RE-INTRODUCTION OF VENDACE - PHASE 1

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SUMMARY

1. The vendace *Coregonus albula* occurs in many lochs throughout north west Europe. In the United Kingdom it has been recorded from only four lakes. In two of these, Castle Loch and Mill Loch at Lochmaben in south west Scotland, vendace became extinct earlier this century probably due to eutrophication, coarse fish introductions and other pressures. Vendace continue to survive in Bassenthwaite Lake and Derwentwater in Cumbria, but there is concern over its status there due to similar pressures as above. Consequently this species is probably the most threatened freshwater fish in the United Kingdom.

2. Throughout its range, vendace occurs in lakes of a wide range of sizes, but prefers those with a deep water refuge. A clean substrate of stones or gravel is required for spawning which usually occurs in December. The eggs hatch in 90-120 days. The diet of vendace consists almost exclusively of zooplankton.

3. The objectives of this study are to identify those lochs in south west Scotland which are best suited for the introduction of vendace, and to provide a plan for the translocation of Cumbrian vendace to the selected sites.

   The area of search covers all the lochs which drain south into the Solway Firth. The selection process includes desk and field studies.

4. The desk study approach was first to eliminate sites with features considered detrimental to the long term survival of vendace. These features included: insufficient depth, hydro electric reservoirs, undesirable fish species, acidification, previous sites for rare fish, proximity to urban areas, and extensive catchment afforestation. Following this review, seven sites remained. Daer Reservoir, which lies adjacent to the area of search, was added. These eight sites were then subjected to further scrutiny and selection resulting in four (Loch Skeen, Afton Reservoir, Loch Arthur and Daer Reservoir) being chosen for examination in the field.

5. Brief visits were made to each of the four waters above to obtain information not previously available, and to inspect them for suitable spawning substrate, access and other relevant features. Afton Reservoir and Loch Arthur (and Loch Trool) were found to be unsuitable, whereas Loch Skeen and Daer Reservoir possessed many good qualities for vendace introductions, and appeared acceptable pending inspection of their fish communities.

6. A survey of the fish species in these two sites was carried out in November 1995, by netting and electro fishing. At both sites only brown trout *Salmo trutta* and minnows *Phoxinus phoxinus* were caught. Importantly, coarse fish such as pike *Esox lucius* and perch *Perca fluviatilis* were not found.

7. Consequently, Daer Reservoir and Loch Skeen are the sites recommended to be considered as host waters for the translocation of vendace from Cumbria.

8. A translocation plan is given and details the methods recommended for such introductions. The different stages are: (1) select introduction site(s) (above); (2) select parent stock site(s) and obtain necessary licences and permissions; (3) collect ripe adults using multi-filament mixed-mesh gill nets; eggs from 15-20 females should be taken in each year of the programme; (4) fertilise on site with mixed batches of eggs and milt from several fish; (5) transport eggs immediately to at least two hatcheries; (6) soon after hatching, transport unfed fry to the introduction site(s). A three year programme is recommended. The estimated effort is 68 staff days in each year.

9. Protection and monitoring will be required at the host site for any translocations undertaken. Both Loch Skeen (a Site of Special Scientific Interest) and Daer Reservoir (a public water supply) have existing levels of protection which are probably adequate, provided the introduction of alien fish and detrimental changes in catchment management are prevented. Monitoring of any introduced vendace stocks should be done after about four years, and at subsequent agreed intervals.

10. The feasibility of restoring one of the lochs at Lochmaben (e.g. the Mill Loch) for vendace is examined. This would require reducing nutrient input from the catchment, perhaps dredging of sediments, and the elimination of the present fish populations (and fish parasites). Such an operation would be costly and perhaps unpopular locally but is worth investigating further in view of the historic importance of vendace to Lochmaben.

11. Previous attempts to introduce vendace to other Scottish lochs have had little success. Eggs from the Mill Loch vendace were distributed in two Galloway lochs which subsequently acidified. Fry from Bassenthwaite vendace put into a pond at Doune did not survive the introduction of pike and perch, and the fate of others put into Loch Earn is unknown.

12. Conservation action on vendace is now urgently required and translocations should start soon. However, more locations than the two sites identified above will be required, probably elsewhere in Scotland, to re- establish the species adequately in this country.

INTRODUCTION

Distribution and abundance

The vendace *Coregonus albula* (Linnaeus, 1758) occurs in many lakes in north west Europe, from northern Scandinavia and Russia to Bavaria, and from the English Lake District to western Russia (Svardson, 1956). Though this is mainly a lake species, some populations also occur in the Baltic Sea, migrating into fresh water to spawn. In the United Kingdom it has been known from only four lakes. Two of these are in Scotland (where it is called the Lochmaben vendace and was formerly described as a distinct species and subspecies - *Coregonus vandesius vandesius*), and two are in England (the Cumberland vendace - *Coregonus vandesius gracilior*) (see Ferguson, 1974).

The population in the Castle Loch, beside the village of Lochmaben, has been extinct for many decades and none has been recorded since shortly after a new sewage works was opened there in 1911 (Maitland, 1966a). In the Mill Loch, Lochmaben, specimens were caught in 1966 (Maitland, 1966b) and in subsequent years, but since none has been found for more than a decade vendace must now be regarded as extinct here too (Maitland and Lyle, 1991).

In Cumbria, the vendace occurs in Bassenthwaite Lake and Derwentwater which are larger and deeper than the Lochmaben lochs. It was found to be common in both lakes in 1966 (Maitland. 1966b) and has been the subject of a number of studies since then (e.g. Winfield *et al.*, 1994; Beaumont *et al.*, 1996). Surveys suggest populations of several tens of thousands of individuals in both lakes. However, threats here include eutrophication and the introduction of alien fish species (Winfield, 1995).

Habitat preferences

The vendace, over its whole range, occurs in lakes of a hectare or so upwards. These lakes are often quite rich and are rarely exceedingly oligotrophic. Depths of several metres are probably important to give freedom from summer heat stress and oxygen depletion (Jurvelius *et al*, 1988). Areas of clean gravel and stones are required for spawning. Strong competition and/or predation from pike *Esox lucius*, perch *Perca fluviatilis*, roach *Rutilus rutilus*, and other species is probably harmful unless a suitable deep/open water niche is available. The size of individual populations may fluctuate greatly from time to time, for which the reasons are not always clear but intraspecific competition for zooplankton has been shown to be one cause (unpublished observation).

Ecology

The vendace is a delicate pelagic fish which lives mainly in shoals in open water offshore areas. It remains in deeper (dimly lit) water during the day rising to the surface at dusk to feed, then descending at dawn (Maitland, 1967a; Dembinski, 1971). Spawning is carried out over gravelly/stony shores during winter, probably late November into December, though the actual timing varies from site to site (and perhaps from year to year) by a few weeks. The mature males gather early on the spawning areas and as females ripen they join the males and spawn together in midwater, the fertilised eggs dropping down into crevices among the stones and gravel. The fecundity varies with size, and ranges from 1,500 to 5,000 eggs per adult female. The eggs are 1.5-1.8 mm in diameter and yellowish in colour. The incubation period varies with temperature, but is normally 90-120 days at 1-4°C.

The young possess a small yolk sac on hatching, but, like other whitefish, they are free and able swimmers immediately. After absorbing their yolk sac over the first few days of life, the vendace fry start to feed on zooplankton which forms their main diet throughout life.They are normally some 7-9 mm in length but soon start to grow rapidly as the surface waters of their lake warm up and zooplankton becomes available. At the end of the first year they reach a length of 8-10 cm. After two years they may be 14-18 cm, at which time many are mature and growth slows, so that most adults only reach some 20-25 cm, even after 5 or 6 years, which is the normal length of life.

Conservation status

The vendace is probably the most threatened freshwater fish in the United Kingdom. It now exists in only Bassenthwaite Lake and Derwentwater, which are interconnected and suffer from a number of pressures. Bassenthwaite Lake shows signs of advanced eutrophication - the probable cause of the demise of vendace in Scotland. Derwentwater has 'natural' late summer near-anoxia in the deep water. One major pollution incident or outbreak of disease could eliminate both stocks. There is an urgent need therefore to give these sites special protection and to establish 'safeguard' stocks in suitable sites in both Cumbria and southwest Scotland.

THE LOCHMABEN VENDACE

The history of the Lochmaben vendace in southwest Scotland is interesting and at one point this fish was extremely important socially to the people of the Lochmaben area. The exact origin of the populations in the Castle and Mill Lochs at the village of Lochmaben is uncertain, but it is likely that they were derived from a common stock which inhabited the original post glacial Loch Maben (Maitland, 1970). This stock in turn, like the Cumberland vendace, is presumed to have originated from anadromous vendace which inhabited the marine basin now occupied by the Irish Sea.

The basis of the unusual local interest in this species is also rather unclear. It may have been due to the fact that the species was believed to occur nowhere else, but whatever the reason, considerable attention was given to the vendace by the townsfolk of Lochmaben and this species was the focus of two clubs which were active locally. The nature of these clubs is clear from a contemporary report which appeared in 'The Scotsman' (Wednesday, July 25, 1855) at the time (Anon., 1855):

"VENDACE AT LOCHMABEN - On Thursday last, at Lochmaben, was held the annual gathering of the St Magdalene Club, whose objects are at set seasons to fish the lochs for vendace and other finny tribes, and socially to masticate the same when cooked. When the fishings commenced in the forenoon, a considerable crowd of members and others had collected on the shore of the Mill Loch. The first haul of the net brought up about 28 dozen of vendace - some of them small, but mostly seven or eight inches in length, which is about their full size. Another cast or two of the net added only a few dozen to the previous number, and in the Castle Loch, which was next tried, not a solitary vendace came within range. Meanwhile on the Castlehill were being carried on such pastimes as foot-racing, leaping, wrestling and putting the stone, and races between grown-up girls and even stout dames for prizes of bonnets, caps, &c. About five o'clock the outdoor recreations terminated, and the members of St Magdalene's adjourned to a dinner at the Commercial Inn, in which vendace formed, as a matter of course, a principal dish. About half-past eight the party broke up, and thus ended the anniversary gathering of the St Magdalene's Fishing Club of Lochmaben."

Interest in the vendace and in the fishing clubs continued for many decades but gradually declined. It is not clear why this was so but it may well have been related to decreasing populations in both lochs. About 1911, a new sewage works for Lochmaben was opened beside the Castle Loch, into which the treated effluent was discharged. No vendace have been recorded from the Castle Loch since 1912. The situation in the Mill Loch was uncertain for many years,

but on the basis of unsuccessful netting there by Dr Harry Slack in 1953 (personal communication) the vendace was declared extinct in Scotland by Dottrens (1958). However, subsequent netting there in 1966 showed that the species was still present (Maitland, 1966a), but believed to be endangered (Maitland, 1966b, 1967a).

Although the Mill Loch was notified by the Nature Conservancy as a Site of Special Scientific Interest and was regarded as Grade 1 in the national Nature Conservation Review (Ratcliffe, 1977) no attempt at management was carried out and gradually the quality of the Mill Loch deteriorated. The factors involved will be discussed in detail elsewhere (Maitland & Lyle, in preparation) but may be summarised as:

Increasing eutrophication from surrounding farmland
Activities of anglers, including introduction of bream
Heavy parasitisation by the fish louse, *Argulus foliaceus*
Construction of a housing estate adjacent to one bank
Dumping of local rubbish adjacent to and into the loch
Lowering of loch level to allow public access around loch

Although the Mill Loch was netted at various times during the 1970s and 1980s no vendace have been recorded since 1970 and it is virtually certain that the species is extinct there. Dense algal blooms can now be found every summer and the character of the loch has changed completely.

