



## Conservation of the vendace (*Coregonus albula*), the U.K.'s rarest freshwater fish

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with 3 figures

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**Abstract:** Although also formerly present in two lochs in South West Scotland, populations of vendace (*Coregonus albula*) were until recently believed to persist in only two U.K. lakes, i.e., Bassenthwaite Lake and Derwent Water in North West England. However, although Derwent Water has retained its natural mesotrophic conditions and the status of its vendace population is acceptable, monitoring at Bassenthwaite Lake has failed to record any specimens since 2000 and the species has recently been declared locally extinct. Bassenthwaite Lake has experienced increasing problems from eutrophication, sedimentation and the introduction of fish species including roach (*Rutilus rutilus*) and ruffe (*Gymnocephalus cernuus*), both of which have more recently also been introduced to Derwent Water and give concern over possible food competition and egg predation. In addition to monitoring, considerable efforts have been made in recent years to conserve vendace through the protection and improvement of their habitats and the establishment of refuge populations. The latter has resulted in the establishment of a population originating from Bassenthwaite Lake in Loch Skeen of South West Scotland, with further attempts still in progress at two other sites. Public awareness of the conservation of this species, which is the U.K.'s rarest freshwater fish, has also been actively promoted.

**Keywords:** eutrophication, sedimentation, species introductions, monitoring, habitat management, translocation, public awareness, Bassenthwaite Lake, Derwent Water, Loch Skeen.

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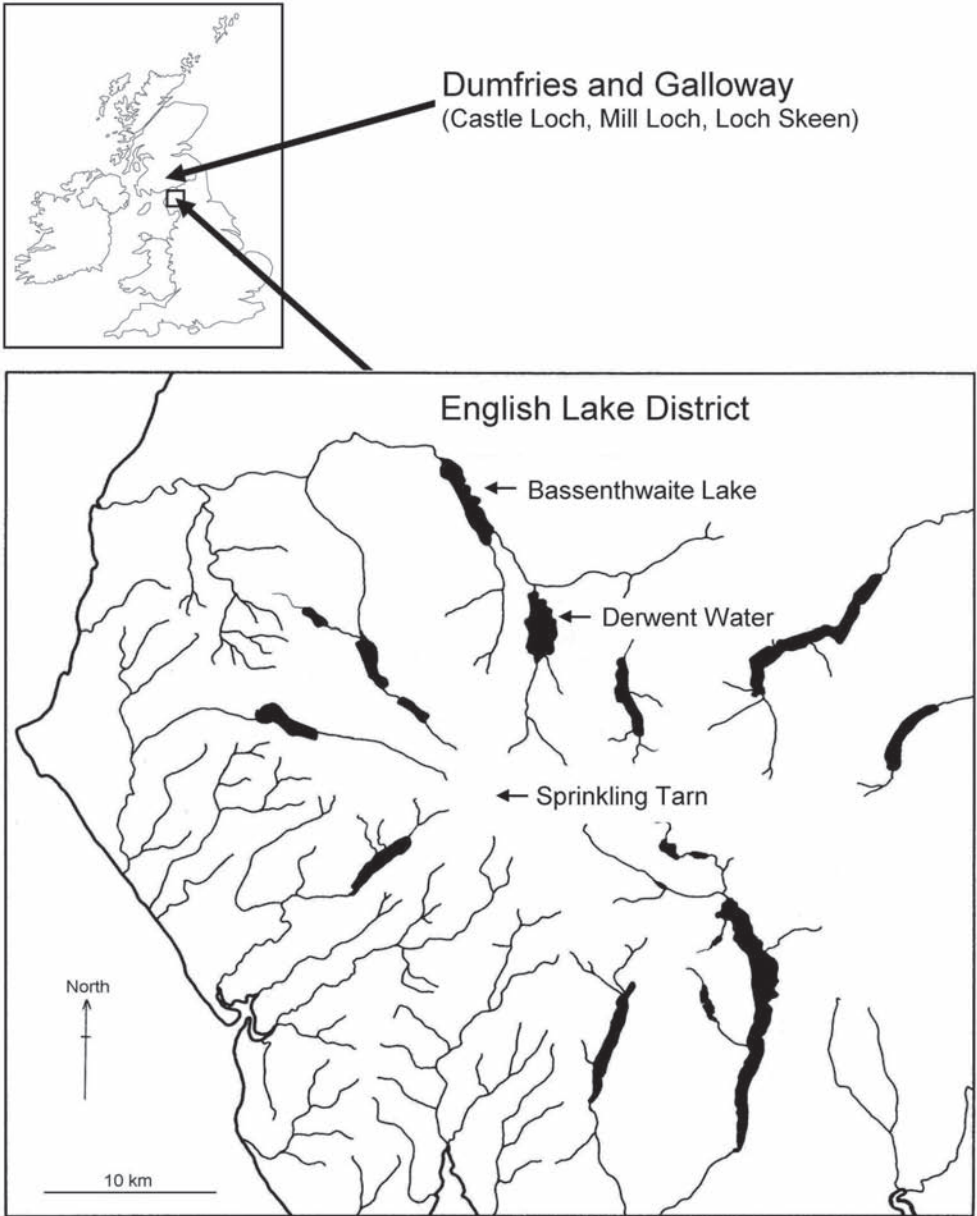
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## Introduction

