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Translocation of vendace from Derwentwater to safe refuge locations

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Translocation of vendace from Derwentwater to safe refuge locations

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Summary

The status of the vendace *Coregonus albula* in Great Britain is threatened and in decline. The principal population of this species is now in Derwentwater, Cumbria. English Nature commissioned this project to translocate vendace from Derwentwater to refuge locations in Daer Reservoir, Lanarkshire, and Burnmoor Tarn, Cumbria. The project also involved locating a temporary site in Cumbria in which to create a brood stock for further translocations.

The project objectives were to transfer *c.* 75,000 eggs to Daer Reservoir *c*. 20,000 eggs to Burnmoor Tarn and *c*. 5,000 eggs to the brood stock site.

The search for a brood stock site considered 34 waters in Cumbria. Only one of these, Bowscale Tarn SSSI, merited an investigative field survey, which confirmed its suitability. However, full permission to introduce vendace there has not yet been granted from English Nature. This is also presently the case for Burnmoor Tarn owned by the National Trust.

To collect the required number of vendace eggs, their spawning grounds were netted intensively from late November to late December. Deep water nets were also used to assess vendace spawning status. Eggs collected and fertilised were to be held in specially designed incubation boxes at Derwentwater, then transferred to the refuge sites before hatching. In total 45 nets were set and 80 vendace caught. The majority of these fish were taken from deep water and only 12 from possible shoreline (spawning) locations. None of these fish were ready to shed eggs or milt and consequently no eggs were collected. Dense macrophyte beds have encroached onto the previously known spawning grounds which, we believe, have changed the vendace spawning behaviour. Pre spawning vendace were found in the early stages of the netting programme and spent fish in the late stages. Spawning therefore took place in Derwentwater during the period of sampling but the locations remain unknown.

We recommend that a review of alternative translocation methods is considered (eg transferring adult fish), that the feasibility of further attempts to collect eggs from spawning adults is assessed, and if still required, that a brood stock site may have to be found outwith Cumbria.

1. Introduction and background

This conservation project concerning vendace *Coregonus albula* was commissioned by English Nature to be carried out in the winter of 2004/2005 and its purpose was to translocate vendace from Derwentwater in Cumbria to refuge locations at Daer Reservoir (Lanarkshire) and Burnmoor Tarn (Cumbria) to establish safeguard populations. A third site had to be identified in which to create a brood stock of this species.

Introductions of vendace were carried out at Daer Reservoir (12,800 unfed fry) in 1998 (Lyle and others1998), and to Loch Skene (65,000 unfed fry and eyed eggs) in 1997 and 1999 (Lyle and others 1998, 1999). This work was funded by Scottish Natural Heritage as part of its Species Recovery Programme. Subsequently, small scale surveys of these waters in 2003 funded by English Nature (Maitland and others 2003) showed that vendace had become established in Loch Skene but no vendace were found at Daer Reservoir. At the latter site it is uncertain if a small stock of vendace may have survived but below a level that is readily detectable. The earlier introductions of vendace fry to Daer Reservoir were low in number and it is appropriate that further introductions are carried out to improve the likelihood of establishing a self sustaining population and also to enhance genetic diversity.

The status of vendace in Great Britain is now of serious concern. Of the two main, large, populations in Bassenthwaite Lake and Derwentwater, the former has declined significantly as a result of adverse environmental conditions (Winfield and others, 2004). Two smaller Scottish populations in the Mill Loch and Castle Loch in Dumfriesshire became extinct during the last century and of the two sites where vendace was recently introduced (see above) only in Loch Skene, a relatively small site (28ha), are vendace known to have become established.

A survey commissioned by the Environment Agency (Lyle & Winfield 1999) to find possible translocation sites for permanent refuge locations for vendace in Cumbria failed to identify any that were immediately suitable. However, Burnmoor Tarn was nominated as being one of four in the area which came to closest to the required criteria. This site has now been chosen by English Nature (in liaison with the UK BAP Steering Group for Vendace) in which to attempt to establish a new Cumbrian vendace population. It has also been decided to locate a site in Cumbria which, while it may not fulfil the criteria of a permanent home for vendace, can act as a holding site to provide a brood stock for further vendace translocations.

The vendace population of Derwentwater has been monitored by the Centre for Ecology and Hydrology, Lancaster (formerly CEH Windermere) under commission to the Environment Agency using a combination of hydroacoustics and survey gill netting since 1998 and its status is described in a series of annual reports, the most recent of which is Winfield and others (2004). The latter covered sampling undertaken in 2003 and concluded that although the abundance of vendace in Derwentwater had declined in 2003, it still fell within the lower end of the range of values reported from other European lakes. The status of the vendace population of Derwentwater in 2003 was thus considered to be acceptable. However, Winfield and others (2004) noted that concern will increase if the recent decline in population abundance, which fell within the normal variation shown by this species, did not reverse soon. Although the results of the monitoring programme in 2004 have yet to be fully analysed and interpreted, preliminary analyses indicate that no further decline has occurred and a range of year classes persists in the vendace population of this lake (CEH Lancaster,

unpublished data). It may be concluded that a healthy population of vendace inhabited the deep areas of Derwentwater immediately prior to the beginning of the present programme. Vendace normally occupy the open water areas of lakes, being in deep water through the day and rising to nearer the surface at night. They are almost exclusively plankton feeders. Their spawning period occurs between late November and late December when they move onto clean, inshore gravels. Males gather on the spawning grounds early, waiting for females to arrive when they are ready to lay their eggs. Males may still be found on the spawning grounds late in the period even after the females have spawned. Although females may carry up to 5000 eggs it is unlikely that such a number of good quality eggs can be obtained from a single fish by their collection from the wild. The average from the 1997 netting was *c.*2800 eggs per stripped female (Lyle and others1998).

A review of the criteria of spawning habitat for vendace in Derwentwater and Bassenthwaite Lake was carried out by Maitland (1996). The study identified a number of factors controlling the success or otherwise of spawning, egg incubation and the recruitment of young vendace in the wild. Some of these factors are completely natural (eg weather) and little can be done to modify their impact. Others are the result of human activities and thus possibly open to modification. One important point to note is that high variability in year-class success is a characteristic of many populations of vendace.

The dynamic nature of ecosystems and interrelationships of factors are important. For example, regular high recruitment should lead to a large spawning stock number and biomass but several workers have shown this is a major factor involved in poor recruitment of the next generation. Storms are known to be a negative factor during spawning and to incubating eggs but at other times of year, wind-induced wave action is important in disturbing substrate to keep it clean by washing away silt and algae. The British populations of vendace are winter spawners and the main period of spawning is late November and December. Thus the main incubation period is December to March, a common time for severe storms which may be increasing in number and severity at this time due to global warming (Maitland 1991).

