high-value product was usually sold locally in butchers rather than fishmongers and
247 that its lucrative potting operations facilitated transport further afield to London and elsewhere.
248 Many interviewees were also well aware of the fishery's demise from a peak in Victorian times and
249 the relative rarity of contemporary fishing activities for this remarkable species.

250

251 In addition to the above demonstrable local cultural importance of the Arctic charr populations of
252 Windermere, these fish recently also received international recognition when the Lake District was
253 listed as a UNESCO World Heritage Site on 9 July 2017 (Lake District National Park Partnership,
254 2016). This listing was made in the category of Cultural Landscape, reflecting the area's identity as a
255 dramatic farmed landscape, the inspiration that it has given to art, literature and love of place, and
256 its pivotal early role in the nature conservation movement of the UK. The nomination case also
257 made specific reference to the area's populations of Arctic charr, and incidentally also to two other
258 rare fish species, vendace *Coregonus albula* (Linnaeus, 1758) and European whitefish *Coregonus*
259 *lavaretus* (Linnaeus, 1758), known locally as schelly.

260

261 This listing of the Lake District as a UNESCO World Heritage Site will undoubtedly elevate the area's
262 international recognition, potentially boosting tourism and thus delivering benefits to local
263 communities and businesses as a direct result. An associated programme of celebration with the
264 Social Media hashtag #WeAreTheLakes has been developed and contains two components directly
265 related to the Arctic charr populations of Windermere. Firstly, as part of the Lakes Ignite Festival a
266 large metal sculpture of a group of larger-than-life Arctic charr (Fig. 4) was installed in a high profile
267 location in the town of Ambleside at the north end of Windermere, which will be seen by many of

the approximately 16M national and international tourists that visit the lake and its surrounding areas each year. Secondly, and again precipitated in large part by the Lake District's successful bid to become a UNESCO World Heritage Site, the 12-minute film 'Brass, Three Down' centred on the Arctic charr fishery of Windermere was made by two of the present authors. This film brings together environmental issues described earlier and also celebrates the role that the Arctic charr has played and continues to play in the cultural life of Windermere. This film premiered at the Kendal Mountain Festival in November 2017, where it attracted both regional and national media interest, and has subsequently been shown to a number of local natural history and other groups and is also accessible online (https://vimeo.com/241788130, accessed 11 June 2018). Although taking the fishery as its main theme, this film also considers wider environmental issues and documents an evident shift of Arctic charr from historically providing a purely provisioning ecosystem service to now providing a multi-faceted cultural ecosystem service.

**Closing remarks**

The Arctic charr populations of Windermere have been researched continuously for approximately 78 years, during which time major contributions have been made to fundamental scientific understanding. At the same time, well-documented changes have been observed in Arctic charr habitat and population abundance in response to a range of pressures including eutrophication, climate change, and species introductions. All of these pressures are currently being addressed through management informed by the improved scientific understanding. Although a poorly managed commercial fishery historically had a significant adverse impact on the Arctic charr populations, this was eventually and far-sightedly closed and fishing activities persist today only as a negligible-impact recreational activity.

The cultural importance of the Arctic charr populations of Windermere to its local communities has been evident since the 1200s through frequent and substantial references in the non-scientific literature, museum collections, and oral histories. This local importance is now recognised internationally through a specific mention of Arctic charr in the recent listing of the Lake District as a UNESCO World Heritage Site in 2017. This intervening period of over 800 years has also documented the shift of the Arctic charr populations of Windermere from historically providing a purely provisioning ecosystem service in the form of food for local and distant human populations, to now providing a range of cultural ecosystem services encompassing cultural, spiritual, historical, recreational, and educational dimensions. Given the extensive geographical distribution of Arctic charr and closely related species, the specific case history presented here provided by the Windermere populations is likely to have relevance and application to the management and societal importance of these remarkable fishes in many other locations around the globe.

**References**

Baroudy, E. 1995. Arctic charr (*Salvelinus alpinus*) in Windermere (Cumbria). Freshwater Forum 5: 185-192.

Clarke, R. & M. Anteric. 2014. Final evaluation of the Windermere Reflections Landscape Partnership. Report by University of London Centre for European Protected Area Research to Heritage Lottery Fund.

315 Curia Regis Rolls. 1955. Curia Regis Rolls of the reign of Henry III, preserved in the Public Record
316 Office. HMSO, London.