The vendace (*Coregonus albula*) is a medium-sized and typically lacustrine coregonid of northern Europe, where it is extensively exploited in commercial fisheries (e.g., SALONEN 1998, NYBERG et al. 2001). In common with many other members of the genus *Coregonus*, this species has essential habitat requirements of relatively low water temperatures (e.g., HAMRIN 1986, LUCZYNSKI 1991), high concentrations of dissolved oxygen (e.g., DEMBINSKI 1971, CZERKIES et al. 2002), and spawning areas with no overlying fine sediments (e.g., WILKONSKA & ZUROMSKA 1982, HAKKARI & BAGGE 1992). In addition, vendace feed extensively on zooplankton throughout their life cycle and the availability of this prey is a common driver of what are typically highly variable population dynamics (e.g., SANDLUND et al. 1991, AUVINEN 1995).

In the United Kingdom (U.K.), the vendace has not been commercially exploited since the start of the twentieth century (MAITLAND 2007), but it is nevertheless currently protected under national nature conservation legislation and appears on the U.K. List of Priority Species and Habitats of the U.K. Biodiversity Action Plan ([www.ukbap.org.uk](http://www.ukbap.org.uk)). This protection is afforded because vendace populations have historically been recorded from only four U.K. lakes. Two of these populations, in Castle Loch and Mill Loch in Dumfries and Galloway in South West Scotland (Fig. 1), have been extinct since the 1910s and the 1970s, respectively (MAITLAND 2007), leaving just two remaining populations in Bassenthwaite Lake and Derwent Water of the English Lake District in North West England (Fig. 1). The biology of these surviving populations was studied in detail in the early 1990s by WINFIELD et al. (1996), with WINFIELD et al. (2004) summarising both limited earlier studies and the results of a subsequent monitoring programme up to 2001. WINFIELD et al. (2004) also identified climate change, eutrophication, sedimentation, and species introductions as significant threats to the local survival of the vendace. Using enzyme electrophoresis, BEAUMONT et al. (1995) were unable to detect significant genetic differences between vendace from Bassenthwaite Lake and Derwent Water, but recommended further studies using nuclear or mitochondrial DNA markers to support future management decisions for these populations. Such analyses were subsequently undertaken by THOMPSON et al. (2008) and did indeed find significant genetic variation between the populations.

Following the ecological review of WINFIELD et al. (2004), the objectives of this paper are to report more recent findings of the vendace monitoring programmes in Bassenthwaite Lake and Derwent Water, and to describe conservation measures currently in progress for this species in the U.K. in terms of habitat measures, refuge populations and public awareness. Although the threat of climate change to the local survival of the vendace has been explored recently by modelling the effects of variations in weather (GEORGE et al. 2006) and regional climate change (ELLIOTT et al. 2005, ELLIOTT & BELL 2011), this issue will not be addressed here.



**Fig. 1.** Locations of Dumfries and Galloway (containing Castle Loch, Mill Loch and Loch Skeen) and the English Lake District (containing Bassenthwaite Lake, Derwent Water and Sprinkling Tarn) in the U.K. Note that Sprinkling Tarn is not visible at the scale of the figure. Partly redrawn with permission from RAMSBOTTOM (1976).