The substrate of the spawning grounds used by vendace appears to be very similar across its European range. It has been variously described as 'stony gravel' or 'gravel and small stones' and the particle sizes involved range from 5-100 mm. Most spawning substrates appear to be a mixture of such sizes, the actual composition depending on local circumstances. One common feature is that it is clean and free of excessive silting or covering by attached algae or macrophytes. This clean porous nature allows oxygen to reach the eggs which fall into the substrate interstices immediately after spawning. The substrate off exposed headlands and on offshore reefs in lakes is often particularly suitable because wave action can produce clean substrates. It is rare for fish to spawn in very shallow (ie < 25 cm) water where spawning adults would be vulnerable to predation and the eggs would be badly disturbed or washed ashore by regular wave action.

The actual spawning itself can be affected by several factors. If the spawning grounds have been reduced in extent or lost altogether (eg by changes in water level) or changed in character (eg silted over or covered by algae or macrophytes) then the homing instinct may well be disrupted and there will be less suitable substrate over which to lay their eggs. Storms during the spawning period may drive fish off the spawning grounds (especially those in shallow water) and the fact that fish apparently release their eggs further off the bottom during storms may mean that fewer eggs find their way on to the appropriate substrate for incubation. Predators are also a threat to the eggs of vendace and the introduction of the ruffe

Gymnocephalus cernuus to Derwentwater is a considerable cause for concern. Lake temperatures during incubation are critical. They must not be too high or the eggs die from heat stress and low oxygen in the substrate. On the other hand, if they are very low then the much greater length of time taken for incubation means that they are more vulnerable to currents and predators.

2. Objectives

The stated objectives of the project are as detailed below.

- Identify a holding site capable of supporting a stock of vendace to be used as a brood stock.
- Collect *c.* 100,000 eggs from the Derwentwater vendace population.
- Incubate these eggs in the most appropriate manner for the subsequent introduction of *c.* 75,000 vendace eggs to Daer Reservoir, *c.* 20,000 eggs to Burnmoor Tarn and *c.* 5,000 eggs to a brood stock site to create vendace populations in these waters.

3. Methods

3.1 Permissions for access to sites and handling vendace

Permission for access to sites for inspection and sampling was obtained from owners, and where necessary, in the case of sites with conservation status, from English Nature – the work was also done within the authority of the Environment Agency. Netting at Derwentwater was carried out under the authority of the Environment Agency which was also the licence holder for handling vendace under the Wildlife and Countryside Act 1981. In this regard, the authors were the accredited agents of the Environment Agency.

At Daer Reservoir permission to carry out a further introduction of vendace was obtained from Scottish Water. There was some early doubt over this permission being granted since Daer Reservoir was being considered as part of a drought order scheme which would mean drawing water levels down and Scottish Natural Heritage were concerned over possible impacts on any vendace that may be there (see Introduction). This issue was resolved by discussion between Scottish Water and Scottish Natural Heritage.

Burnmoor Tarn is owned by the National Trust which has expressed concern over the introduction of vendace there as a non-native species to that site. It is also an SSSI and English Nature and the National Trust have discussed the issue but this was suspended (given the subsequent unavailability of eggs) so that further consideration could be made more fully, but in time for any translocation attempt in 2005/06.

3.2 Identification of a brood stock site

Earlier searches for sites suitable to sustain viable populations of vendace in south west Scotland (Lyle and others 1996) and Cumbria (Lyle and Winfield 1999) produced only one site (Loch Skene) that was considered to be immediately suitable. Lake size was a limiting criteria in these studies and only those depicted on 1:250,000 scale OS maps (ie approximately > 4 hectares) were considered. However, as a holding site for a brood stock,

survival is a first priority, reproduction is secondary. Therefore certain selection criteria were relaxed e.g. spawning habitat. It was also appropriate to examine smaller water bodies since there is the added advantage that the vendace would be more readily recoverable from them, although it should be of sufficient size to support at least several hundred fish.

Some criteria considered desirable for a successful brood stock site are: (a) a manageable size of a few to several hectares so that retrieval of fish for stripping in 3 to 6 years time could be achieved with reasonable effort, (b) preferably of simple form with no obstructions or restrictions to netting, (c) a depth of at least 3 m to give the fish some refuge from heat stress and predators, (d) security from disturbance/pollution/recreation/poaching etc, (e) no formal angling and stocking interest, (f) no commercial or industrial interference, (g) good water quality, and (h) low numbers of other fish, particularly species which can be predatory to vendace eg pike *Esox lucius* and perch *Perca fluviatilis*.

A first step was to consider some of the waters that had been rejected as permanent sites from the Lyle and Winfield (1999) survey, then consider smaller sites not depicted on the 1:250,000 scale maps. The preferred location for a brood stock site was considered on an extending geographic basis favouring those nearest the parent site, Derwentwater, and if possible any within the Derwentwater catchment. Desk studies were undertaken followed by site inspection visits and finally a field survey (of the single candidate site found that merited it). Desk studies included map analysis, general information gathering from local and organisational sources, and literature was reviewed where applicable. As in the Lyle & Winfield (1999) survey, a significant proportion of the waters in Cumbria are automatically excluded if they lie within the catchments of sites containing other rare species, ie schelly *Coregonus lavaretus* or Arctic charr *Salvelinus alpinus*. Site inspection visits focussed on practical aspects of access, fish introduction and retrieval, discussions with owners over current and future site use, security and general physical and ecological features (eg depth, shore substrates, shore vegetation etc). Field survey focussed mainly on identifying the current fish status by netting and electro fishing, (substantial bathymetric, biological and chemical information was already available in the literature).

3.3 Collection of vendace eggs at Derwentwater

To achieve the required number of vendace eggs (ie 100,000) it was estimated from earlier work (Lyle and others 1998) that approximately 35 ripe females might be required plus at least an equivalent number of ripe males.

The vendace spawning period can occur between late November and late December (Winfield and others 1998) so a preliminary netting visit was undertaken in late November to try to establish the spawning condition of vendace at that time. Subsequent netting was carried out each week for the next five weeks until the end of December.

Netting in Derwentwater was mostly at near shore locations previously identified as being vendace spawning grounds (Lyle and others 1998; Winfield and others 1998) using a combination of multi-mesh survey nets and multi-mesh and single-mesh nets specifically designed for vendace work, set onto the lake bed. Some deep water netting was also done throughout to assess the reproductive status of vendace. On one occasion a single survey net was set on the bottom in a mid-depth location between the main deep area and the islands. Technical details of the nets used are as follows:

Survey multi-mesh nets - monofilament (code - Smo): 40 m long by 1.5 m deep consisting of 14 panels of meshes 6.5, 8, 16.5, 75, 38, 25, 12.5, 33, 50, 22, 43, 30, 60 & 10 mm.
Survey multi-mesh nets – multifilament (code - Smu): 60 m long by 1.5 m deep consisting of panels of the same meshes as above but in order of size.