OBJECTIVES AND APPROACH

The main objectives of this study are two-fold. Namely, to identify lochs in south west Scotland which are currently the most suitable for the re-introduction of vendace to this area, and to provide a feasibility plan for the translocation of vendace from Cumbria to the selected sites.

The identification of the most suitable sites was achieved in three stages. First, a desk study of all standing waters in the area using existing information was carried out. Second, preliminary field inspections were made to waters selected from the desk study to investigate further the relevant physical, chemical and biological features. Third, field surveys were undertaken to establish the species composition of existing fish populations in the final sites selected.

The translocation plan draws on the personal knowledge of the authors who have past experience of all the stages involved in the translocation of this species. The plan includes a detailed assessment of the effort and resources required for the full translocation process. In addition, the feasibility of the restoration of previous vendace sites is considered.

Also included for reference, are copies of Species Action Plans prepared previously for vendace in Great Britain (Maitland, 1995) and in England (Winfield, 1995) in Appendix (i) and Appendix (ii) respectively.

DESK STUDY

The objective of the desk study was to assess freshwater lochs in south west Scotland for their potential as sites for the re-introduction of vendace to this area, and to select up to four of the most suitable sites for study in the field, including a survey of their existing fish species. The only previously known sites for vendace in Scotland are the aforementioned Castle and Mill Lochs at Lochmaben (Figure 1). As specified by SNH, this area was to be given priority in the search for suitable lochs for the re-introduction of vendace to Scotland, but, by agreement, the area of search was extended to include the five Hydrometric Areas (77-81) which drain into the Solway Firth (Figure 1). In addition, sites outwith these areas, but geographically close, could be included for consideration if they appeared to possess outstanding qualities for this purpose.

Preliminary list

The initial group of sites reviewed was taken from the survey of fresh waters in Great Britain by Smith and Lyle (1979), where the total number of lochs within the selected area is 109 (Table 1). That survey was conducted from 1:250,000 scale maps on which the lower size limit of lochs depicted is *ca.* 4 ha. This size defined a first working criterion for selection since smaller lochs are unlikely to be physically suitable (e.g. too shallow) for vendace, or sufficiently resistant to change.

As a first step, all 109 lochs were listed by Hydrometric Area and National Grid Reference. Also listed, where available, was information on surface area, depth and those which are controlled reservoirs.

Elimination of unsuitable sites

The next objective was to reduce the number of sites to a manageable number for more intensive investigation of physical, chemical and biological features which could only be determined from site visits. The various criteria used to eliminate sites are detailed below, and the sources of information were from : literature (Murray and Pullar, 1910; Smith and Lyle, 1979; Flower *et al.*, 1987; Maitland *et al.*, 1987; McLeod, 1993); personal communications (Dumfries and Galloway Regional Council, Forest Enterprise, Scottish Natural Heritage, Strathclyde Regional Council, West Galloway Fisheries Trust), Ordnance Survey 1:50,000 scale maps; and personal experience of the authors. A questionnaire on fish was also distributed to angling clubs in the area.

1. *Depth*

All waters whose maximum depth was known to be less than 5m were discarded. The benefit of a deep water refuge for vendace is absent at such sites. The fact that one of the previous sites for vendace (the Castle Loch) has a maximum depth of only 5.5m did not affect this view, since vendace are now extinct there. Also, threats such as eutrophication and climatic change are perhaps increasing generally and are more likely to be influential in shallow waters.

For a number of lochs in the smallest size category listed by Smith and Lyle (1979), i.e. < 25 ha, depth was unknown. There was no capability in the project to survey depths for the preliminary assessment of suitability and consequently such sites were eliminated.

2. *Hydro-electric reservoirs*

Because of the littoral spawning requirement of vendace, the potential exposure of eggs by reservoir drawdown is an important negative feature. During the egg incubation period (December to February), electricity demand is high and rapidly fluctuating reservoir levels are common. Consequently, such sites were eliminated.

Note: Conversely, public water supply reservoirs have less demand in winter than in summer and levels are more stable. In addition, by implication of use, water quality must be high. However, in any controlled site there is the threat, in the long term, of severe drawdown for maintenance. Also, the likelihood of low levels during summer droughts, which may lead to unsuitably high temperatures for vendace and the loss of their deep water refuge, should be examined in each instance. In general however, public water supply reservoirs are viewed favourably for fish introductions, not least because they are artificial, and thus natural ecosystems are not being affected.

3. *Predatory fish*

It would be an unnecessary risk to attempt to establish vendace, a purely planktivorous fish, in sites inhabited by piscivorous species such as pike and perch, if avoidable. Or, indeed, sites where bottom feeders such as tench *Tinca tinca* or ruffe *Gymnocephalus cernuus* could feed on vendace eggs. There is also the danger of alien species being introduced as live bait by pike fishermen, as has happened at Bassenthwaite Lake, Loch Lomond and Llyn Tegid - all sites for Coregonid species. Although pike, for example, occur in both existing British vendace waters, the interaction between these two species there must be in balance. In sites proposed for introductions such predatory species are an unwanted pressure on the establishment of new vendace populations,

and where known to occur, such waters were eliminated.

4. *Acidification*

A number of sites within the area of search are known from previous studies to have been severely affected by acidification, to the extent, in some cases, of complete fish loss (Maitland *et al.*, 1987). Although some amelioration in acidity has been reported recently, and in some cases the return of fish, acidification constituted an unnecessary risk in the long term (particularly in view of the new policy on power station emissions in Ireland). Also, some of these waters are now, or will become, sites for scientific research (Freshwater Fisheries Laboratory, Pitlochry, personal communication).

Lochs on the fringes of high acidification areas were noted as such, but not necessarily eliminated for this factor, at this stage.

5. *Rare species*

Waters which once had rare or endangered fish species were excluded on principle (Maitland, 1985). Two sites known previously for Arctic charr *Salvelinus alpinus* (Loch Dungeon and Loch Grannoch) should not have vendace introduced since they may be considered for re-introduction of Arctic charr in future.

The two earlier sites for vendace were rejected. Both Castle Loch and Mill Loch are now highly eutrophic with substantial populations of coarse and predatory fish (see below).

6. *Urban*

Sites in close proximity to urban development were eliminated. For the purposes of this exercise such waters were considered highly vulnerable to pollution/environmental change/undesirable fish species introductions/disturbances. In this respect, they were regarded as having a low potential for the protection of a vendace population.

7. *Known waters*

Waters for which there was little formal information but were known from previous surveys or visits to be unsuitable in terms of, for example, substrate for spawning, location and use (e.g. intensive angling) were not considered further.

8. *Forestry*

Because of potential enrichment, from artificial fertilisation, and possible sedimentation of spawning gravels, pollution and general disturbance, sites with a high proportion of commercial forest in their catchments, particularly in close proximity to the loch itself, were not considered to be safe or stable sites for vendace introduction.

Sites where any of the above eight reasons for elimination apply are indicated by dark shaded boxes in Table 2. Although two reasons are given for some sites, in general, once a site was eliminated it was not investigated further. Light shaded boxes in Table 2 indicate marginal concerns which taken singly may not be cause for elimination, but where two such concerns occur against a site it was then discarded. Sites in bold type are those selected for further investigation.

Note: The results of the fish questionnaire were not available until very late in the study and are not included in Table 2. They did not, however, significantly alter the conclusions of the desk study. In total, the questionnaires returned reported pike to occur in 29 waters, viz - numbers 4,5,6,7,18,21,23,31,32,34,36,37,38,40,41,43,45,46,47,48,53,57,59,60,64,80,89,90, and 91.

At this stage it should be borne in mind that the objective of this desk exercise was to select those waters from the original set which are most likely to be best suited to the long term survival and reproduction of vendace. Elimination does not always mean that sites are incapable of supporting vendace in the short term, (or even in some cases in the longer term), but that, for this exercise such waters possess features which are either of higher potential risk, or of lower potential benefit for vendace introductions than the sites selected.

Possible sites

After the preliminary elimination stages, seven of the original 109 potential sites remained. At this point Daer Reservoir was added to the list. This site lies just outwith the selection area (Figure 1) and is within the River Clyde catchment. It was included principally because of its size (it is one of the largest waters in this area) and that it is an artificial water supply reservoir. Physical details of these eight waters are given in Table 3.

A further selection process was carried out for these eight sites on the basis of a more detailed examination of their potential for vendace, so as to reduce the number to about four sites to be inspected in the field.

Loch Urr and Long Loch of Glenhead were marginal selections since there were doubts over the presence there of predatory coarse fish, and vulnerability to acidification, respectively (Table 2). Examination of bathymetric maps (Murray and Pullar, 1910) showed that although Whinyeon Reservoir and Loch Ochiltree had acceptable maximum depths, the areas of deep water were very small and could provide only minimal deep water habitat for vendace. Consequently, these four sites carried either, a higher risk level or a lower benefit level than the others, and were now

omitted. *(Pike were later reported to occur in Lochs Urr and Ochiltree from the questionnaire returns).*

The desk study phase was completed by a final examination of relevant features of the four remaining sites: Loch Skeen, Afton Reservoir, Loch Arthur and Daer Reservoir.

Basin shape is important in terms of determining the proportion of deeper water available. In this respect volume development (V_d) was considered, calculated by $V_d = 3D_{mean}/D_{max}$, where higher values represent a greater proportion of deep water (Hakanson, 1981). No detailed bathymetry was available for Afton Reservoir, but the calculated values of V_d for Loch Skeen, Loch Arthur and Daer Reservoir are 1.49, 1.55 and 1.02 respectively. (The values for Loch Urr, Long Loch of Glenhead and Loch Ochiltree are 0.83, 0.99 and 0.68 respectively, further demonstrating their lower suitability).

All four remaining sites were considered to have good protection potential should they be selected for vendace introduction. Loch Skeen is a Site of Special Scientific Interest and it and its catchment are owned by the National Trust for Scotland; also, it is only accessible via a steep mountain path. Loch Arthur is privately owned by a local community who have expressed an interest in conservation issues. Both reservoir sites, as public water supplies, have existing protection over a range of likely damaging activities both for the reservoirs themselves and their catchments.

Recent chemical information on water quality for Afton Reservoir and Daer Reservoir was provided by Strathclyde Water Services, and data from 1988 were available from an earlier study at Loch Skeen. Details are given in Table 4. No aspects of water chemistry were found which might be detrimental to vendace survival and reproduction. Indeed, pH values indicated that protection from acidification was high for these sites.

Brown trout *Salmo trutta* was the only fish species reported to occur at Loch Skeen, Afton Reservoir and Daer Reservoir (no information on fish had yet been found for Loch Arthur). Casual angling occurs for the natural stock of brown trout at Loch Skeen, whereas at Afton and Daer Reservoirs formal club angling takes place and these two sites have been stocked with brown trout in the past. These situations were perhaps the minimum potential interference to vendace by other species which could be expected in this area which has high angling participation, including an expanding interest in coarse fisheries.

Thus, Loch Skeen and Loch Arthur (natural lochs) and Afton Reservoir and Daer Reservoir (artificial water supply reservoirs) were considered those waters most likely to be suitable for vendace introduction from the results of the desk study phase.

The next stage was to investigate these sites further by field survey. It was decided to include Loch Trool in at least the first stage of field visits. This site was discounted earlier because of the presence of pike. However, unlike at other such sites, pike are regularly netted at Loch Trool by the owners and there is thus an element of control over their numbers, making this threat perhaps less damaging than elsewhere.

FIELD SURVEY

Field studies were carried out in two stages. First, each of the sites (Daer Reservoir, Afton Reservoir, Loch Trool, Loch Arthur and Loch Skeen) was visited for preliminary reconnaissance on 31 October/1 November, 1995. These were fact finding visits to investigate further site suitability for vendace introductions, and included littoral substrate examination, water chemistry sampling and, where possible, discussion with local contacts on relevant aspects, particularly fish species and angling. The results of these preliminary visits are given below in note form for each of the five sites.