## Monitoring and current status

### Monitoring vendace in the U.K.

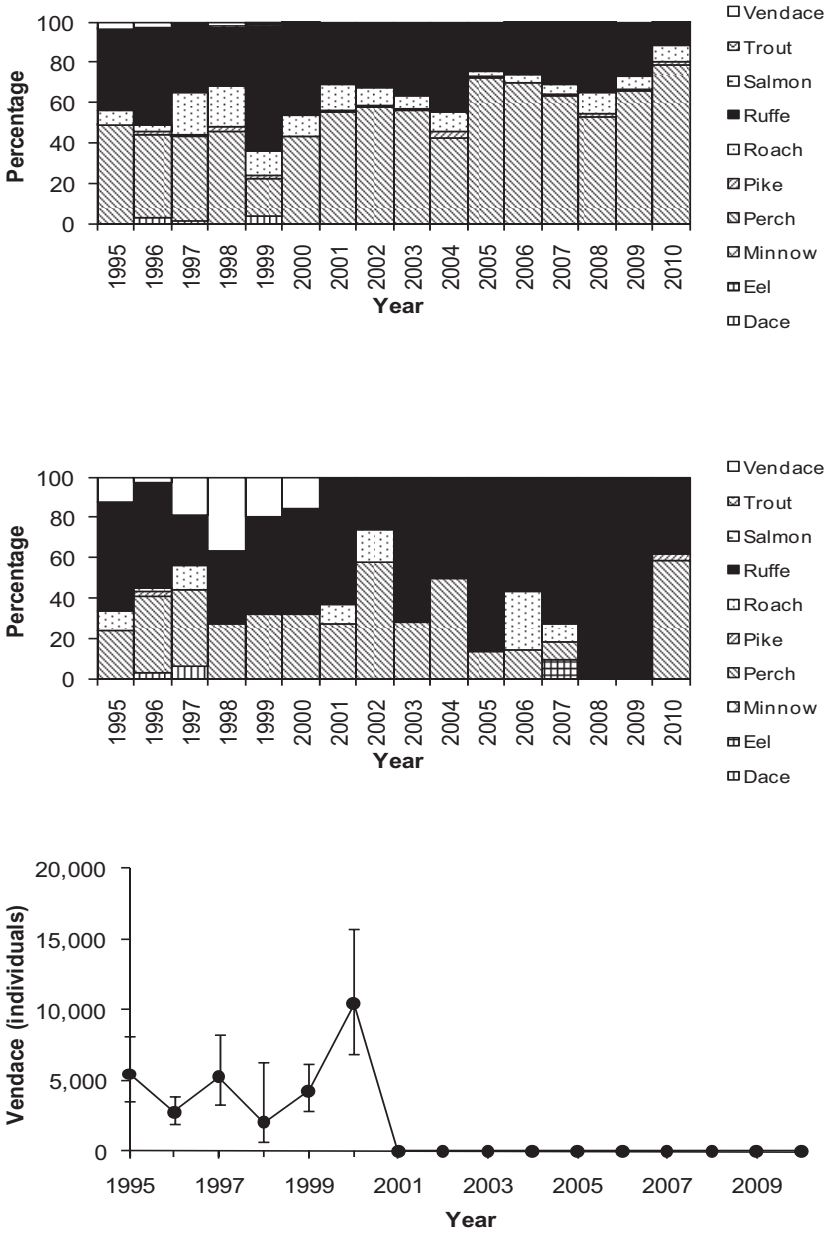
Many vendace populations in Europe are routinely monitored at least in part by the examination of commercial fisheries catches. However, in the U.K. this is not an option for the remaining English populations because they never have been fished commercially. Consequently, since the 1990s, the vendace of Bassenthwaite Lake and Derwent Water, and the other components of the local fish communities including introduced roach (*Rutilus rutilus*), ruffe (*Gymnocephalus cernuus*), and common dace (*Leuciscus leuciscus*) (WINFIELD et al. 2002, WINFIELD et al. 2007), have been monitored by a combination of survey gillnetting and hydroacoustics as reviewed in limited detail by WINFIELD et al. (2004) and given in full detail by WINFIELD et al. (2010).