Single mesh nets for vendace (code - Vn): 25 m long by 1.5 m deep, monofilament, mesh of 22 mm, 25 mm or 30 mm mesh.

Mixed-mesh nets for vendace (code Vmix): 60 m long by 1.5 m deep, monofilament, 12 x 5 m panels in three blocks of meshes 16 mm, 19 mm, 21 mm, and 25 mm.

The reported vendace spawning grounds lie close to the shores of Derwentwater and some islands in the central area of the lake (see Figure 1). Nets were set from shallow, near shore points running out either perpendicular to the shore or at an angle depending on shore profile, macrophyte beds and prevailing wind direction. Predominantly, survey type nets were used in the early part of the netting programme since only small samples of a few vendace were required to determine the onset of the spawning period. Latterly, the special nets designed for vendace were used more frequently. Similarly, the special nets were not deployed in the deep water location until later in the programme. Apart from three occasions when deep water nets were set out for four hour periods in daylight, all nets were set in the afternoon and lifted the next morning.

All vendace caught in the nets were identified to sex and measured for fork length. These fish were retained (frozen) for possible further analysis. Other species of fish caught were identified to species and measured for fork length (other than the many that were released from the net on the boat – many others were released after measuring).

A base for boat launching, net sorting and cleaning, fish handling, egg stripping and fertilising, etc was established at the Derwentwater Marina (by arrangement between the Environment Agency and the marina owner). Two large water tanks with an oxygen supply were set up as a holding facility for females that may not have been quite ready to release eggs, and similarly for males but also because they are capable of producing more than a single contribution of milt. Smaller tanks were also carried on the boat when retrieving nets so that any vendace caught could be removed from the nets and held in water until return to the shore base. These tanks, the boat used, a boatman and sundry other equipment were supplied by the Environment Agency.

It was intended that eggs would be stripped from ripe female vendace and fertilised with milt from males at the shore base. Fertilised eggs would be placed into incubation boxes which were prepared, based on a model successfully used in the introduction of schelly *Coregonus lavaretus* from Haweswater to Small Water in 1997 by Winfield and others (1997). Each box was constructed from a plastic plant propagator measuring *c.* 350 mm long, 250 mm wide and 170 mm high and lined with a layer of synthetic grass (Model RA1) made by Nordon Enterprises Limited (Metcalf Drive, Altham Business Park, Accrington, Lancashire BB5 5TU, U.K.). Twelve such boxes were assembled into two rows of 6 boxes in a metal frame measuring 1.85 m long and 1.02 m wide, resting on legs which held the synthetic grass 0.23 m above the substrate.

The frame was then installed in Derwentwater at a sheltered but relatively silt-free location of water depth *c.* 1 m on 1 December 2005. After extensive inspections of the lake and with the

kind permissions of the National Trust and Mr Douglas Barnes, the specific site chosen for installation was at the eastern extreme of the north shore of Derwent Isle (Latitude 54º 35.517' North, Longitude 3º 8.617' West) see Figure 1.

The volume of the eggs collected would be measured to enable an assessment of their number using the relationship established by Lyle and others (1998). Each incubation box can accommodate approximately 10,000 eggs.

As a potentially useful exercise at no extra cost to the project, it was agreed to give a small quantity of eggs to Jen Nightingale of Bristol Zoo Gardens who, holding appropriate licences, had agreed to act as a primary contact for a number of aquaria and zoological gardens keen to develop captive populations of vendace for conservation purposes.

3.4 Egg incubation and transfer of eggs to the introduction sites

It was intended that throughout the incubation period, which is dependent on water temperature but would be approximately three months, checks were to be carried out on the security of the boxes and, when practical, egg development. These checks could be carried out in conjunction with regular fortnightly field monitoring work by CEH staff thus reducing the effort and cost of special visits. When the embryos were well developed and approaching hatching they were to be transferred into vacuum flasks for transportation to the introduction sites. The eggs would be taken immediately to the new sites and either replaced into the incubation boxes or distributed directly onto substrate suitable for their security and final incubation stage.

This method of retaining the eggs at Derwentwater and then distributing them to the refuge sites, probably in March, was chosen for logistic and cost reasons. The effort involved in transferring eggs to the new sites at the time of their collection is uncertain and could involve several staff standing by over the netting periods and perhaps making several lengthy journeys. This would be costly, difficult to plan and the weather in December could prevent some journeys being made, for example there is no road access to the high lying Burnmoor Tarn. At Daer Reservoir we were concerned for the viability of the incubation boxes over the lengthy incubation period at a site where water level fluctuations may be a serious disadvantage to egg incubation and survival (low levels) and to box checking and retrieval (high levels). By keeping the eggs at Derwentwater there is also the added advantage that it provides more time to identify a brood stock site should there be difficulties in finding a suitable location.

The concept of incubating the eggs in a hatchery and introducing the vendace as unfed fry (as in the earlier vendace translocations) was considered but found to be logistically and financially cumbersome. Furthermore, the frequent transfers of fry to the introduction sites required over the hatching period of about one month are prohibitively expensive.

4. Results

4.1 Brood stock site selection

The sites from the study by Lyle & Winfield (1999) that were considered for a vendace brood stock are given in Table 1 along with reasons for rejection. None of these sites was suitable and for a few we were unable to get fully satisfactory information despite repeated requests.

Subsequent investigations then involved examination of the 1:50,000 scale OS maps and enquiries to Environment Agency field staff, English Nature, Cumbria County Council and the Lake District Special Planning Board. Amongst the sites suggested for consideration were several water filled quarries which, since they are totally artificial and may have few or no other fish, became to be regarded as potentially ideal sites for brood stock purposes. These sites are also listed in Table 1. In the case of one site, Rowrah Quarry, which was potentially a satisfactory site, the protective legislation afforded to vendace by the Wildlife and Countryside Act 1981 effectively discouraged the owners from accepting vendace into the quarry since they felt that this might prevent any further commercial use of the quarry, even although that may not be anticipated for some eight years, which is an adequate period for use of a brood stock. The owners did suggest that a special arrangement with English Nature, in which they still retained the right to drain and work the quarry when/if required, might be acceptable but it is uncertain if this is legally feasible. Although English Nature could agree to such an arrangement, the decision to prosecute lies with the Crown Prosecution Service, and there is no guarantee that another party would not wish to pursue such an action. So, while licensing under the Wildlife and Countryside Act 1981 in relation to protected species is controlled by English Nature, decisions to prosecute under this legislation are not.