Exploratory Visits

Daer Reservoir

This is a public water supply reservoir controlled by the Water Services Department of Strathclyde Regional Council. At 202 ha in surface area and 37.1m maximum depth, it is the largest of the sites visited, and one of the largest waters in the area. There are extensive areas of clean gravel/stone substrate suitable for vendace spawning around the shoreline, with very few areas of aquatic vegetation. Water levels are consistently high throughout the winter months (i.e. during the vendace spawning and egg incubation period). The lowest water supply take-off depth is 20m, and even if this drawdown was reached during a severe summer drought (which is extremely unlikely) a loch of some 46 ha in area and 17m in depth would remain (this is larger and deeper than some of the others under consideration).

Brown trout was the only species reported for this site. The reservoir was stocked previously with this species but no stocking has occurred in recent years. Angling is controlled and only boat fishing is permitted. The site is relatively remote, although a narrow public road does run along the west shore. Any fish entrained during abstraction are caught in the filtration works. However, it may be possible for fish to escape in compensation water, or reservoir overflow, into the outflow river. The prospect of vendace doing so should not be a problem since there are no standing waters below this point. Water chemistry is given in Table 4.

Afton Reservoir

Afton Reservoir is also controlled by Strathclyde Water Services as a public water supply. Similarly to Daer Reservoir, this site has many favourable aspects, e.g. adequate spawning gravels, good water quality, high water levels in winter. However, detailed bathymetry was not available prior to visiting this site after which its value for vendace became doubtful as it lies in a steep sided V-shaped valley and has a low proportion of deep water. Furthermore, discussions with the engineers on site revealed that the reservoir levels can drop very low in summer, almost

to the point of complete drainage. This site was therefore dismissed as a candidate for vendace introductions. The reservoir is stocked bi-annually with brown trout, and angling takes place from the banks. Water chemistry is given in Table 4.

Loch Trool

Loch Trool is owned by Littlewoods Estates and is one of the larger natural lochs in the area, although levels are affected by a sill at the outflow. Site inspection showed that spawning substrate was available in places although this tended to have a higher proportion of large stones and was not as 'clean' as at the reservoir sites (the latter perhaps an effect of the outflow sill). This site is regarded as being of marginal suitability because of its pike population - however, as mentioned above, there is some control over pike by netting for the benefit of brown trout angling. Although not considered further at present, this site does have potential for vendace but further investigation and management, outside the scope of the current project, would be required. Public access, on foot, is readily available from a nearby camping/caravan site which could give some concern over aspects of site protection. Water chemistry is given in Table 4.

Loch Arthur

This is a natural loch, privately owned by the Loch Arthur Village Community. It is believed the owners would favourably regard use of this site for conservation purposes. However, the site visit revealed a paucity of likely spawning habitat, most of the shoreline having emergent macrophyte growth. Additionally, the public road close to the west bank gives ready access to the loch side. Local investigations revealed that casual angling is commonplace and that pike and perch are amongst the species caught *(this was confirmed later from questionnaire returns).* Whilst fishery management could improve the situation, control over access and angling practices could be problematic. Also, some increase in potential spawning substrate might be required. Water chemistry is given in Table 4.

Loch Skeen

This is a completely natural, unregulated, loch, owned by the National Trust for Scotland and is a Site of Special Scientific Interest. In addition, it is within the original vendace catchment (i.e. River Annan). It is the highest altitude site considered and will freeze over in most winters, but this is not perceived to be a problem. Only brown trout were reported to be present and casual angling does occur. Although reasonably remote, the loch is on a popular walkway - albeit access requires a steep climb. While this enhances site protection, it may give logistical problems for the transport of vendace to the site. Should any introduced vendace leave the loch through the outflow, they would have to survive the vertical falls of the Grey Mare's Tail. There are no standing waters below this point. Water chemistry is given in Table 4.

Following consideration of the above results from the preliminary field surveys, it was concluded that only Daer Reservoir and Loch Skeen present scenarios which appear to be immediately without risk for vendace introduction, pending confirmation of the species composition of their fish communities by a second stage of field survey

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Field Sampling

The surveys of fish populations were carried out at Daer Reservoir and Loch Skeen between 21 and 23 November, 1995. The methods used were ; standard survey type mixed mesh gill nets (12 panels with mesh sizes ranging from 19 - 120 mm), fyke nets and back-pack electro-fishing apparatus using pulsed DC current. Four gill nets were used at each site, set out for approximately 18 hours overnight in both littoral and deep water habitats. The nets were set by boat at Daer Reservoir, but at Loch Skeen long lines across the loch or its bays were required. Fyke nets (two) were set just offshore at Daer Reservoir only. Measured lengths of shore with different habitat types were electro-fished at both waters. The locations of the sampling sites for each of the methods are shown in Figures 2 and 3.

Details of the results of the fish surveys are given in Table 5. Brown trout and minnows *Phoxinus phoxinus* were the only fish species found, and occur at both sites. The main difference between the fish at these sites is that the brown trout population in Daer Reservoir has been enhanced by past stocking from various sources, whereas there is no evidence to suggest that the brown trout in Loch Skeen are anything but a natural stock. For this reason, a sample of the brown trout taken at Loch Skeen has been retained for future biological analysis, if required. A comparison of the length/frequency of fish from both sites is given in Figure 4.

TRANSLOCATION PLAN

This section describes the stages of operation required for the translocation of vendace from the Cumbrian populations - the only GB stocks available - to the two sites in south west Scotland selected by the processes described above. The plan is specific to the locations of the parent stocks, the introduction sites and the likely location of hatcheries. At each stage there may be several options in terms of methodology and logistics and the following summarised proposals are those considered to be the most practical, cost efficient and appropriate for the successful reintroduction of vendace to south west Scotland. It is recommended that initial planning should consider an annual translocation operation in each winter of a three year period.

Procedure

Stage 1. The selection of suitable introduction sites has already been carried out, as described above. This produced two waters - Daer Reservoir and Loch Skeen - but the number of sites should be expanded to at least five in the next one or two decades, probably over a broader geographical area, to achieve the satisfactory establishment of this species in Scotland.

Clearly, any translocation programme to a Scottish loch will require the agreement and goodwill of the owner(s) of that loch. This will need to be negotiated by SNH before any translocations start.

Stage 2. The selection of the parent stock for this translocation can only be from the Bassenthwaite Lake or Derwentwater populations, or from both. At present, there is greater knowledge of vendace spawning behaviour in the former site which is therefore favoured for reasons of practical efficiency.

The collection of adult vendace from these lakes will require permission and licences from English Nature (Wildlife and Countryside Act 1981) and the National Rivers Authority (for any netting), also it is advisable that permission is gained from the Lake District Special Planning Board and that Keswick Police are notified of any fish netting operations. In addition, permission may be required from riparian owners regarding access and boat launching.

For the translocation of vendace to the Scottish lochs, permission and licence will be required from Scottish Natural Heritage (Wildlife and Countryside Act 1981).

Stage 3. The successful collection of sufficient numbers of of ripe adult vendace from the parent stock cannot always be assured. This fish normally spawns on specific spawning grounds

during late November/December but at times which may vary from year to year by several weeks. Also, studies by Winfield *et al.* (1994) show that recruitment of vendace in Bassenthwaite Lake is inconsistent. Although several methods of capture are theoretically possible, it is recommended that multi-filament, mixed-mesh gill nets are used. This is for reasons of efficient, unbiased collection and humane removal of fish (to be returned after stripping unless required for, say, genetic analysis). To maximise genetic diversity, fish should be taken at different places and dates, if possible. For the scale of the operation envisaged here it is recommended that an average of 15 to 20 females and at least an equal number of males, are stripped in each year of a three year programme. This figure is probably a minimal number of fish to aim for to ensure adequate genetic diversity, but has been restricted to minimise potential damage to parent stock and for transportation and hatchery logistics (see below).

This stage, which may require repeated netting sessions at the lake(s), should ideally be carried out by personnel with experience of the species and the site(s) to avoid wasted effort and unnecessary damage to the stock. However, the potential for disruption of the netting operation by dangerous winter weather conditions should be borne in mind when planning.

Stage 4. Stripping and fertilisation of eggs should be carried out at the netting site with as much care as conditions and circumstances will permit. It is recommended that batches of eggs from a number of females are mixed, then fertilised with a mixture of milt from a number of males. Some measure of the volume of eggs collected should be made for an estimate of numbers. Similarly, details should be taken of the fish stripped. Eggs can then be transported in thermally insulated containers to the hatchery. The eggs may be transported 'dry' or in lake water.

Stage 5. Care and experience of eggs of this species are required for their successful incubation. In mainland Europe, eggs of *Coregonus* species are generally incubated in upright jars, although the authors have had good success using shallow trays (Maitland, 1967b, 1969). It is recommended that the location of hatcheries is nearer the introduction site(s) than the collection site(s) so that the main transport is of eggs which are at least as resilient as young fish (in *Coregonus* species) and much less bulky. It would be best to use more than one hatchery to safeguard against accidental loss, and it may be a useful long term strategy to investigate the possibility of contracting a commercial hatchery to incubate some of the eggs.

The incubation of vendace eggs takes some 90-120 days and egg husbandry will constitute the bulk of the effort required. Almost daily attention will be required and it is estimated that, on average, some 20-30 staff days of effort will be required at each hatchery during the incubation and hatching periods. Clearly this is the predominant consideration in resource allocation.

Stage 6. The transfer of vendace from hatcheries to introduction sites should take place soon after hatching, at the unfed fry stage. This avoids the additional complications, efforts and costs of rearing fish to, say, the 'fingerling' stage and also further risking accidental loss. In addition, the numbers reared will be smaller, total genetic diversity may be changed and feeding behaviour impaired for introduction to the wild. Also, at Loch Skeen, there is the practical difficulty of getting them to the site. Past experience by the authors shows that hatching occurs over about one month, so at least three transfers would be required throughout this period from each hatchery. In doing so, careful consideration should be given to creating a good mix of the fish introduced to each site by taking batches from different hatcheries at different times to maximise genetic diversity.

The direct transfer of adults is not recommended. Firstly, it would remove fish from the parent site. Also, it would only be practical to transport relatively very low numbers of adults (almost impossible at Loch Skeen unless by helicopter transport). Vendace is a delicate fish and mortalities might be high throughout the process. Consequently, it could be difficult to achieve an acceptable genetic diversity. There is also the further complication of possibly transferring disease or parasites to the introduction site.

The full translocation process should be repeated for two additional years, making three translocations in total. This will help to increase the genetic diversity of the new stocks and also their chances of success which may be impaired by unforeseen (or unknown) problems arising in any one year.

Site protection and monitoring

Clearly, if vendace are to be introduced to Loch Skeen and/or Daer Reservoir, then some form of site protection for this species must be instigated there.

Loch Skeen is already part of an existing SSSI and the owner (the National Trust for Scotland) is likely to be supportive of any proposals made. In fact, existing protection is probably adequate, assuming that the introduction of other fish species and detrimental changes in management are both prevented. The catchment (132 ha) is almost exclusively rough grazing.

Daer Reservoir presents a more difficult situation, for, though the owners (presently Strathclyde Regional Council) are likely to be sympathetic to the project, the primary aim of the reservoir is to produce water for public supply and this criterion will control management there. Nevertheless, such management is likely to be largely favourable to vendace and, if agreement can be reached with the owner to avoid such threats as the introduction of coarse fish, drawdown

during winter, etc., it should be possible to protect the stock adequately. The catchment (4739 ha) should also be protected from inappropriate change. Land use at present comprises 88% rough grazing and 12% forest.