### Vendace in Bassenthwaite Lake

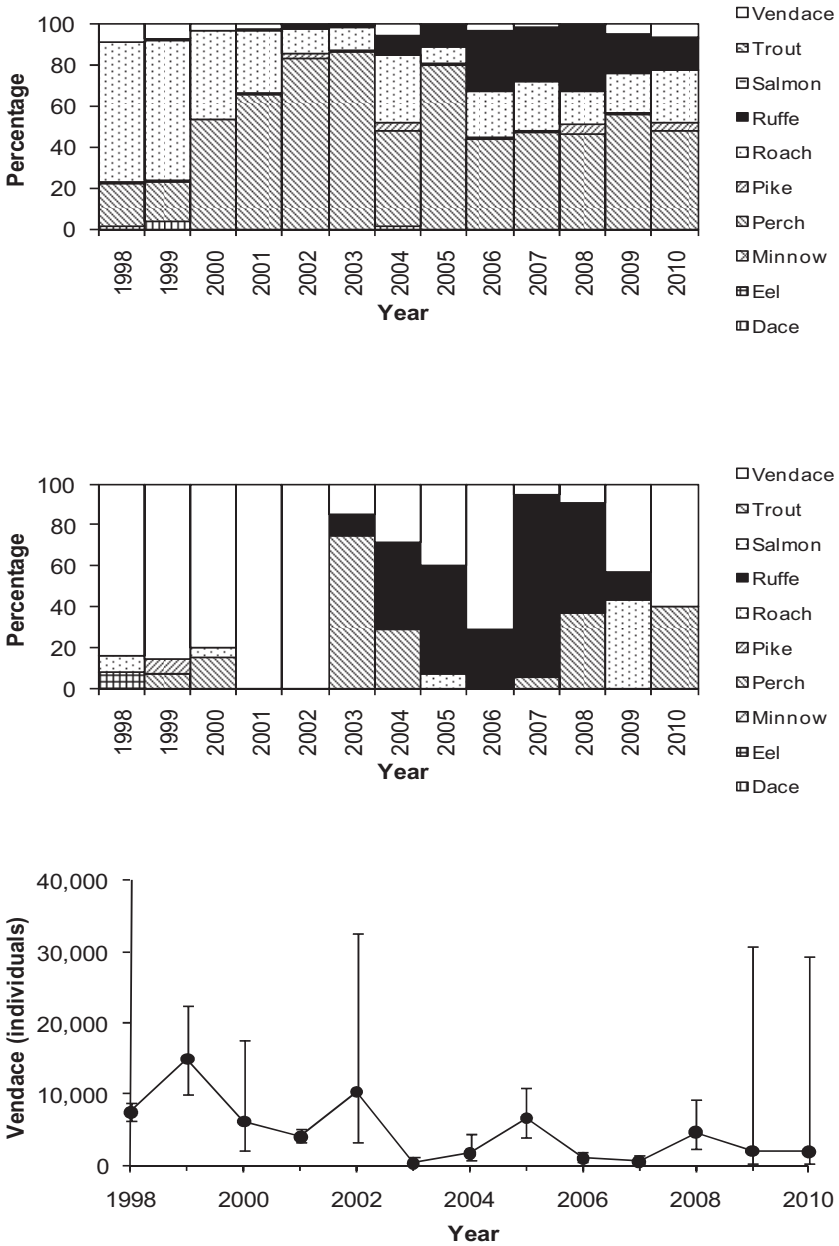
Collating information from previous studies, WINFIELD et al. (2004) concluded that in terms of population characteristics of abundance and age/size diversity typically shown by the species, the status of the vendace population of Bassenthwaite Lake had deteriorated from good in the 1960s and early 1970s to poor by the late 1980s. This situation persisted into the early 1990s, but based on results of the recent monitoring programme that started in 1995, a further decline subsequently occurred. No vendace have been captured within this monitoring programme since 2000 (Fig. 2), although a very few individuals were caught in an unsuccessful egg collection exercise in 2001 (see below). It is notable that even though vendace population estimates produced by total fish abundance recorded by hydroacoustics being apportioned to vendace using gillnetting data (WINFIELD et al., 2010) ranged between approximately 2,000 and 10,000 individuals from 1995 to 2000 (Fig. 2), this species was even then only a minor component of the total fish community in which introduced roach, ruffe and common dace have together comprised between 27% and 78% of all fish, with native Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), European eel (*Anguilla anguilla*), Eurasian minnow (*Phoxinus phoxinus*), northern pike (*Esox lucius*), and European perch (*Perca fluviatilis*) also present. The deep-water (approximately 20 m depth) fish community, where the vendace used to occur exclusively outside the spawning season, has become increasingly dominated by ruffe, which was the only species recorded in this location in 2008 and 2009. Extensive searches for vendace outside the monitoring programme in 2007/2008 failed to find a single specimen and the species has now been declared locally extinct (WINFIELD et al. 2008).