Only three sites were given preliminary field inspections – Boaterby Quarry, Cardrew Mires Quarry and Bowscale Tarn. These inspections were carried out on 9 November with the help of Environment Agency staff. In the case of Boaterby Quarry which, on initial inspection, satisfied most of the criteria, the owners subsequently required that responsibility be taken over by English Nature for all aspects of managing the site, security (eg fencing) and access. This was not acceptable. Cardrew Mires is in fact still a working quarry and consists of three separated ponded areas. One of these is scheduled to become a local nature reserve and may be very suitable as a vendace holding location in future but is presently still affected by quarry working. Bowscale Tarn is a natural waterbody, an SSSI and is located within the Lake District National Park. The owners, Dalemain Estates, readily gave permission for the tarn to be surveyed and for any subsequent vendace introduction. Since it is an SSSI, permission to survey and introduce vendace is also required from English Nature.

Only Bowscale Tarn was subjected to field survey which was carried out on 24 and 25 November with the assistance of Environment Agency staff. The survey consisted of electro fishing by Environment Agency staff in the available habitat types at seven points around the shore plus a 50 m length of the outflow (see Figure 2). No fish were caught or seen during the electro fishing but at this time of year with low water temperatures (6^{o}C) fish are fairly inactive and may have retreated to deeper water. The outflow becomes steep with a sequence of small falls and pools and is probably impassable for migratory fish. Three survey gill nets of type Smo (see Methods) were set in the afternoon of 24 November and lifted the next morning. The nets were set to sample mainly into the deeper water. Only net C (see Figure 2) caught fish – a single perch, 112 mm fork length. A report by Haworth (2003) gives bathymetry (Figure 2) and other information on this tarn – altitude 471 m, area 2.7 ha, maximum depth 17 m, pH 6.6 (in 1998). Consequently, Bowscale Tarn is considered a suitable site for a vendace brood stock, subject to permission being given by English Nature to introduce this species there. Indeed, the shoreline substrates seem excellent for spawning and the presence of a deep area for refuge suggest that vendace could reproduce here and may survive for many years, although, because of the small size of the water and its oligotrophic status, only a minor population could be expected whose continued existence may be vulnerable because of these factors.

Another site reviewed, Watendlath Tarn, in the Derwentwater catchment is presently a stocked rainbow trout fishery but is owned by the National Trust. Our information is that future plans intend that stocking may be stopped after 2006. This site may then make a good brood stock (perhaps small permanent) site for vendace. The physical aspects of the site seem suitable but a proper assessment would have to be made, for example, Blea Tarn upstream of Watendlath Tarn is heavily populated with perch (Lyle & Winfield, 1999).

4.2 Egg collection at Derwentwater

During the six separate netting sessions at Derwentwater between 22 November and 29 December a total of 45 nets were set out in several different locations (see Figure 1). Thirty six nets were set overnight in shallow water for spawning vendace. Nine were set in the deep area of approximately 20 m, six of these overnight and three for only four hours in daylight. The purpose of the deep nets was to examine the general reproductive state of the vendace - 68 of the 80 vendace caught came from the deep water nets. Full details of all the nets, periods of setting and catches are given in Appendix 1.

Spawning vendace had previously been caught at Derwentwater (and at Bassenthwaite Lake) over shoreline gravel areas (Lyle and others 1998). However, the early netting in this project found that, unlike previously, the shoreline nets when lifted were often badly fouled by macrophytes, many of which were the alien New Zealand pygmyweed *Crassula helmsii* and were therefore operating at reduced effectiveness. On 7 December we undertook an inspection survey of the shoreline areas around the central islands and stretches of the east, west and southern shores of the lake to try to locate areas of clean gravel that would be suitable for successful vendace spawning. No obviously ideal areas were found and nets were therefore set onto gravels between the extensive macrophyte beds and the shore (an area that will vary with lake level) on the assumption that the vendace would seek to spawn over such areas. The netting locations were generally those where spawning vendace had been found before (Lyle and others 1998, Winfield and others 1998) plus others considered to be possible spawning locations (Figure 1). Fouling of the nets by macrophytes was a consistent problem throughout, particularly during and after high winds when even some of the deep water nets were badly affected.

During the first netting session, shore net S1 (Figure 1) on 23 November caught two ripe male vendace and deep net D2 on the same date caught four ripe males and ten ripe females. Although these fish are classed as ripe none were yet at the 'running' stage of spawning and indicated that the spawning period might begin within one week or so, particularly because of the presence of males in the shore net. However, despite repeated netting over the next five weeks, no vendace were caught by inshore nets until the final session on 29 December when ten females were caught in nets set about 50 metres off the east shore, but these were all spent. Consequently, no ripe and running vendace were caught and no eggs collected. Details of the vendace caught are given in Appendix 2 and the fork lengths of other species measured in Appendix 3. Length frequencies for male and female vendace are shown in Figure 3. Several of the vendace caught were noticed to be infected by the parasite Argulus. Of the 12 vendace caught in the final netting session on 28 December, five were infected. Those seen with Argulus are probably fewer than the number contaminated since the parasite can be removed during the act of retrieving the nets. Fryer (1982) notes that Argulus "was not known in the Lake District until 1971" … "it probably did not occur naturally but ….. has spread as a result of indiscriminate introductions of fishes and the liberation of fishes used as live bait".

5. Conclusions and discussion

The search for a brood stock site illustrated the difficulty in finding a suitable water body in Cumbria that satisfies the ecological criteria required for the purpose, and also one where the introduction of vendace is acceptable to the owners or relevant authority. The pursuit of the required information from various sources on potential sites became prolonged and it was often difficult to get adequate details, such that no brood stock site has yet been agreed.

In the case of Rowrah Quarry, an apparently satisfactory location, it is indeed ironic that the conditions of protective legislation (the Wildlife and Countryside Act 1981) should deter the owners from entertaining even the temporary introduction of vendace. Similarly, it was this legislation that caused doubt for permission being given for a second vendace introduction at Daer Reservoir. Approval from the National Trust to introduce vendace to Burnmoor Tarn has still to be obtained and will be pursued in time for any translocation work in 2005/2006. Should the introduction of vendace to Bowscale Tarn be judged unacceptable because of its SSSI status then it is likely that a brood stock site must be sought outwith Cumbria. To this end some enquiries were made for sites in southwest Scotland and several possibilities arose but these remain to be properly investigated. However this area may not be acceptable to the funding policy of English Nature.