Transferred stocks should be monitored by netting programmes which should start approximately 4 years after the first translocation.

An estimate of the effort required to carry out each stage of the translocations is given in Table 6. These are guidelines to the minimum effort required - the fish netting/egg collection stage is difficult to predict accurately; the estimate for incubation husbandry will depend on the existence/availability of suitable hatcheries, the methods used (e.g. jars or trays) and whether a commercial hatchery is employed. The assessments are given in staff days to enable the production of a rough estimate of the overall costs which may be incurred.

THE LOCHMABEN LOCHS - FEASIBILITY OF RE-INTRODUCTION

If the theory proposed by Maitland (1970) concerning the origin of the vendace at Lochmaben and outlined above, is correct, then it may be assumed that, as the glacial Loch Maben drained, then vendace probably occurred in all the kettle hole lochs left in its basin. This would include, not only the Castle and Mill Lochs, but also the Kirk and Hightae Lochs and probably even the Dry Lochs. As ecological succession proceeded in these lochs, however, it is likely that the vendace disappeared fairly quickly from the smaller lochs as they enriched and macrophytes invaded any stony shores. The larges ones too became unsuitable as eutrophication progressed and other threats (e.g. the introduction of various coarse fish species, especially pike and perch) developed. As noted earlier, these and other pressures were eventually responsible for the extinction of the vendace in even the largest of the lochs during the 20th century.

For both zoogeographic and social reasons it would clearly be desirable to re-introduce the vendace to one or more of the Lochmaben Lochs - but how feasible is such an option? The task would involve reversing current trends in all these lochs and turning them back to what they are believed to have been like, say, 150 years ago, when vendace thrived there (Anon.,1855). Several ecological and political problems need to be addressed if this option is to be attempted.

Of the set of six lochs within the original Loch Maben basin some are much more suitable than others. The Dry Lochs are really too small and shallow to be worth considering. The Castle Loch, although by far the largest in area of the group, is felt to be unsuitable because of its small mean depth and the absence of any area of deep water, as is also the case in the Hightae Loch. This leaves two lochs as contenders - the Mill Loch (probably the most suitable on morphometric grounds) and the Kirk Loch. The existing problems are rather comparable at both lochs and so the management techniques required to restore (and maintain) either of them as suitable sites for vendace are similar.

Eutrophication

Increasing nutrient enrichment from the catchments, (with subsequent changes in loch ecology and perhaps hypolimnion deoxygenation in summer), is probably a major factor in the elimination of vendace from the Lochmaben lochs. Reversal of this trend would be possible, but both difficult and expensive. It would involve the development of a detailed catchment management plan which would greatly reduce the input of nutrients from such as agricultural fertilisers and septic tank discharges, to the stream networks. In addition, if success is to be achieved quickly, it may be necessary to remove the nutrient-rich top layers of mud from the loch bed. This could be done during a period of drawdown for other purposes (see below).

Coarse fish

If either of the lochs could be moved back to a mesotrophic or even an oligotrophic situation then the coarse fish present are likely to do less well. However, the best management option would be to eliminate all coarse species and thus maximise the establishment and performance of vendace there. To do this would require the use of a piscicide such as rotenone (Morrison, 1987), ideally in combination with a lowering of the loch level to below the sublittoral zone. Such a programme could be successful, but is likely to meet with considerable resistance from some of the local people (both anglers and those whose income depends on visiting anglers). In addition, it would also be necessary to ban any angling there in future and prevent the re-introduction of any coarse fish species - either naturally (via connections with the other lochs) or through angler introductions.

Alien plants

The role of alien plants in recent changes and the extinction of vendace is uncertain but is a factor which must be considered. In particular, it is believed that some species invade areas of spawning substrate, gradually smothering clean gravels and accumulating organic silts there. Several species are involved. Some have been present for several decades (e.g. *Elodea canadensis*), others are relatively recent introductions (e.g. the invasive *Nymphoides peltata*, introduced to the Mill Loch from gardens now bordering the loch). Such species, like coarse fish, are likely to do less well if the loch could be moved back to a mesotrophic or even an oligotrophic status. However, elimination would be the best option and this, though difficult, could be achieved through the use of herbicides and drying out when the loch level is lowered.

Parasites

The role of parasites in any of the Lochmaben lochs is uncertain, but the extensive infestations of *Argulus foliaceus* on vendace (and other fish) prior to its demise in the Mill Loch (Maitland, 1966a; Campbell, 1971) must at least have been a contributory factor. This parasite, and probably others, are likely to have been introduced with coarse fish in the past. Its extinction would be possible if all fish were to be eliminated from the loch for some time by the use of piscicides (see above).

In conclusion, it can be seen that the restoration of one of the Lochmaben lochs to a habitat suitable once more for vendace, though possible, would involve difficult catchment management, substantial (temporary) lowering of loch levels and the use of both piscicides and herbicides. Such a programme would be extremely expensive and probably not popular locally.

PAST TRANSLOCATIONS

Lochmaben Vendace

Following the re-discovery of vendace in the Mill Loch and the two Cumbrian lakes it was apparent that the species was under considerable threat at the Lochmaben site (Maitland, 1966b) and that conservation action should be taken as soon as possible. Unfortunately, though a translocation scheme was proposed at the time, it was not supported officially and subsequent work had to be done on a part-time basis.

Following an exercise rather similar to the present one, two lochs were chosen as host sites - Loch Valley and Loch Neldricken in the upper catchment of the River Cree. At the time, these lochs appeared extremely suitable for vendace, having appropriate physico-chemical conditions and a limited range of fish species. Unfortunately, what was not known at that time was that these lochs (and other lochs in the vicinity) were acidifying and soon to become unsuitable for fish (Maitland *et al.*, 1987).

Ripe vendace were collected from the Mill Loch on 7 December, 1968, stripped and returned to the loch. The fertilised eggs were placed in thermos flasks and transported immediately to Lochs Valley and Neldricken, where they were carefully distributed over appropriate clean gravels. The lochs were subsequently netted in 1974, by which time apparently acidification had reached significant levels. No vendace were found but several brown trout were taken - the last to be found in these lochs until recent times.

Cumbrian Vendace

As part of an experimental programme to investigate the incubation and hatching of the eggs of threatened fish species (Maitland and Lyle, 1990, 1992), ripe vendace were collected from Bassenthwaite Lake on 1 December, 1988, stripped and returned to the lake. The fertilised eggs were placed in thermos flasks and transported immediately to hatcheries at FCC Stirling and IFE Penicuik, where they were incubated. A very successful hatching was achieved and unfed fry were subsequently released at two sites - Doune North Pond and Loch Earn. The former, though gill netted with negative results prior to stocking, was subsequently found to have an introduced pike and perch population and none of the 2,000 fry introduced there survived.

Loch Earn, apart from its position outwith south west Scotland, fulfils most of the translocation requirements for rare fish species (Maitland and Lyle, 1992). In addition, it has lost much of its intrinsic natural interest owing to various pressures, including regulated water level, cage fish farming, water sports and mild eutrophication. In spite of these problems, it is believed to be a

suitable habitat for vendace and similar in many respects to some of the large Scandinavian lakes (e.g. Lake Mjosa) where vendace thrive (Aass, 1972).

Some 8,400 vendace fry were introduced to Loch Earn in April, 1989. There has been no opportunity to date to check on their survival, but if the introduction was successful the stock should now be in its third generation and vulnerable to survey gill netting. The situation is thus highly relevant to the current vendace re-introduction programme and it is proposed that netting should be carried out there as part of Phase 2. However, the stock here originated from a small number of parents at Bassenthwaite Lake and may be low in genetic diversity. Consequently, without further investigation, this stock should not be considered immediately for translocation elsewhere. It may be appropriate, however, to consider adding further vendace fry to Loch Earn if they become available during future vendace translocations to Scotland.

CONCLUSIONS

The vendace merits its place amongst the species included in the Scottish Natural Heritage Species Recovery Programme. It is both rare and endangered in Great Britain, being found now in only two inter-connected waters in England. An increase in the number of locations for this species, and an expansion of its geographical distribution are urgently required (Maitland, 1985). It is therefore highly appropriate that actions are now being taken to seriously consider the re-introduction of vendace to Scotland(particularly to the south west of the country where it was found until earlier this century) both for the preservation of the species and for the benefit of biodiversity. It is believed that for this species, translocation without captive breeding is the best option (Maitland and Evans, 1986).

However, this study has demonstrated that in south west Scotland there is a paucity of waters which are currently suitable for this purpose. Of the 110 waters investigated, only two could fully satisfy the criteria required. It is fortunate that one of these, Loch Skeen, lies within the same (River Annan) catchment as the Lochmaben lochs. A number of lochs in the area of research could become acceptable for vendace but only after changes have been made to ameliorate problematic features. The particularly applies to the primary area of interest at Lochmaben where no waters could currently support vendace without extensive and costly restoration and management. However, it would be worth while to investigate the practicality and cost of such an exercise at either the Mill Loch or the Kirk Loch.

Even if translocations of vendace to Daer Reservoir and Loch Skeen are undertaken and are successful, this is still an inadequate number of locations for the satisfactory establishment of this species to Scotland. The 110 waters considered constitute only about 2% of the Scottish total (Smith and Lyle, 1979). Consequently, a similar exercise to this study may be required over a greater geographical area to identify other suitable sites. However, in previous translocation operations to establish safeguard stocks of other endangered fish species (Maitland and Lyle, 1990) one of the most difficult aspects was finding acceptable sites for introductions.

The successful transfer of vendace to the two selected sites will require a commitment of resources over some years. In such operations it is inherently difficult to be assured of success for any of the stages involved and some allowance for this has been built into the feasibility plan discussed above.

A translocation programme for vendace should be established soon since the status of the only parent stocks in Cumbria is considered to be coming under increasing threat.

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REFERENCES

AASS, P. 1972. Age determination and year-class fluctuations of Cisco, *Coregonus albula* L., in the Mjosa hydroelectric reservoir, Norway. Rep. *Inst. Freshw. Res. Drottning*. **52**, 5-22.

ANON. 1855. Vendace at Lochmaben. *The Scotsman*. Wednesday, July 25.

BEAUMONT, A.R., BRAY, J., MURPHY, J.M. and WINFIELD, I.J. (In press). Genetics of whitefish *Coregonus lavaretus* and vendace *Coregonus albula* in England and Wales. *J. Fish. Biol.*

CAMPBELL, A.D. 1971. The occurrence of *Argulus* (Crustacea: Branchiura) in Scotland. *J. Fish Biol.* **3**, 145-146.

DEMBINSKI, W. 1971. Vertical distribution of Vendace *Coregonus albula* L. and other pelagic fish species in some Polish lakes. *J. Fish Biol.* **3**, 341-357.

DOTTRENS, E. 1958. 'Sur les Corégones de Grande-Bretagne et d'Irelande, *International Congress of Zoology*, **15**, 404-406.

FERGUSON, A. 1974. The genetic relationships of the coregonid fishes of Britain and Ireland indicated by electrophoretic analysis of tissue proteins. *J. Fish. Biol.* **6**, 311-315.

FLOWER, R.J., BATTERBEE, R.W. and APPLEBY, P.G. 1987. The recent palaeolimnology of acid lakes in Galloway, south west Scotland: diatom analysis, pH trends and the role of afforestation. *J. Ecol.* **75**, 797-824.

HAKANSON, L. 1981. *A manual of lake morphometry*. Springer-Verlag, Heidelberg. 78pp.

JURVELIUS, J., LINDEM, T. and HEIKKINEN, T. 1988. The size of a Vendace, *Coregonus albula* L., stock in a deep lake basin monitored by hydro-acoustic methods. *J. Fish Biol.* **32**, 679-68.