317

318 Davy-Bowker, J. 2015. Report of Activities from the Acting Director/Chief Executive/Director.
319 Eighty-Third Annual Report of the Freshwater Biological Association. Freshwater Biological
320 Association, Ambleside.

321

322 Day, F. 1887. British and Irish Salmonidae. London & Edinburgh.

323

324 Defoe, D. 1727. A Tour Thro' The Whole Island of Great Britain. Vol. III.

325

326 Elliott, J. M. & E. Baroudy. 1992. Long-term and short-term fluctuations in the numbers and catches
327 of Arctic charr, *Salvelinus alpinus* (L.), in Windermere (northwest England). Annales de Limnologie
328 28: 135-146.

329

330 Elliott, J. M. & E. Baroudy. 1995. The ecology of Arctic charr, *Salvelinus alpinus*, and brown trout,
331 *Salmo trutta*, in Windermere (northwest England). Nordic Journal of Freshwater Research 71: 33-
332 48.

333

334 Environment Agency. 2009. North West Fisheries Byelaws. Environment Agency, Warrington.

335

336 Ferguson, A., C. E. Adams, M. Jóhannsson, F. Kelly, R. A. King, P. S. Maitland, I. McCarthy, M.
337 O'Grady, P. A. Prodöhl, S. Skúlason, E. Verspoor & I. J Winfield. in press. Trout and Char of the North
338 Atlantic Isles. In Kershner, J. L., J. E. Williams, R. E. Gresswell, & J. Lobon-Cervia (eds), Diversity and
339 Status of Trouts and Chars of the World. American Fisheries Society, Bethesda.

340

341 Frost, W. E. 1965. Breeding habits of Windermere charr, *Salvelinus willughbii* (Gűnther), and their
342 bearing on speciation of these fish. Proceedings of the Royal Society of London. Series B, Biological
343 Sciences. 63: 232-284.

344

345 Frost, W. E. 1989. The fish. In Pearsall, W. H. & W. Pennington (eds), The Lake District. Collins New
346 Naturalist Series: 81-85.

347

348 Johnson, L. 1984. Charr and man: the philosophy of limited interaction. In Johnson, L. & B. L. Burns
349 (eds). Proceedings of the International Symposium on Arctic Charr, Winnipeg, Manitoba, May 1981.
350 University of Manitoba Press, Winnipeg: 523-586.

351

352 Jones, I. D., I. J. Winfield & F. Carse. 2008. Assessment of long-term changes in habitat availability
353 for Arctic charr (*Salvelinus alpinus*) in a temperate lake using oxygen profiles and hydroacoustic
354 surveys. Freshwater Biology 53: 393-402.

355

356 Klemetsen, A. this volume. 37 years of charr meetings. Hydrobiologia.

357

358 Kipling, C. 1972. The commercial fisheries of Windermere. Transactions of the Cumberland &
359 Westmorland Antiquarian & Archaeological Society LXXII: 156-204.

360

361 Kipling, C. 1973. The netting sites of Windermere. Transactions of the Cumberland & Westmorland
362 Antiquarian & Archaeological Society LXXIII: 111-119.

363

364 Klemetsen, A. 2010. The charr problem revisited: exceptional phenotypic plasticity promotes
365 ecological speciation in postglacial lakes. Freshwater Reviews 3: 49-74.

366

367 Kuehne, L. M. & J. D. Olden. 2015. Opiniion: Lay summaries needed to enhance science
368 communication. Proceedings of the National Academy of Sciences of the USA 112: 3585-3586.

369

370 Lake District National Park Partnership 2016. Nomination of The English Lake District for Inscription
371 on the World Heritage List. The Lake District National Park Partnership, Kendal.

372

373 Le Cren, E. D., C. Kipling & J. C. McCormack. 1972. Windermere: effects of Exploitation and
374 Eutrophication on the salmonid community. Journal of the Fisheries Research Board of Canada 29:
375 819-832.

376

377 Maberly, S. C. & J. A. Elliott. 2012. Insights from long-term studies in the Windermere catchment:
378 external stressors, internal interactions and the structure and function of lake ecosystems.
379 Freshwater Biology 57: 233-243.

Maitland, P. S., I. J. Winfield, I. D. McCarthy & F. Igoe. 2007. The status of Arctic charr *Salvelinus alpinus* in Britain and Ireland. Ecology of Freshwater Fish 16: 6-19.

Mills, C. A. 1989. The Windermere populations of Arctic charr, *Salvelinus alpinus*. Physiology and Ecology Japan Special Volume 1: 371-382.