Despite a netting effort of almost four times that anticipated, the netting programme failed to collect any of the 100,000 eggs required. In the early stages it was considered that the water temperature (Figure 4) was perhaps too high to stimulate spawning, this view being supported by local reports of delays in spawning by salmon. However, a check of water temperature in December 1997 (Lyle and others 1998) when good numbers of vendace were found on some of the same areas being netted here, showed temperatures to be similar ie around 7^{o}C.
The fact that ripe vendace were found early and spent vendace found late in the netting programme showed that spawning had occurred somewhere in the lake but the intense netting effort indicated that the spawning locations were now different from previous years and possibly not on habitats regarded as satisfactory for successful reproduction. Areas of heavy macrophyte growth, including *Crassula helmsii,* are clearly widespread in Derwentwater and we believe that this has significantly affected the spawning behaviour of vendace. This feature is already, or will become seriously adverse to successful vendace spawning in future and the continued existence of this species there. In this respect a resurvey of habitat conditions on vendace spawning grounds would be useful. The highly invasive characteristics of *Crassula helmsii* can enable it to establish quickly in neighbouring waters where it may become problematic to other valuable fish populations.

In view of the experience reported above, serious consideration should be given to translocating adult vendace in any future project. We have no clear indication where vendace spawned in Derwentwater in December 2004 and the next attempt to locate spawning fish will be to a large extent investigative. It is likely that then, as happened in this project, there would be significant mortality of the vendace caught during necessary exploratory work. If however, the project aims and methods were to catch and transfer live adult fish, such mortalities could largely be avoided. Of course, transfer of adult vendace has a number of biological and logistical problems. Any fish caught must be minimally damaged and transferred as soon as possible to the host site. It is suggested for discussion, that fish could be caught in autumn when they are at their fittest and water temperatures had fallen, but before the onset of spawning, using surface gill nets which are frequently checked, say every

two hours. Fish can be transported in chilled tanks with aeration. It may be necessary to treat the fish to prevent the transfer of unwanted parasites (eg Argulus). Such translocations are most feasible for Daer Reservoir which has road access but it is the farthest away site. Access is more difficult to Burnmoor Tarn and (perhaps) Bowscale Tarn.

Transfers of adult vendace are not uncommon elsewhere in Europe. Jarvinen (1987) notes that, although most early stocking programmes used fry, more recently transfers have used yearlings or adults. Jurvelius and others (1995) describe the transfer of eight tonnes (*c*. 827,000 fish) of wild caught vendace (ages 0+, 1+ and 2+ years) in Finland from Lake Onkamo to Lake Puruvesi, 100 km further south. Fish were transported in oxygenated tanks on a lorry.

6. Recommendations

We recommend the following:

1. That a decision on whether or not it is acceptable that vendace can be introduced to Bowscale Tarn SSSI be made by English Nature as soon as possible.

2. If the above fails then new investigations to find a suitable brood stock site should be undertaken including areas outside Cumbria – that is, if it is agreed that a brood stock site is still required, for example, if there is a change of method to adult transfer (see 4. below). Also, to maintain an awareness of the possible future suitability of other sites identified here, eg Watendlath Tarn, Cardrew Mires and Rowrah Quarry.

3. That clarification of whether or not it is acceptable to the National Trust that vendace can be introduced to Burnmoor Tarn is sought as soon as possible.

4. To consider the feasibility of, and methods for, the capture of adult vendace outwith their spawning period for direct transfer to safeguard sites.

5. To consider the necessity, feasibility and practicality of carrying out another attempt to collect vendace eggs in November/December 2005.

6. A survey of macrophyte distribution on vendace spawning grounds.

7. Acknowledgements

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Table 1 The sites considered for potential brood stock waters for vendace

Only one was found to be suitable (**Bowscale Tarn**). Principal reasons for rejection are given.
* Indicates those from the 1999 survey by Lyle & Winfield (1999).

Name	Easting	Northing	Comment
Sites considered in the Derwent Water catchment			
Watendlath	3276	5161	presently unsuitable - angling interests
Dock Tarn	3273	5143	difficult access
Blea Tarn	3293	5141	remote, predatory species (perch, 1999 survey)
Styhead Tarn	3222	5098	too remote
Sprinkling Tarn	3228	5092	too remote
Angle Tarn	3245	5076	too remote
Sites considered from the 1999 survey, 1:50,000 maps and suggested by contacts			
(Ayside) x 2*	3400	4840	unsuitable - angling interests
Barnacre*	3526	4479	unsuitable - angling interests
Barns Fold*	3579	4413	unsuitable - angling interests
Blencowe Quarry (Newbiggin)			unreliable water levels
Boaterby Quarry	3475	5495	potentially suitable - owners requirements unsuitable
Borrans*	3430	5010	unsuitable - angling interests
Bowscale Tarn	**3336**	**5314**	**sampled - suitable if EN permit (SSSI)**
(Castle Carrock)*	3543	5546	unsuitable - working rsvr, fluctuating levels
Cardrew Mires Quarry	3350	5507	presently unsuitable - still active
Chapelhouse Rsvr	3260	5358	unsuitable - angling interests + pike, perch
Clints Quarry Moota	3143	5363	shallow, uncertain water levels SSSI
Cogra moss* (Arlecdon R.)	3097	5196	unsuitable - angling interests
Dubbs*	3421	5019	unsuitable - angling interests
Grizedale*	3525	4484	unsuitable - angling interests
Grizedale Lea*	3532	4483	unsuitable - angling interests
Harlock*	3249	4794	unsuitable - angling interests
Hodge Close Quarry	3317	5017	complex basin, used for diving
Jubilee Pond*	3553	5620	unsuitable - angling interests
High Fairbanks Rsvr*	3449	4974	unsuitable - shallow, angling interests
Over Water	3251	5350	unsuitable, SSSI - English Nature
Pennington*	3259	4790	unsuitable - angling interests
Poaka beck*	3243	4784	unsuitable - angling interests
Rowrah Quarry	3060	5175	possibly suitable - owners refusal
Skegles*	3479	5034	too remote and too shallow
Thrustonfield Lough*	3320	5563	unsuitable - angling interests, SSSI - English Nature
Wet Sleddale*	3549	5114	water transfer to Hawswater (schelly, charr)
Whins Pond*	3555	5309	unsuitable - angling interests
Wyndhammere*	3591	4851	little information - coarse fish angling probable