MAITLAND, P.S. 1966a. The fish fauna of the Castle and Mill Lochs, Lochmaben, with special reference to the Lochmaben Vendace, *Coregonus vandesius* Richardson. *Trans. Dumfr. & Gall. Nat. Hist. Antiq. Soc.* **43**,31-48.

MAITLAND, P.S. 1966b. Present status of known populations of the Vendace *Coregonus vandesius* Richardson, in Great Britain. *Nature, Lond.* **210**, 216-217.

MAITLAND, P.S. 1967a. Echo sounding observations on the Lochmaben Vendace, *Coregonus vandesius* Richards. *Trans. Dumfr. Gall. Nat Hist. Antiqu. Soc.* **44**, 29-46.

MAITLAND, P.S. 1967b. The artificial fertilisation and rearing of the eggs of *Coregonus clupeoides* Lacepede. *Proc. Roy. Soc. Edin.* **70**, 82-106.

MAITLAND, P.S. 1969. The reproduction and fecundity of the Powan, *Coregonus clupeoides Lacepede*, in Loch Lomond, Scotland. *Proc. Roy. Soc. Edin.* **70**, B, 233-264.

MAITLAND, P.S. 1970. The origin and present distribution of *Coregonus* in the British Isles. *Int. Symp. Biol. Coregonid Fish, Winnipeg*. **1**, 99-114.

MAITLAND, P.S. 1985. Criteria for the selection of important sites for freshwater fish in the British Isles. *Biol Conserv*. **31**, 335-353.

MAITLAND, P.S. 1995. A Species Action Plan for the Vendace *Coregonus albula* in Great Britain. Report to the Royal Society for the Protection of Birds and the Department of the Environment.

MAITLAND, P.S. and EVANS, D. 1986. The role of captive breeding in the conservation of fish species. *Int. Zoo Yb.* **25**, 66-74.

MAITLAND, P.S. and LYLE, A.A. 1990. Practical conservation of British fishes: current action on six declining species. *J. Fish Biol.* **37A**, 255-256.

MAITLAND, P.S. and LYLE, A.A. 1991. Conservation of freshwater fish in the British Isles: the current status and biology of threatened species. *Aquatic Conservation.* **1**, 25-54.

MAITLAND, P.S. and LYLE, A.A. 1992. Conservation of freshwater fish in the British Isles: proposals for management. *Aquatic Conservation.* **2**, 165-183.

MAITLAND, P.S., LYLE, A.A. and CAMPBELL, R.N.B. 1987. *Acidification and fish populations in Scottish lochs.* Institute of Terrestrial Ecology, Grange-over-Sands.

McLEOD, D.H.B. 1993. Fisheries Management, *Proceedings of the Loch Dee Symposium. Foundation for Water Research* 1993, pp 13-21.

MORRISON, B.R.S. 1987. Use and effects of piscicides. Institute of Terrestrial Ecology Symposium. **19**, 47-52.

MURRAY, J. and PULLAR, L. 1910. *Bathymetrical Survey of the Fresh Water Lochs of Scotland*, Challenger Office, Edinburgh.

RATCLIFFE, D.A. 1977. *A Nature Conservation Review.* Cambridge University Press, Cambridge.

SMITH, I.R. and LYLE, A.A. 1979. *Distribution of Freshwaters in Great Britain*, Institute of Terrestrial Ecology, Cambridge.

SVARDSON, G. 1956. The coregonid problem. VI. The palaearctic species and their intergrades. *Rep. Inst. Freshw. Res. Drottning.* **38**, 267-356.

WINFIELD, I.J. 1995. Species Action Plan for vendace (*Coregonus albula*). Report to English Nature. 9pp.

WINFIELD, I.J., FLETCHER, J.M. and CUBBY, P.R. 1994. Ecology of the vendace, *Coregonus albula*, in Bassenthwaite Lake. Institute of Freshwater Ecology Report to North West Water Ltd. 62pp.

Table 1 : Basic information for the 109 lochs in Hydrometric Areas 77-81 which were assessed for their potential as possible vendace introduction sites. (S&L<.25 are the sites in Smith and Lyle (1979) which are less than 25 ha in area).

Loch N°.	Hydro. Area	Loch Name or (assumed)	Grid Reference Easting	Northing	S&L <.25	Area ha	Depth max m
1	77	**Black Esk R.**	3205	5968		35	>6.5
2	77	**Winterhope R.**	3275	5826	+	8.3	>4.4
3	78	**Skeen**	3171	6165		27.9	11
4	78	**Mill**	3076	5830	+	13	16.8
5	78	**Kirk**	3078	5821	+	13.4	7.6
6	78	**Castle**	3088	5815		78.2	5.5
7	78	**Hightae Mill**	3082	5802	+	7.7	4
8	78	**Hallhills R.**	3163	5887	+		
9	78	**Purdomstone R.**	3212	5774	+		
10	78	**Torbeckhill exR.**	3230	5795	+		
11	79	**Creoch**	2597	6151	+		
12	79	**o" the Lowes**	2602	6147	+		
13	79	**(New Cumnock)**	2613	6126	+		
14	79	**(crannog)**	2795	6105	+		
15	79	**Afton R.**	2635	6042		40.4	>7
16	79	**Kettleton R.**	2896	6005	+	10.1	>7
17	79	**Ettrick R.**	2945	5938	+		
18	79	**Howie**	2697	5834	+	18.2	11.9
19	79	**Skae**	2710	5836		8.1	10.7
20	79	**Glenkiln R.**	2845	5780		26.6	>6
21	79	**Lochrutton R.**	2899	5730		52.2	17.7
22	79	**(Ironhurst)**	3048	5719	+		
23	79	**Arthur**	2905	5689	+	30	15.2
24	79	**Kindar**	2968	5642		54.3	12.5
25	80	**Kendoon R.**	2608	5906		59.5	>1.9
26	80	**R.L.Dungeon**	2465	5846	+	4.5	10.4
27	80	**L.L.Dungeon**	2466	5840	+	4.4	6
28	80	**Harrow R.**	2526	5867	+	15.4	8.8
29	80	**Minnoch R.**	2530	5858	+		
30	80	**Dungeon R.**	2524	5844		35.6	28.6
31	80	**Carsfad R.**	2608	5860		40.5	>7.7
32	80	**Earlstoun R.**	2612	5830		55.8	
33	80	**Barscobie**	2669	5812	+		
34	80	**Lochinvar R.**	2659	5832		27.5	3
35	80	**Knocksting**	2699	5881	+		
36	80	**Urr**	2760	5845		52.3	13.2
37	80	**Dee**	2469	5791		100	14.7
38	80	**Clat"shaws R.**	2543	5771		400	>8.8
39	80	**Grannoch**	2540	5700		117	20.7
40	80	**Stroan**	2645	5703	+		
41	80	**Mossdale**	2655	5710	+		
42	80	**Corsock R.**	2752	5756	+		
43	80	**Black**	2782	5719	+		
44	80	**Lochenkit R.**	2801	5757	+		
45	80	**Auchenreoch**	2820	5717		34.8	10.4
46	80	**Milton**	2840	5716		62	4.6
47	80	**Lochaber**	2920	5703	+	21.1	16.8
48	80	**Skerrow**	2605	5682		50.6	10.1
49	80	**Lochenbreck**	2642	5656	+	15.8	4.6
50	80	**Whinyeon R.**	2624	5609		42.5	10.1
51	80	**Mannoch R.**	2665	5607		33	
52	80	**Bargatton**	2694	5619	+		
53	80	**Woodhall**	2671	5672		68	14.9
54	80	**(Blates Mill)**	2680	5671	+		
55	80	**Glentoo**	2700	5625	+		

Table 1 (cont'd) :

Loch N°.	Hydro. Area	Loch Name or (assumed)	Grid Reference Easting	Northing	S&L <.25	Area ha	Depth max m
56	80	**Dornell**	2704	5658	+		
57	80	**Ken R.**	2705	5692		580	18.9
58	80	**Roan R.**	2743	5691	+		
59	80	**Erncrogo**	2744	5676	+		
60	80	**Carlingwark**	2761	5613		42.5	5.2
61	80	**Fern R.**	2863	5624	+	5.9	2.9
62	80	**(Plantain)**	2840	5601	+	3.1	7.3
63	80	**Fellcroft**	2757	5506	+	7	1.8
64	80	**Clonyard**	2855	5554	+	4.7	7.4
65	80	**Barean**	2860	5558	+	9.4	12.2
66	80	**White**	2864	5547	+	12	12.8
67	80	**Tongland R.**	2703	5550		85	>10.5
68	81	**Goosey**	2300	5823	+		
69	81	**Moan**	2349	5858		55	
70	81	**Kirriereoch**	2364	5865	+	6.5	4.6
71	81	**Neldricken**	2446	5829		32.9	17
72	81	**Valley**	2444	5817		35.8	17.2
73	81	**L.L.Glenhead**	2445	5809	+	10.4	11.5
74	81	**R.L.Glenhead**	2450	5803	+	12.5	13.5
75	81	**Kilantringan**	2090	5790	+		
76	81	**Derry**	2250	5736	+		
77	81	**Maberry**	2285	5752		70.9	4.3
78	81	**Dornal**	2291	5760		44.6	3
79	81	**Fyntalloch**	2312	5740	+	10.5	4.6
80	81	**Ochiltree**	2318	5747		63.2	10.4
81	81	**Middle R.**	2395	5740	+		
82	81	**Trool**	2411	5799		58.3	16.8
83	81	**(Lochnaw)**	1992	5631	+	19	1.8
84	81	**Connell**	2018	5672		23	
85	81	**White**	2106	5609		60.3	11.6
86	81	**Black**	2113	5614		59.1	15.2
87	81	**Ree**	2103	5699	+	10.9	13.4
88	81	**Penwhirn R**	2122	5697		48.6	>4.2
89	81	**Ronald**	2265	5642		43	
90	81	**Heron**	2272	5648	+		
91	81	**Black**	2280	5655	+		
92	81	**Garnachie**	2350	5688	+		
93	81	**Eldrig**	2353	5666	+		
94	81	**Fleet**	2560	5699	+	17.4	17.1
95	81	**Kno"quhassenR.**	2020	5595	+		
96	81	**Soulseat**	2101	5589		28.8	12.8
97	81	**Whitefield**	2235	5551	+	19	4.3
98	81	**Dernaglar**	2264	5582	+		
99	81	**Barhapple**	2260	5590	+		
100	81	**Castle**	2287	5538		92.3	3.4
101	81	**Mochram**	2302	5532		93.2	4
102	81	**Black**	2302	5546	+		
103	81	**Fell**	2310	5552	+		
104	81	**Clugston**	2344	5573	+		
105	81	**Ornockenoch R.**	2580	5591	+		
106	81	**Cally**	2600	5554	+		
107	81	**Loganhouse R.**	2101	5430	+		
108	81	**Elrig**	2323	5492	+	17.8	3
109	81	**White,Myrton**	2359	5435	+	20.7	12.2

Table 2: The results of the desk study investigation into site suitability for vendace introductions.Dark shaded boxes show unsuitability for the reason indicated, light shading suggests doubt for that reason (see text for full explanation). Sites in bold type were selected for further investigation.