### Vendace in Derwent Water

In contrast to the deteriorating situation at Bassenthwaite Lake, WINFIELD et al. (2004) concluded that the status of the vendace population of Derwent Water, again defined with respect to population characteristics of abundance and age/size diversity typically shown by the species, had been consistently good from the 1960s to the early 2000s. Vendace have been con-



**Fig. 2.** Species composition by numbers of the total (upper figure) and deep-water (middle figure) fish communities (total sample size 5,924 individuals), and the abundance of vendace (lower figure, geometric means with 95% confidence limits) at Bassenthwaite Lake from 1995 to 2010. Note that for clarity within the figure, the six species Atlantic salmon, brown trout, common dace, European eel, European perch and northern pike are referred to by their short common names.



**Fig. 3.** Species composition by numbers of the total (upper figure) and deep-water (middle figure) fish communities (total sample size 2,974 individuals), and the abundance of vendace (lower figure, geometric means with 95% confidence limits) at Derwent Water from 1998 to 2010. Note that for clarity within the figure, the six species Atlantic salmon, brown trout, common dace, European eel, European perch and northern pike are referred to by their short common names.

sistently recorded in the monitoring programme instituted from 1998 onwards (Fig. 3) and this species has continued frequently to dominate the deep-water (approximately 20 m depth) fish community (Fig. 3). Nevertheless, the vendace is only a minor component of the total fish community in this lake, within which introduced roach, ruffe, and common dace have together comprised between 12% and 72% of all fish, with native Atlantic salmon, brown trout, European eel, Eurasian minnow, northern pike and European perch also present. It is notable that, as at Bassenthwaite Lake, introduced ruffe have generally become increasingly abundant in the deep-water fish community in recent years. Vendace population estimates, again produced by total fish abundance recorded by hydroacoustics being apportioned to vendace using gillnetting data (WINFIELD *et al.*, 2010), have ranged between approximately 250 and 15,000 individuals with an apparent 3-year cycle in abundance (Fig. 3). The current status of the vendace in Derwent Water is thus considered to be acceptable, although there is some suggestion of a gradual decline in abundance overlaying the apparent 3-year cycle.

## Conservation action

### Habitat measures at Bassenthwaite Lake

The high scientific interest and conservation value of Bassenthwaite Lake have been recognised for many years, resulting in it being given national designations as a Site of Special Scientific Interest, a National Nature Reserve, and a component of a Special Area of Conservation. All of these designations should in theory bring some measure of environmental protection, but as noted above, in reality the lake has suffered significant eutrophication in recent decades. This process has primarily been caused by nutrient inputs, particularly of phosphorus, due to the lake being downstream of the town of Keswick (MAY *et al.* 2001). Bassenthwaite Lake is also designated as a Sensitive Water under the European Union Urban Wastewater Treatment Directive (EUROPEAN COMMUNITIES 1991), which together with the local presence of vendace, was responsible for the introduction of phosphate-stripping at the Keswick sewage treatment works in 1995. This action has resulted in some reduction in phosphorus concentration in the lake, but this effect has been relatively limited and the lake looks set to remain eutrophic for many years to come for reasons explained in detail by THACKERAY *et al.* (2006).

In addition to eutrophication and its attendant problems of periodically low hypolimnetic dissolved oxygen levels and the deposition of algal remains on vendace spawning gravels (WINFIELD *et al.* 2004), most recent sedimentation is of allochthonous origin (THACKERAY *et al.* 2006). Based on extensive underwater video surveys, WINFIELD *et al.* (2006), WINFIELD *et al.* (2008), and COYLE & ADAMS (2011) have shown that all known spawning grounds of vendace contain extremely high amounts of fine sediments, which make successful egg incubation highly unlikely. Although some success was initially shown by the development of artificial spawning substrates to provide vendace with appropriate *in situ* spawning habitat, the winter levels of sedimentation in the lake subsequently increased to the extent that this approach had to be abandoned (WINFIELD *et al.* 2006). It thus appears that the solution to the sedimentation problem of Bassenthwaite Lake will have to come from understanding and tackling the problem at its source in the lake's watershed, rather than trying to deal with its

symptoms in the context of vendace spawning requirements. While appropriate catchment-level research (e.g., HATFIELD & MAHER 2008, WARBURTON 2010) and initiatives (e.g., reduction of grazing pressure on sensitive uplands, encouragement of woodland on steep slopes) are now in progress, it is clear that there will be no swift solution to this problem.