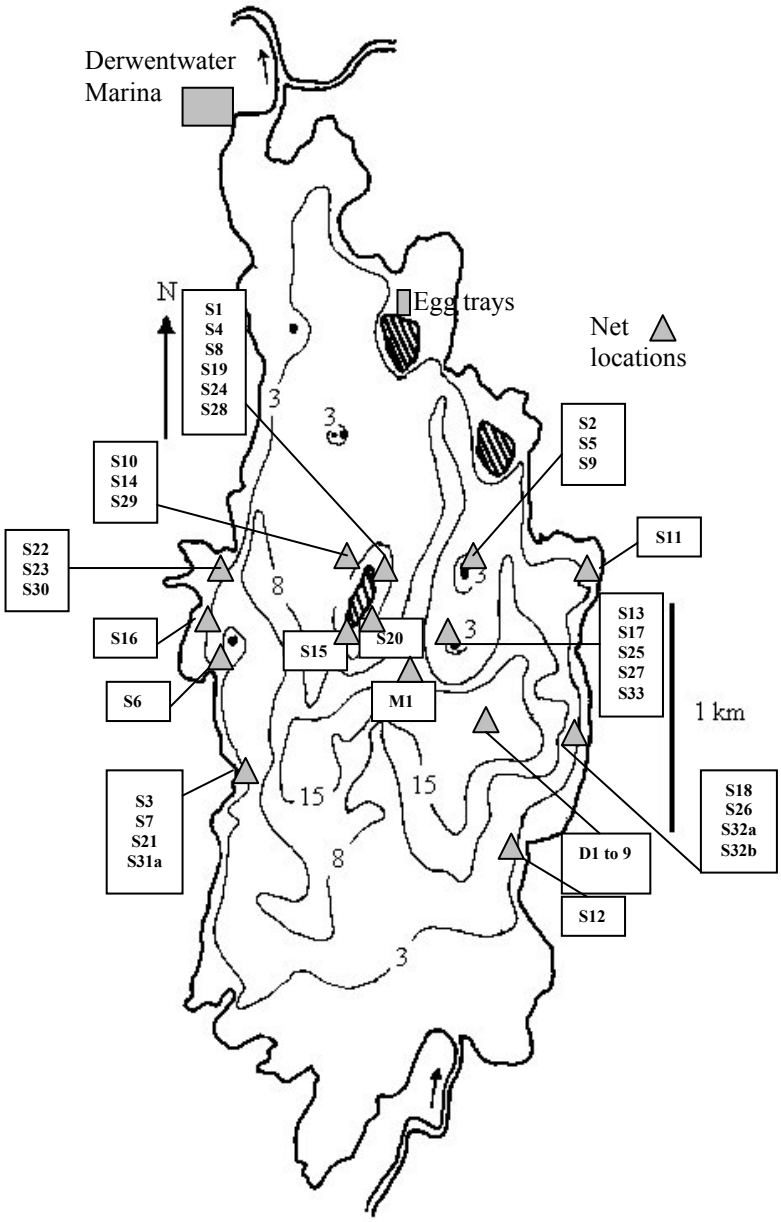

Figure 1 A map of Derwentwater showing bathymetry in metres and the locations and code numbers of the nets

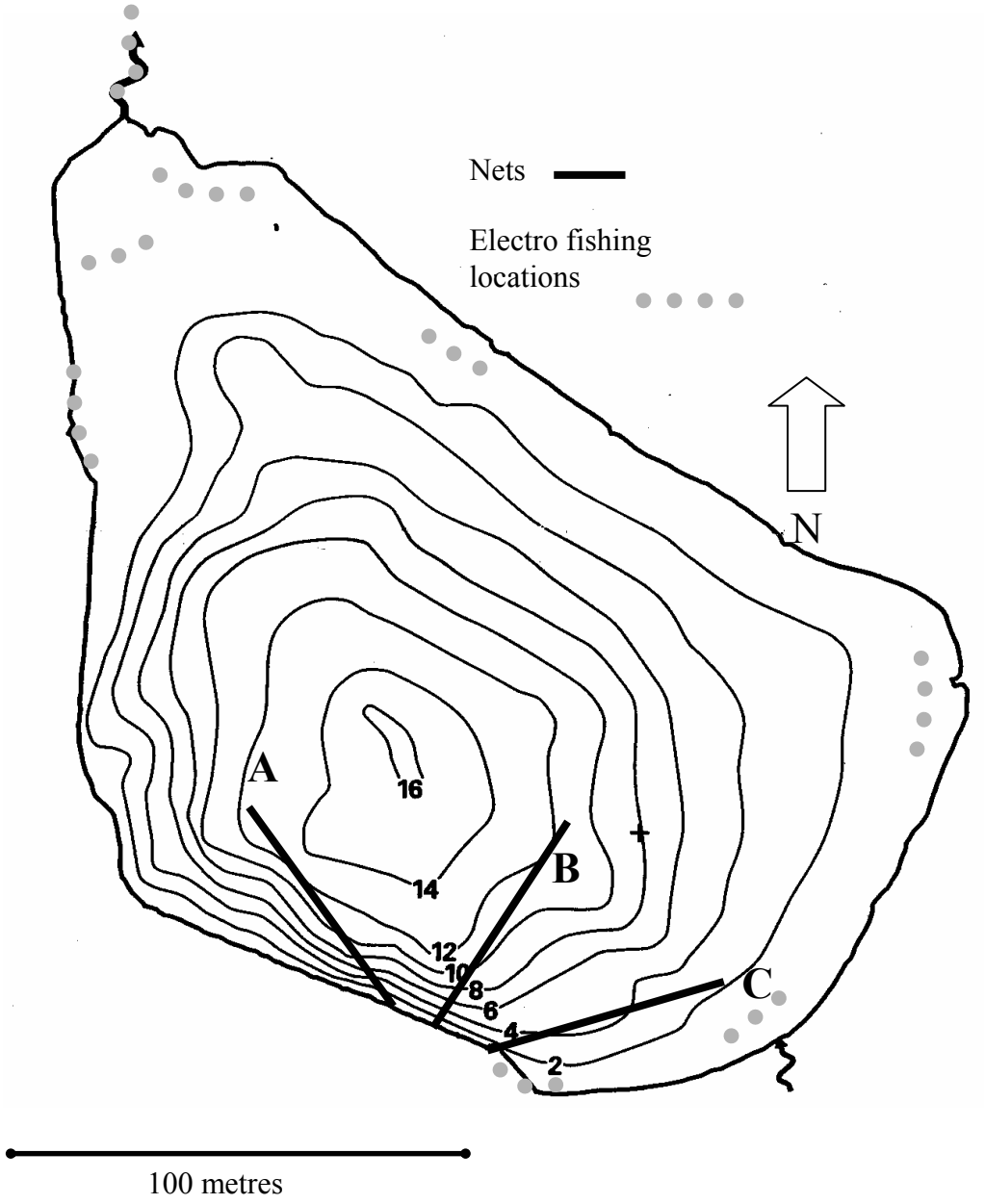

Figure 2 Map of Bowscale Tarn showing bathymetry in metres, the locations of nets and electro fishing sites