Loch No.	Loch Name or (assumed)	Grid Reference Easting	Northing	Reason for elimination (see text) 1 depth	2 hydro	3 pr.fish	4 acid	5 rare	6 urban	7 known	8 forest
1	Black Esk R.	3205	5968								
2	Winterhope R.	3275	5826								
3	**Skeen**	**3171**	**6165**								
4	Mill	3076	5830								
5	Kirk	3078	5821								
6	Castle	3088	5815								
7	Hightae Mill	3082	5802								
8	Hallhills R.	3163	5887								
9	Purdomstone R.	3212	5774								
10	Torbeckhill exR.	3230	5795								
11	Creoch	2597	6151								
12	o" the Lowes	2602	6147								
13	(New Cumnock)	2613	6126								
14	(crannog)	2795	6105								
15	**Afton R.**	**2635**	**6042**								
16	Kettleton R.	2896	6005								
17	Ettrick R.	2945	5938								
18	Howie	2697	5834								
19	Skae	2710	5836								
20	Glenkiln R.	2845	5780								
21	Lochrutton R.	2899	5730								
22	(Ironhurst)	3048	5719								
23	**Arthur**	**2905**	**5689**								
24	Kindar	2968	5642								
25	Kendoon R.	2608	5906								
26	R.L.Dungeon	2465	5846								
27	L.L.Dungeon	2466	5840								
28	Harrow R.	2526	5867								
29	Minnoch R.	2530	5858								
30	Dungeon R.	2524	5844								
31	Carsfad R.	2608	5860								
32	Earlstoun R.	2612	5830								
33	Barscobie	2669	5812								
34	Lochinvar R.	2659	5832								
35	Knocksting	2699	5881								
36	**Urr**	**2760**	**5845**								
37	Dee	2469	5791								
38	Clat"shaws R.	2543	5771								
39	Grannoch	2540	5700								
40	Stroan	2645	5703								
41	Mossdale	2655	5710								
42	Corsock R.	2752	5756								
43	Black	2782	5719								
44	Lochenkit R.	2801	5757								
45	Auchenreoch	2820	5717								
46	Milton	2840	5716								
47	Lochaber	2920	5703								
48	Skerrow	2605	5682								
49	Lochenbreck	2642	5656								
50	**Whinyeon R.**	**2624**	**5609**								
51	Mannoch R.	2665	5607								
52	Bargatton	2694	5619								
53	Woodhall	2671	5672								
54	(Blates Mill)	2680	5671								
55	Glentoo	2700	5625								

Table 2: (cont'd)

Loch No.	Loch Name or (assumed)	Grid Reference Easting	Northing	Reason for elimination (see text) 1 depth	2 hydro	3 pr.fish	4 acid	5 rare	6 urban	7 known	8 forest
56	Dornell	2704	5658								
57	Ken R.	2705	5692								
58	Roan R.	2743	5691								
59	Erncrogo	2744	5676								
60	Carlingwark	2761	5613								
61	Fern R.	2863	5624								
62	(Plantain)	2840	5601								
63	Fellcroft	2757	5506								
64	Clonyard	2855	5554								
65	Barean	2860	5558								
66	White	2864	5547								
67	Tongland R.	2703	5550								
68	Goosey	2300	5823								
69	Moan	2349	5858	?							
70	Kirriereoch	2364	5865								
71	Neldricken	2446	5829								
72	Valley	2444	5817								
73	**L.L.Glenhead**	**2445**	**5809**								
74	R.L.Glenhead	2450	5803								
75	Kilantringan	2090	5790								
76	Derry	2250	5736								
77	Maberry	2285	5752								
78	Dornal	2291	5760								
79	Fyntalloch	2312	5740								
80	**Ochiltree**	**2318**	**5747**								
81	Middle R.	2395	5740								
82	Trool	2411	5799								
83	(Lochnaw)	1992	5631								
84	Connell	2018	5672								
85	White	2106	5609								
86	Black	2113	5614								
87	Ree	2103	5699								
88	Penwhirn R	2122	5697								
89	Ronald	2265	5642								
90	Heron	2272	5648								
91	Black	2280	5655								
92	Garnachie	2350	5688								
93	Eldrig	2353	5666								
94	Fleet	2560	5699								
95	Kno"quhassenR.	2020	5595								
96	Soulseat	2101	5589								
97	Whitefield	2235	5551								
98	Dernaglar	2264	5582								
99	Barhapple	2260	5590								
100	Castle	2287	5538								
101	Mochram	2302	5532								
102	Black	2302	5546								
103	Fell	2310	5552								
104	Clugston	2344	5573								
105	Ornockenoch R.	2580	5591								
106	Cally	2600	5554								
107	Loganhouse R.	2101	5430								
108	Elrig	2323	5492								
109	White,Myrton	2359	5435								

Table 3 : Physical details of the eight sites selected for further investigation following the desk study.

Loch No.	Loch Name	Grid Reference		Alt.	Area	Depth m		
		Easting	Northing	m	ha	max	mean	Vd
3	Skeen	3171	6165	530	27.9	11	5.45	1.49
15	Afton R.	2635	6042	400	40.4	>7	-	-
23	Arthur	2905	5689	73	30	15.2	7.85	1.55
36	Urr	2760	5845	190	52.3	13.2	3.65	0.83
50	Whinyeon R.	2624	5609	215	42.5	10.1	3.72	1.1
73	L.L.Glenhead	2445	5809	295	10.4	11.5	3.79	0.99
80	Ochiltree	2318	5747	104	63.2	10.4	2.34	0.68
-	Daer R.	2980	6090	342	202	37.1	12.66	1.02

Table 4: Chemical information on water quality for Loch Skeen, Afton Reservoir, Daer Reservoir, Loch Arthur and Loch Trool.

		Colour Hazen	pH	Alkalinity mg l^{-1}	Conductivity $\mu s\ cm^{-1}$
Loch Skeen	1988	40	6.9	3.4 $CaCO_3$	30
	1995	-	6.9	9 $CaCO_3$	30
Afton Reservoir	1994(mean)	43	6.62	6.7 HCO_3	40
	1995	-	6.3	8 $CaCO_3$	30
Daer Reservoir	1994(mean)	31	7.07	10.3 HCO_3	45
	1995	-	6.8	8 $CaCO_3$	40
Loch Arthur	1995	-	6.8	13 $CaCO_3$	90
Loch Trool	1995	-	6.4	10 $CaCO_3$	60

Table 5: Results of the survey for fish at (a) Daer Reservoir on 21/22.11.95 and (b) Loch Skeen on 22/23.11.95 (see Figures 2 and 3).

(a) **Gill Netting.**	**Net**	**Species**	**Number of Fish**	
	G1.	Brown trout	21	
	G2.	Brown trout	20	
	G3.	Brown trout	3	
	G4.	Brown Trout	5	
Fyke Nets.				
	F1.	Brown trout	1	
	F2.	Nil	-	
Electro Fishing.	**Area**			**Habitat**
	E1.	Brown trout	1	75m stony
	E2.	Minnows	6	75m weedy
	E3.	Nil	-	75m stony
(b) **Gill Netting.**	**Net**	**Species**	**Number of fish**	
	G1.	Brown trout	14	
	G2.	Brown trout	6	
	G3.	Brown trout	16	
	G4.	Brown trout	16	
Electro fishing.	**Area**			**Habitat**
	E1.	Minnows	ca 30	83m weedy
	E2.	Minnows	ca 30	75m stony

Table 6: A breakdown of the different stages and effort required for vendace translocation from Cumbria to the two sites in Scotland.

	Stage		Unit Effort	Probable annual effort	Staff days
1.	Fish netting/ Egg collection	Several attempts may be required to obtain sufficient numbers of fish/eggs	Each attempt would require 2 staff days	3 attempts	6
2.	Egg transport to hatcheries	Probably transportation for each netting attempt.	Each transportation would require 1 staff day	3 transportations	3
3.	Incubation husbandry	Preferably at least 2 different hatcheries	Each hatchery will require ca 25 staff days (over 90-120 days)	Staff at 2 hatcheries	50
4.	Transport of fry to introduction sites	Fry taken in 3 batches over hatching period	For Daer Rsvr. - 1 staff day per batch For L.Skeen - 2 staff days per batch	Staff to 2 sites	9
			Total staff days for each year		68
			Total for full 3-year programme		204
	Post introduction monitoring		Approximate annual effort		10

FIGURE LEGENDS

Figure 1: A map of south west Scotland showing the locations of the lochs considered for vendace introductions. Sub-divisions are those of Hydrometric Areas 77-81. The grid overlay corresponds to the National Grid Reference system. Sites important to the study are named.

Figure 2: A map of Daer Reservoir. Bathymetric contours are in metres. The bars (G) show the positions of gill net settings, the symbols (F) show fyke net locations and the dots (E) indicate electro-fishing areas for the field survey of fish species (see also Table 5).

Figure 3: A map of Loch Skeen. Bathymetric contours are in feet (after Murray and Pullar 1910). The bars (G) show the positions of gill net settings and the dots (E) indicate electro-fishing areas for the field survey of fish species (see also Table 5).

Figure 4: The length frequency of brown trout taken by gill nets from Daer Reservoir and Loch Skeen during the field survey of fish species.

Figure 1

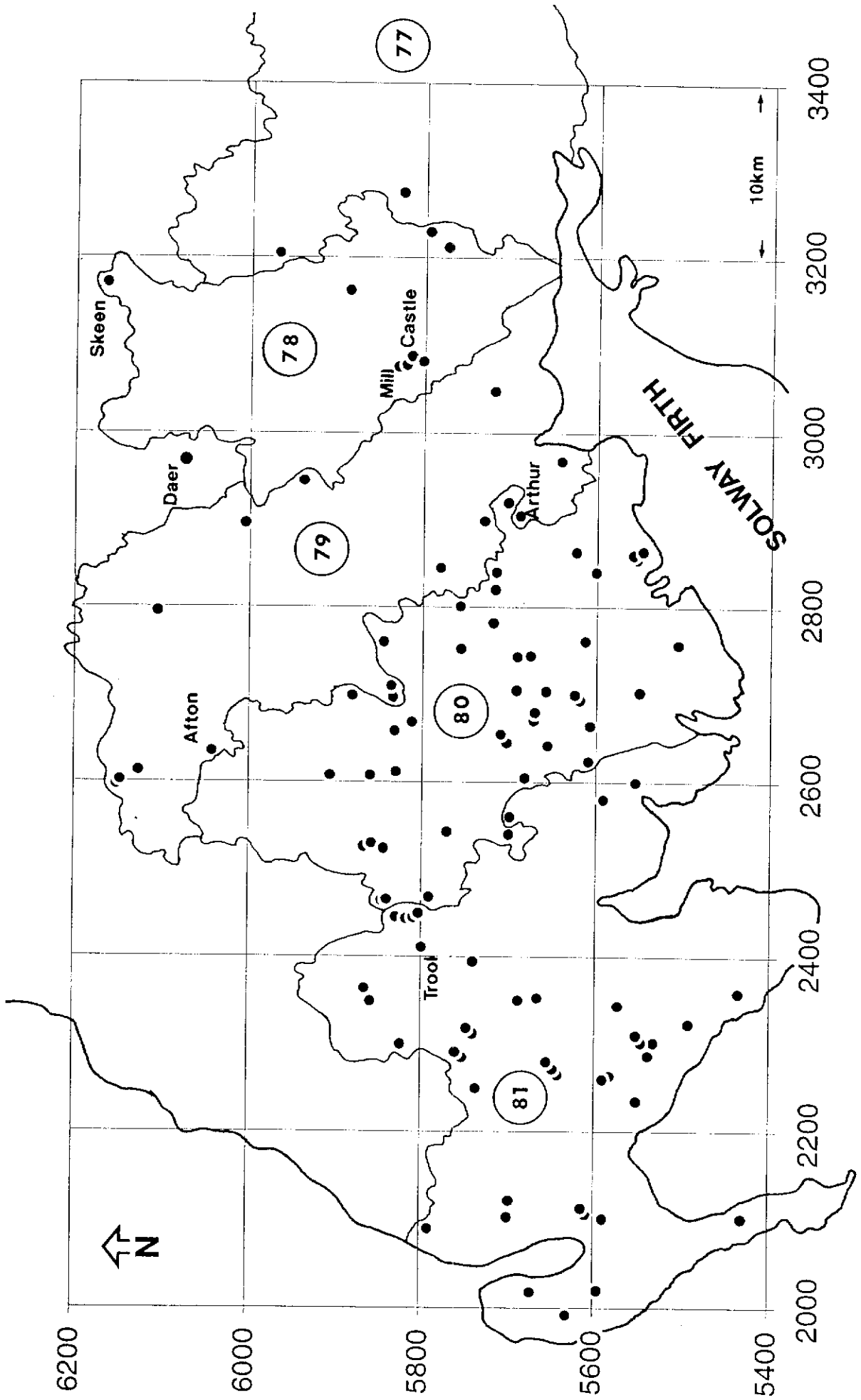

77
78
79
80
81
Skeen
Mill
Castle
Daer
Arthur
Afton
Troo
SOLWAY FIRTH
10km
N
6200
6000
5800
5600
5400
2000
2200
2400
2600
2800
3000
3200
3400