Species introductions, which comprise the third major environmental threat facing the vendace in the U.K., are recognised to be a particularly insidious problem worldwide (ALLEN-DORF & LUNDQUIST 2003). The removal of introduced species, particularly fish, is impracticable in almost all habitats and Bassenthwaite Lake is no exception. The only habitat measure that can be effectively undertaken in response to this problem is to reduce the risk of further species introductions. Given strong circumstantial evidence that the recent fish species introductions to Bassenthwaite Lake, and elsewhere, were the result of live-baiting for northern pike, a ban on freshwater live-bait and dead-bait was introduced at selected lakes in 2002 (WINFIELD & DURIE 2004). No further species introductions have been recorded at Bassenthwaite Lake in the 8 years since this measure was introduced.

Thus, a series of habitat measures is now in place at Bassenthwaite Lake that will ultimately result in significant improvement in the local quality of vendace habitat. However, it is clear that such rehabilitation will take many years.

### **Habitat measures at Derwent Water**

Like Bassenthwaite Lake, the importance of Derwent Water has also been recognised for many years and this lake also enjoys national designations as a Site of Special Scientific Interest and a component of a Special Area of Conservation. Arguably more importantly, in contrast to Bassenthwaite Lake, this lake lies upstream of the town of Keswick and so has not suffered any significant eutrophication. Based on extensive underwater video surveys of actual and potential vendace spawning grounds, WINFIELD et al. (2006) and COYLE & ADAMS (2011) have shown that extensive areas with no or little fine sediments exist in this lake for successful egg incubation.

In the context of species introductions, Derwent Water is one of the other lakes at which a ban on freshwater live-bait and dead-bait was introduced in 2002 (WINFIELD & DURIE 2004). As at Bassenthwaite Lake, no further species introductions have been recorded since this measure was introduced.

In terms of habitat quality, Derwent Water thus continues to offer generally good conditions for its vendace population. However, while eutrophication and sedimentation are unlikely ever to become significant problems, the ruffe population, a species introduced prior to the ban, remains a concern.

### **Refuge populations**

Although nature conservation is ideally undertaken at the habitat level, in practice this is often a difficult and/or a slowly implemented strategy. Consequently, conservationists working with a wide range of taxa have for many years used the establishment of refuge populations as a pragmatic safeguard against the complete loss of a population or even species



(e.g., MINCKLEY 1995). Such action has been employed in the conservation of freshwater fish in the U.K. for a number of years, with MAITLAND & LYLE (1990) summarising a number of early applications, including the trial introductions of several thousand young vendace originating from the Bassenthwaite Lake population to Doune North Pond and Loch Earn in central Scotland in 1988. The Doune North Pond introduction failed, but a single vendace was reportedly and unintentionally caught by an angler at Loch Earn in 2005. However, no further specimens were captured in subsequent extensive survey gillnetting conducted at this location in 2007 (MAITLAND et al. 2011).

Given the alarming situation at Bassenthwaite Lake evident by the early 1990s, considerable efforts have been made in subsequent years to establish vendace refuge populations in both Scotland and England. Although such effort has concentrated on the more threatened, and apparently now extinct, population of Bassenthwaite Lake, that of Derwent Water has also been addressed as a precautionary measure. These activities have been characterised by conscious efforts to avoid the creation of new conservation problems at the recipient site and to maintain the genetic integrity of the refuge populations. The former requirement has required extensive searches for and assessments of potential sites against a wide range of criteria, including characteristics of the receiving fish community (e.g., LYLE & WINFIELD 1999). The latter requirement has resulted in all translocations avoiding the use of hatcheries completely or limiting their use to vendace development only to eyed-egg or swim-up larvae stages to guard against any inadvertent but significant genetic selection which is almost inevitable if older life stages are retained in captivity. In addition, on the basis of the genetics investigations by BEAUMONT et al. (1995) and THOMPSON et al. (2008), progeny from the Bassenthwaite Lake and Derwent Water populations have been kept separate and egg collections have been made a number of times over the course of the spawning season and in more than one calendar year.