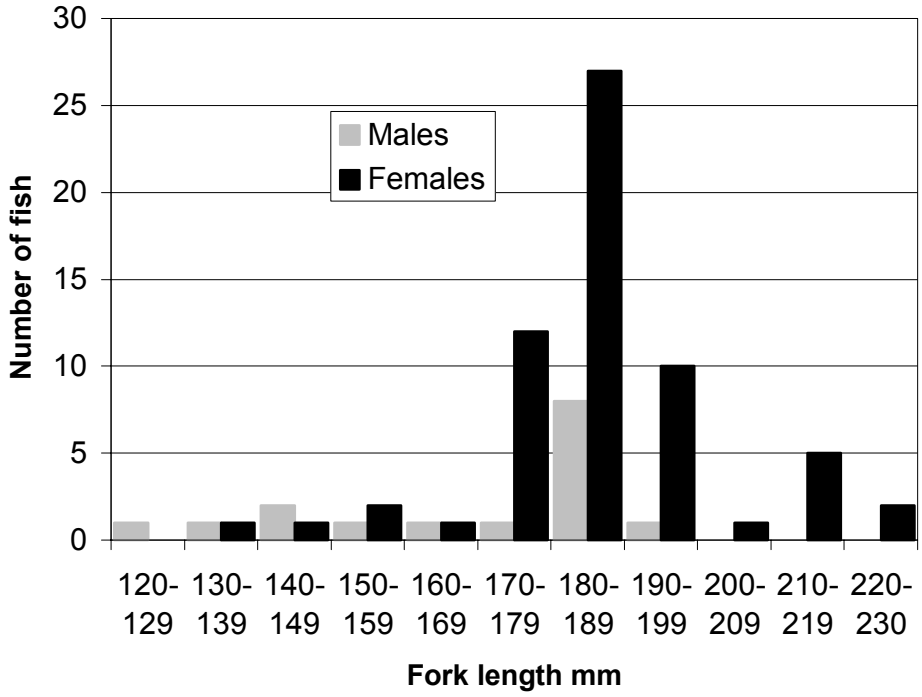

Figure 3 The length frequency distribution for male and female vendace from field data