Figure 2

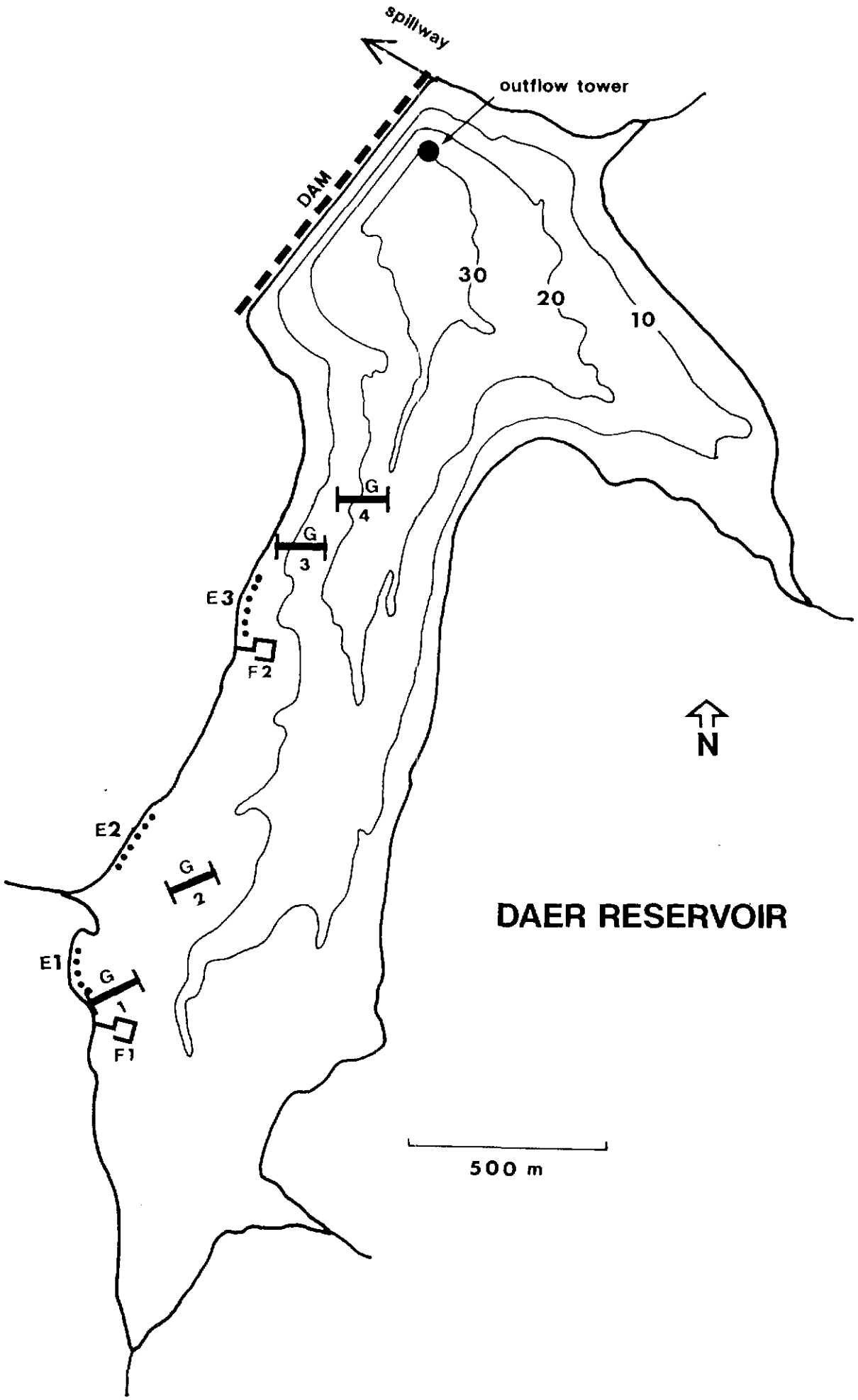

spillway
outflow tower
DAM
30
20
10
G 4
G 3
E3
F2
N
E2
G 2
E1
G 1
F1
DAER RESERVOIR
500 m

Figure 3

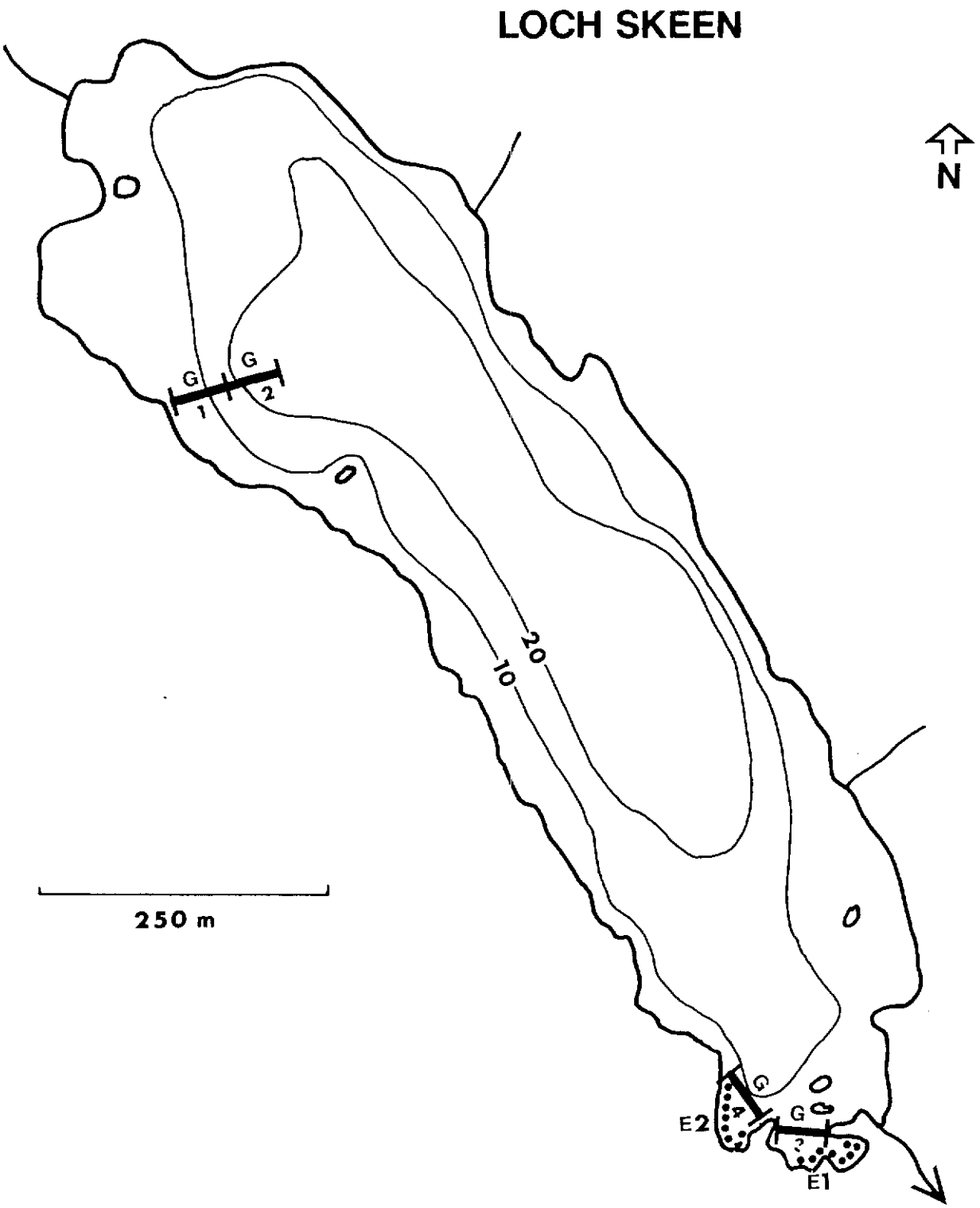
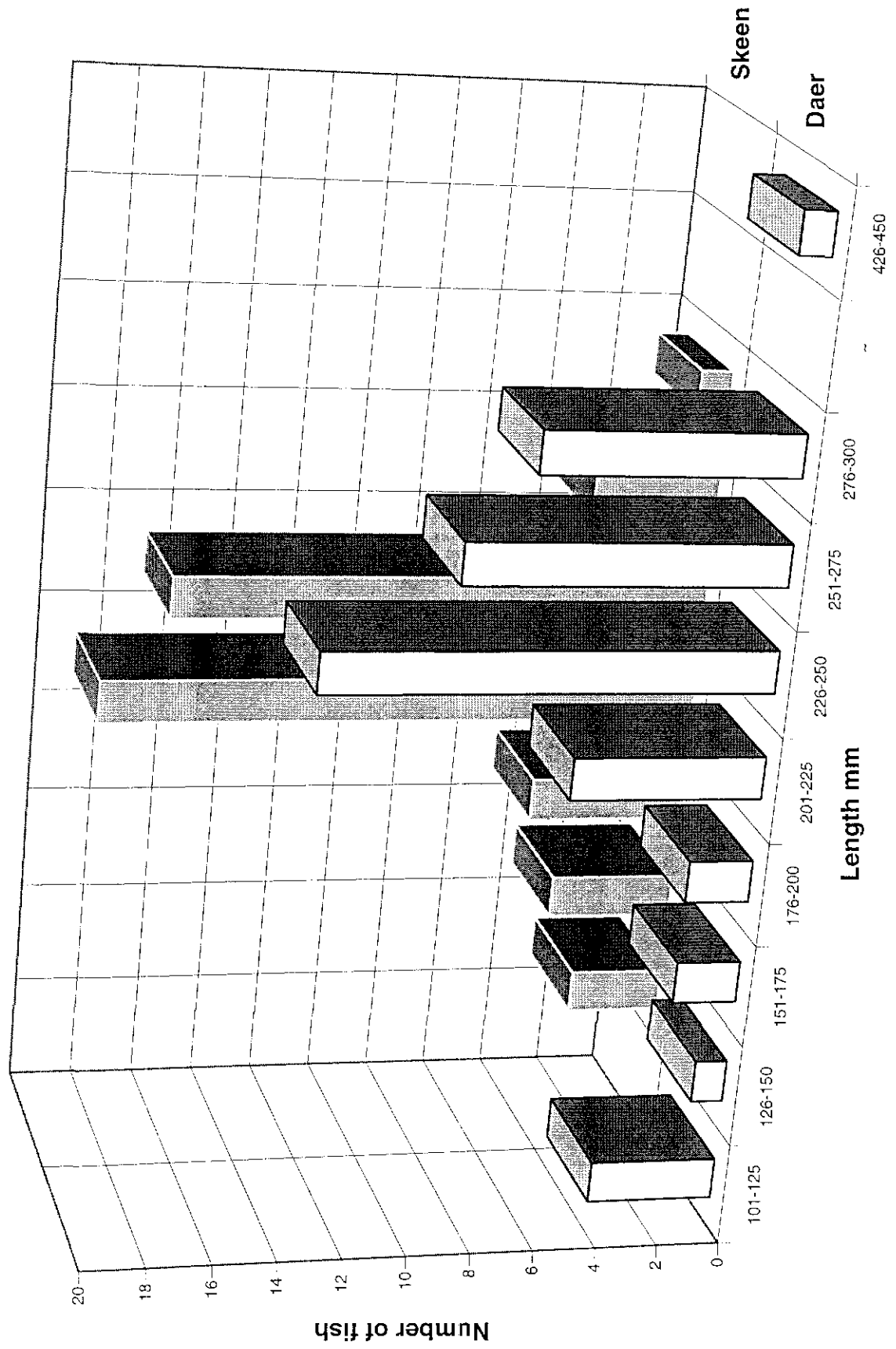


Figure 4


Skeen
Daer
Number of fish
0
2
4
6
8
10
12
14
16
18
20
Length mm
101-125
126-150
151-175
176-200
201-225
226-250
251-275
276-300
426-450

APPENDIX (i)

A Species Action Plan for the Vendace
Coregonus albula in Great Britain.