Mills, C. A. & M. A. Hurley. 1990. Long-term studies on the Windermere populations of perch (*Perca fluviatilis*), pike (*Esox Lucius*) and Arctic charr (*Salvelinus alpinus*). Freshwater Biology 23: 119-136.

Mills, C. A., S. I. Heaney, C. Butterwick, J. E. Corry & J. M. Elliott. 1990. Lake enrichment and the status of Windermere charr, *Salvelinus alpinus* (L.). Journal of Fish Biology 37 (Supplement A): 167-174.

Palmer, W. T. 1945. The English Lakes. A & C Black, London.

Pickering, A. D. 2001. Windermere: Restoring the Health of England's Largest Lake. Freshwater Biological Association Special Publication No. 11, Ambleside.

Walton, I. & C. Cotton. 2008. The Compleat Angler. Oxford University Press, Oxford.

Watson, J. 1899. The English Lake District Fisheries. T N Foulis Ltd, London.

Winfield, I. J., J. M. Fletcher & J. B. James. 2008. The Arctic charr (*Salvelinus alpinus*) populations of Windermere, U.K.: population trends associated with eutrophication, climate change and increased abundance of roach (*Rutilus rutilus*). Environmental Biology of Fishes 83: 25-35.

Winfield, I. J. 2010. Meeting across the river: from science to impact. Aquatic Conservation: Marine and Freshwater Ecosystems 20: 607-610.

Winfield, I. J., J. van Rijn & R. D. Valley. 2015. Hydroacoustic quantification and assessment of spawning grounds of a lake salmonid in a eutrophicated water body. Ecological Informatics 30: 235-240.

Winfield, I. J. 2016. Recreational fisheries in the UK: natural capital, ecosystem services, threats and management. Fisheries Science 82: 203-212.

**Figure legends**

**Fig. 1** The north basin of Windermere, a large multi-use lake within the Lake District UNESCO World Heritage Site which provides a range of ecosystem services to local communities and visiting national and international tourists. Photograph copyright Ian J. Winfield

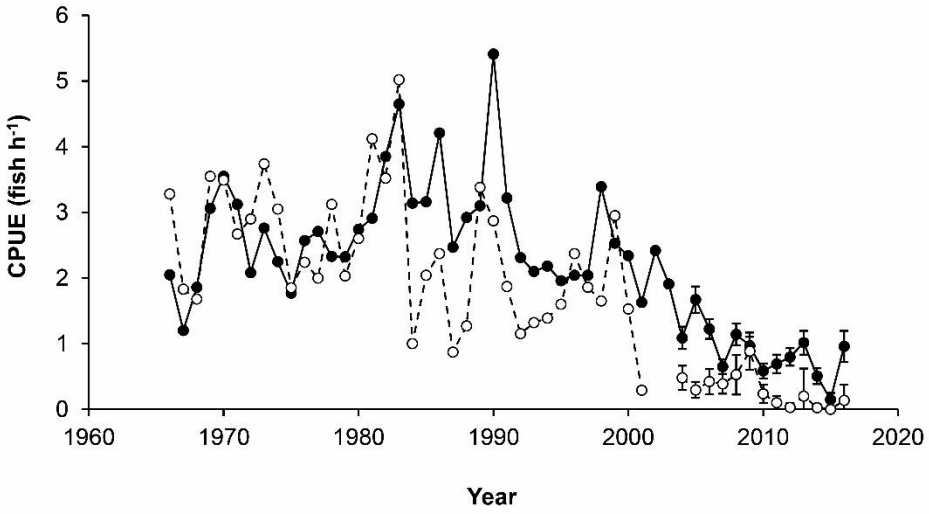
**Fig. 2** A recreational angler fishing for Arctic charr on Windermere using a traditional plumb-line technique. Photograph copyright Henry Iddon

**Fig. 3** Catch-per-unit effort (CPUE, expressed as number of fish angler$^{-1}$ h$^{-1}$) of the Arctic charr fisheries of the north (closed symbols, solid line) and south (open symbols, broken line) basins from 1966 to 2016. No data are available for the south basin in 2002 and 2003, while data points for 2004 and onwards are presented as means ±95% confidence limits.

**Fig. 4** Sculptors Brian (right) and George (left) Fell with their metal sculpture of Arctic charr installed as part of the Lakes Ignite Festival in a high profile public space in Ambleside at the north end of Windermere. Photograph copyright Steven Barber.

435

436




437

438