Following the above approach, a total of 35 female vendace was stripped for eggs at Bassenthwaite Lake in 1997 and 1999 and a total of approximately 65,000 eggs and larvae were introduced during the following springs to the recipient site of Loch Skeen (or Skene) of Dumfries and Galloway in South West Scotland (LYLE et al. 1999). Similarly, 90 female vendace were stripped at Derwent Water in 1998, 2005, and 2008, and then eggs, larvae and adults were introduced to the recipient sites of Daer Reservoir (approximately 45,100 eggs and larvae, and 25 adults) of South Lanarkshire and Sprinkling Tarn (approximately 134,000 eggs) in North West England (LYLE et al. 2005).

Although only limited survey nettings with no positive results have subsequently been carried out at Daer Reservoir (MAITLAND et al. 2003) and Sprinkling Tarn (A. R. GOWANS, Environment Agency, unpublished data), reports of anglers fishing for brown trout at Loch Skeen unintentionally catching vendace justified further investigation at this locality. Based on a brief initial survey in 2003, a reproducing vendace population had become established (MAITLAND et al. 2003). A more comprehensive survey was carried out in 2007 by a combination of survey gillnetting and hydroacoustics (WINFIELD et al. 2011), with associated activities including habitat assessment by underwater video (COYLE & ADAMS 2011), stable isotope analysis of the entire fish community (HARROD 2008), and a vendace genetics assessment of DNA variation at nuclear microsatellite and mitochondrial loci (THOMPSON et al. 2008). The vendace population density was estimated at 231.7 fish ha<sup>-1</sup> (lower and upper 95% confidence limits of 64.0 and 839.6 fish ha<sup>-1</sup>, respectively) with individuals ranging in age from 1 to

6 years, clearly indicating that a viable refuge population had been successfully established. Although vendace have apparently been lost from Bassenthwaite Lake, their descendents survive in Loch Skeen.

## Public awareness

After the closure over 100 years ago of fisheries for the two now extinct vendace populations in Scotland, public awareness of vendace became increasingly very limited, particularly in England. Consequently, throughout the above conservation activities of the last two decades, significant efforts have been made to increase public awareness of the conservation status of this species. These have included press releases of conservation activities that resulted in coverage by newspapers, radio, television, and websites at a national level, together with more extensive and direct contacts at a local level including frequent talks at public meetings and proactive highlighting of the vendace in information media distributed by local environmental initiatives.

Although not precisely public awareness, closely related efforts have also been made to raise the profile of vendace within statutory conservation bodies beyond their immediate champions and above the minimum required by the U.K. Biodiversity Action Plan reporting. In the harsh reality of a world in which conservation needs far outweigh available conservation funding, such actions have proved to be invaluable in securing funding for the vendace in the face of strong competition from charismatic mega-fauna.

## Closing remarks

The U.K. has now lost three of its four native vendace populations, with only that of Derwent Water surviving into the twenty-first century. The main causes of these extinctions have probably been eutrophication and sedimentation, although species introductions may also have been involved. Whatever the mechanisms, it is somewhat depressing that the extinctions in Bassenthwaite Lake and Mill Loch occurred despite these locations being designated as Sites of Special Scientific Interest. Indeed, MAITLAND (2007) lamented that the designation of Mill Loch did little to stop deterioration and was followed by the mid-1970s extinction of the local vendace population, a sequence of events that was sadly repeated at Bassenthwaite Lake. Clearly, any assumption that the similar designation of Derwent Water will protect its vendace population would be naïve.

Consequently, in addition to continuation of the series of restorative environmental management actions currently in progress at Bassenthwaite Lake and the monitoring and reporting programmes already in place for this location and Derwent Water, the protection of the latter lake and its sole surviving native U.K. vendace population is a key priority of future activities. As resources allow, full assessments will also be made of the putative Derwent Water vendace refuge sites of Daer Reservoir and Sprinkling Tarn, together with a commitment to review any developing need to establish further refuge populations. In the longer-term future, an ultimate conservation action will be to use the Loch Skeen refuge population as a source for the reintroduction of vendace to a restored Bassenthwaite Lake.

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