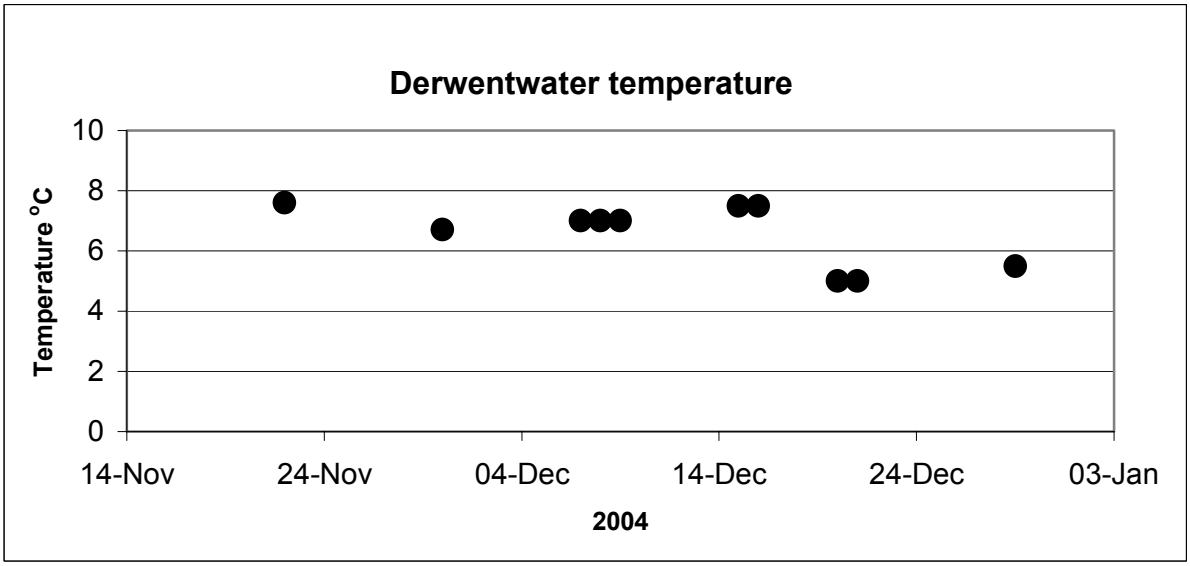

Figure 4. Derwentwater temperatures

Appendix 1 Details of the Derwentwater netting programme and fish catches

Net Code	Date set	Time set	Date out	Time out	Net Type	VENDACE males	VENDACE females	VENDACE TOTAL	Perch	Pike	B.Trout	Salmon	Roach	Ruffe	Dace	Minnow
D1	22-Nov	11.00	22-Nov	15.10	Smo				3	1				1		
D2	22-Nov	15.35	23-Nov	10.10	Smo	4	10	**14**	2							
S1	22-Nov	14.50	23-Nov	9.50	Smo	2		**2**								
S2	22-Nov	15.00	23-Nov	10.00	Smu				10	1	1		17			
S3	22-Nov	15.13	23-Nov	9.40	Smu				2	1				1		
S4	30-Nov	13.25	01-Dec	9.55	Smo				1				9			
S5	30-Nov	13.35	01-Dec	10.05	Smo					2			2			
S6	30-Nov	14.30	01-Dec	9.45	Smu					1						
D3	01-Dec	10.45	01-Dec	14.50	Smo		3	**3**	6	1				4		
S7	01-Dec	14.25	02-Dec	10.00	Smu				7	2			3			
S8	01-Dec	14.35	02-Dec	10.15	Smo								8			
S9	01-Dec	1.40	02-Dec	10.25	Smo				1	1	2		1	1		
S10	07-Dec	13.40	08-Dec	10.20	Smo				1				2			
S11	07-Dec	14.10	08-Dec	10.10	Smo				1	1	1					
S12	07-Dec	14.25	08-Dec	10.00	Smo				1				1			
S13	07-Dec	14.45	08-Dec	10.30	Smu					1	2		2			
D4	08-Dec	11.00	08-Dec	15.00	Smo		1	**1**	8				1	1		
S14	08-Dec	14.20	09-Dec	10.30	Smo								1			
S15	08-Dec	14.25	09-Dec	10.25	Smo				2		2		2			
S16	08-Dec	14.35	09-Dec	9.45	Smo				1	1			3			
S17	08-Dec	14.45	09-Dec	10.15	Smu								1			
S18	08-Dec	14.55	09-Dec	10.00	Smu				5	2	1		7	5	1	
S19	15-Dec	13.25	16-Dec	9.50	Smu					3			8	1		1
S20	15-Dec	13.30	16-Dec	10.00	Smo				1	1			3	2		
S21	15-Dec	13.40	16-Dec	10.10	Smo				1	2			2			
S22	15-Dec	13.45	16-Dec	10.20	Smu					1			3	5		
S23	16-Dec	14.45	17-Dec	10.40	V25/V30				3	3		1	13			
S24	16-Dec	14.55	17-Dec	10.45	V22				4		1		1			
S25	16-Dec	15.00	17-Dec	10.50	Vmix				2	1			1			
D5	16-Dec	15.10	17-Dec	11.00	Smo		part 1	**1**	2					1		
D6	20-Dec	13.30	21-Dec	10.40	Smo	2	6	**8**	4					1		
S26	20-Dec	13.40	21-Dec	10.25	V30				2	1	2		16			
S27	20-Dec	13.45	21-Dec	10.15	Vmix				1				8			
S28	20-Dec	13.50	21-Dec	10.05	V22					2	1		2			
S29	20-Dec	13.55	21-Dec	9.50	V25/V30					1	1					
S30	20-Dec	14.05	21-Dec	9.45	Vmix					2	1		2	1		
D7	21-Dec	13.40	22-Dec	9.50	Smo		2	**2**	1					2		
D8	21-Dec	13.45	22-Dec	10.00	Vmix	7	30	**37**	16					25		
M1	21-Dec	13.50	22-Dec	9.40	Smo				4				2			
S31A	28-Dec	13.20	29-Dec	10.15	Vmix		1	**1**	4	5	2		14			
S31B	28-Dec	13.20	29-Dec	10.15	Smu				1	1			15			
S32A	28-Dec	13.30	29-Dec	10.00	Smu								5	2		
S32B	28-Dec	13.30	29-Dec	10.00	Vmix		9	**9**	6		1		9	1		
D9	28-Dec	13.35	29-Dec	10.05	Smo	2		**2**	2					8		
S33	28-Dec	13.45	29-Dec	9.50	Smo									1		
					TOTALS	17	63	**80**	**105**	**38**	**18**	**1**	**164**	**63**	**1**	**1**

Appendix 2 Fork lengths, sex and reproductive status of vendace caught

INSHORE NETS

Date	Net Code	Net Type	VENDACE length mm	sex	status
23-Nov	S1	Smo	180	m	ripe
			125	m	ripe
29-Dec	S31A	Vmix	185	f	spent
29-Dec	S32B	Vmix	182	f	spent
			188	f	spent
			193	f	spent
			188	f	spent
			198	f	spent
			196	f	spent
			179	f	spent
			179	f	spent
			182	f	spent

DEEP NETS

Date	Net Code	Net Type	VENDACE length mm	sex	status
22-Nov	D2	Smo	145	m	ripe
			155	m	ripe
			167	m	ripe
			175	m	ripe
			135	f	ripe
			178	f	ripe
			180	f	ripe
			181	f	ripe
			181	f	ripe
			182	f	ripe
			183	f	ripe
			184	f	ripe
			185	f	ripe
			189	f	ripe
01-Dec	D3	Smo	188	f	ripe
			222	f	ripe
			190	f	ripe
08-Dec	D4	Smo	215	f	spent
17-Dec	D5	Smo	"210"	f	?
21-Dec	D6	Smo	142	m	spent
			185	m	spent
			149	i	i
			179	f	spent
			198	f	spent
			224	f	spent
			177	f	spent
			175	f	spent

Date	Net Code	Net Type	VENDACE length mm	sex	status
22-Dec	D7	Smo	191	f	spent
			192	f	spent
22-Dec	D8	Vmix	187	f	spent
			182	f	spent
			155	f	spent
			177	f	spent
			187	f	spent
			178	f	spent
			145	f	spent
			150	f	spent
			196	f	spent
			215	f	spent
			181	f	spent
			185	f	spent
			191	f	spent
			181	f	spent
			179	f	spent
			179	f	spent
			178	f	spent
			188	f	spent
			180	f	spent
			183	f	spent
			192	f	spent
			188	f	spent
			166	f	spent
			187	f	spent
			185	f	spent
			182	f	spent
			211	f	spent
			209	f	ripe
			176	f	ripe
			217	f	ripe
			137	m	i
			189	m	spent
			182	m	spent
			183	m	spent
			184	m	spent
			197	m	spent
			182	m	spent
29-Dec	D9	Smo	185	m	spent
			120	i	i

Appendix 3 Fork lengths (mm) of other species caught

Perch		Roach			Pike	Ruffe		B. Trout	Dace	Minnow
316	100	264	254	142	171	127	131	334	199	65
179	101	247	255	128	251	124	151	161		
268	222	275	125	115	735	147	159	223		
241	191	270	274	166	685	123	153	225		
142	189	270	268	200	293	85	129	300		
123	197	195	252	134	347	149	67	376		
124	180	154	245	147	268	77	61	287		
123	189	115	270	145	125	80	85	209		
116	186	94	283	115	122	77	75	204		
131	140	100	253	132	291	85	132			
67	155	116	274	114	303	68	128			
223	135	72	244	114	375	113	135			
272	124	124	265	262	288	59				
95	161	133	249	265	387	72				
235	113	271	295	242	357	108				
252	130	285	261	254	277	130				
240	148	272	267	222	269	115				
189	175	228	244	236	280	111				
210	108	235	283	275	280	109				
263	110	121	110	142	347	143				
171	175	227	267	136		153				
129	268	209	245	123		114				
308	185	153	264	127		118				
165	158	252	250	130		82				
134	162	270	294	130		150				
172	175	125	212	143		135				
124	130	125	250	114		149				
182	123	214	228	240		124				
274	124	243	257	275		129				
323	272	245	253	232		148				
319	243	265	277	239		145				
209	232	251	241	126		128				
214		243	248	238		131				
213		258	238	186		136				
152		279	217	143		131				
178		263	237	125		119				
169		280	124	116		150				
150		196	197	143		154				
114		276	112	243		146				
255		112	154	266		147				
163		143	123	144		90				
294		145	104	117		120				
187		155	113			121				
182		264	120			124				
103		228	143			144				
251		256	147			139				
282		233	260			124				
165		171	140			119				
275		265	145			123				

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