Prepared by:

P.S. Maitland
Fish Conservation Centre
Stirling

Species Action Plan

VENDACE *Coregonus albula* (Linnaeus 1758)

1. Priority statement

The Vendace occurs in many lakes in north-west Europe, from northern Scandinavia and north-west Russia in the north to Bavaria in the south and from the English Lake District in the west to western Russia in the east. Though this is mainly a lake species, some populations also occur in the Baltic Sea, migrating into fresh water to spawn. In the United Kingdom it has been known from only four lakes. Two of these are in Scotland (where it is called the Lochmaben Vendace and was formerly described as a distinct species and subspecies - *Coregonus vandesius vandesius*), and two are in England (the Cumberland Vendace - *Coregonus vandesius gracilior*).

The population in the Castle Loch, Lochmaben has been extinct for many decades and none has been recorded since shortly after a new sewage works was opened there in 1911. The species was thought to be extinct also at one time in the Mill Loch, Lochmaben but specimens were caught there in 1966 and in subsequent years. None has been seen for more than a decade, however, and the species must be regarded as extinct here too.

In Cumbria, the Vendace occurs in two much larger and deeper lakes - Bassenthwaite Lake and Derwentwater - and may be more secure there in the short term. It was found to be common in both lakes in 1966 and since then specimens have been taken under licence in recent years for various research programmes.

2. Current action

Because of its decline and current poor conservation status, the Vendace is now given protection on the Wildlife and Countryside Act 1981 (Schedule 5), Bern Convention (Appendix III), EC Habitats and Species Directive (Annex V).

Bassenthwaite Lake has recently been designated as a National Nature Reserve and both it and Derwentwater will have some protection as SSSIs. Bassenthwaite Lake, which is owned by the National Trust (England and Wales), also now has an agreed general management plan in which the Vendace is highlighted.

Research (funded by the NRA) is being carried out on the ecology of the Vendace in Cumbria, and action has been taken (also by the NRA) to reduce nutrients entering Bassenthwaite Lake by improved treatment at local sewage works. In addition, emergency procedures for accidental spillages from lorries on the nearby A66 are in place and consideration is being given to water level management in the lake by modifying local drainage systems.

Recommendations for action have been given by Maitland & Lyle (1992) and Maitland (1995). An action plan for this species, in England and Wales only, is being prepared by Ian Winfield (IFE) for English Nature.

3. Action plan objectives

3.1 To ensure the continued survival of the species in Great Britain through:

i. Management plans for the species in both Bassenthwaite Lake and Derwentwater

ii. Further research

iii. Safeguard of habitat, including water quality, in Bassenthwaite Lake and Derwentwater

iv. Restoration of one of the Lochmaben lochs so that it is again suitable ecologically for the Vendace

v. Translocation of suitable stocks to (a) additional 'safeguard' sites in Cumbria, and (b) several sites in southwest Scotland (including one at Lochmaben), to restore the species to its original area of distribution.

3.2 To record status through a programme of monitoring

3.3 To raise local awareness of the plight and needs of the Vendace.

4. Proposed action with lead agencies

4.1 Policy and legislation — High priority

Responsibility for coordinating the action plan should rest with a fish conservation officer. **JNCC.** *Target: appoint such an officer by 1996.*

New legislation is necessary for Scotland to give an appropriate statutory organisation (perhaps SEPA) fishery and conservation powers equivalent to those of the NRA in England and Wales. **Scottish Office and H M Government.** *Target: approve such legislation by 1998.*

4.2 Site safeguard and management — High priority

The remaining sites for this species in Great Britain, Bassenthwaite Lake and Derwentwater, should both be targeted for maximum protection aimed specifically at the Vendace - the main objectives being protection of (1) water quality, (2) physical habitat of spawning grounds, (3) native fish communities from invading alien fish species. **NRA, EN.** *Target: agree management plans for both lakes by 1996. Both plans fully operational by 1998.*

4.3 Species management and protection — High priority

The use of livebait and the translocation of alien coarse fish into the entire Bassenthwaite/Derwentwater catchment should be forbidden. **NRA and EN.** *Target: operate regulation by 1996.*

Once suitable lake sites have been located and deemed suitable ecologically, translocation projects should be set up. **JNCC, NRA, EN and SNH.** *Target: (1) prepare translocation plan by 1997, (2) translocate stock annually from 1998-2000.*

4.4 Advisory — Medium priority

The Vendace should be included in a Red Data Book of threatened fish in Great Britain. **JNCC.** *Target: publish Red Data Book by 1996.*

4.5 International — Medium priority

Ensure requirements of the Bern Convention and the EU Habitats Directive are fulfilled. **Conservation agencies.** *Target: as required by agreements.*

4.6 Future research and monitoring — High priority

Research at both Bassenthwaite Lake and Derwentwater should continue. **Funding agencies.** *Target: (1) ensure current research programme continues, (2) complete by 1999.*

Research should also be carried out on other lakes in both Cumbria and southwest Scotland to locate sites which may be suitable for translocations. *Target: locate two suitable sites in Cumbria and three in Scotland by 1997.*

Monitoring programmes for stocks at both Bassenthwaite Lake and Derwentwater should be established and continued on a triennial basis. Translocated stocks should also be included in such a programme. **JNCC, NRA, EN, SNH.** *Target: (1) approve monitoring programme by 1996, (2) ensure monitoring programme operational by 1997.*

4.7 Communications and publicity — Medium priority

A poster or leaflet concerning the Vendace should be prepared and distributed to all relevant people (anglers, school children, naturalists, etc.) in catchments of existing or 'safeguard' lakes. This would explain the value of these populations and the need to protect them and their habitat. **JNCC, NRA, EN, SNH.** *Target: prepare and distribute poster by 1996.*

5. Action plan review

The action plan should be reviewed on a quinquennial basis by the conservation (EN, SNH) and fishery (MAFF, SOAFD, NRA) agencies. **JNCC.** *Target: (1) approve action plan in 1995, (2) review quinquennially thereafter.*

APPENDIX *(ii)*

A Species Action Plan for the Vendace *Coregonus albula* in England.

Prepared by:

I.J. Winfield
Institute of Freshwater Ecology
Windermere

CONTENTS

Summary

The vendace (*Coregonus albula*) is a rare fish in Britain, although it is more common in northern mainland Europe where it is heavily exploited in commercial fisheries. In addition to overfishing, many European populations are threatened by eutrophication. This agency is also believed to have been responsible for the extinction of two vendace populations in Scotland, with the result that in Britain the vendace is now found only in Bassenthwaite Lake and Derwentwater of the English Lake District. The main threats to this species in Bassenthwaite Lake are eutrophication and possibly the effects of introductions of roach (*Rutilus rutilus*) and ruffe (*Gymnocephalus cernuus*), while the population of Derwentwater is possibly threatened by a very recent introduction of roach. Given the habitat requirements of the vendace, it is unlikely that many other lakes suitable for their introduction exist in England, although a survey of possible sites in their native catchment is recommended. The most effective means of their conservation is undoubtedly the safeguarding of their remaining natural habitats, i.e. Bassenthwaite Lake and Derwentwater.

1. Priority statement

The vendace is a rare and declining fish confined in Britain to only two lakes, both of which are in England. English Nature therefore attaches high priority to conservation action for vendace.

2. Action plan objectives

Objective 1: In the short term, to assess the probable effects of roach (*Rutilus rutilus*) and ruffe (*Gymnocephalus cernuus*) introductions on vendace population dynamics, to assess the feasibility of spawning ground restoration/improvement in Bassenthwaite Lake, to assess the suitability of other water bodies for possible introductions, and to assess the feasibility of captive breeding and keeping.

Objective 2: In the medium term, to implement any feasible management options identified in Objective 1, and to establish minimum-impact vendace monitoring programmes for Bassenthwaite Lake and Derwentwater.

Objective 3: In the long term, to secure suitable conditions and consistently-recruiting vendace populations in Bassenthwaite Lake and Derwentwater.

3. Legal status

Protected under Schedule 5 of the Wildlife and Countryside Act 1981, Appendix III of the Bern Convention and Annex V of the EC Habitats and Species Directive. Bassenthwaite Lake is also a National Nature Reserve and Site of Special Scientific Interest.

4. Biological assessment

4.1 Introduction

The vendace is a declining species in Britain, having been lost from two of its known four

localities during the present century. It is now found in only Bassenthwaite Lake and Derwentwater in the English Lake District. The maintenance of suitably deep lakes, with clean inshore areas for spawning, is essential for the survival of this species in Britain.

4.2 Ecology

The vendace is a silver, streamlined fish which typically lives for up to 6 years, by which time it may have attained a length of up to 28 cm (Luczynski, 1986). The diet of vendace in Europe has been extensively studied and has been found to be dominated at all ages by zooplankton such as *Daphnia* species (Jacobsen, 1982), which may lead to severe intraspecific competition and subsequent marked oscillations in population size (Hamrin & Persson, 1986). Reproduction occurs during the winter months when many small (less than 2 mm in diameter) eggs are scattered in silt-free inshore areas, which then have a long incubation time before hatching sometime in the following spring (Zuromska, 1982). Vendace eggs are not deposited in the relative safety of redds, as they are in salmonids such as salmon (*Salmo salar*) and trout (*Salmo trutta*) which have similarly long incubation periods, and so they face a very long period during which they are susceptible to siltation (Resetnikov, 1988; Sterligova *et al.*, 1988) or predation by benthivorous fish such as ruffe (Pokrovskii, 1961). As in many fish species, events during the first year of life are thought to be of critical importance to the dynamics of the vendace population as a whole (Hamrin, 1986). Research in this area of vendace and other lake fish ecology remains hampered by the difficulty of sampling the young stages (Winfield, 1991).

4.3 Distribution and population

The vendace is found in lakes east of the Elbe in Germany, in Sweden, Norway and Finland, in Lakes Ladoga and Onega, lakes in the upper Volga catchment area, in the Gulf of Bothnia, and in the Waginger and Tachen Lakes of Bavaria (Lelek, 1987). In recent times it has also been introduced further south, particularly into man-made lakes in the former U.S.S.R., France, Poland and the former Czechoslovakia (Lelek, *op. cit.*). The British Isles lay towards the southern limits of the distribution of the vendace and offer only a few sites capable of meeting their requirements for relatively cool and oxygen-rich water. There is considerable evidence that oxygen availability is of particular importance in the distribution of vendace, both between and within lakes (Hamrin, 1986). Within Britain, the vendace now occurs in only two lakes, Bassenthwaite Lake and Derwentwater in the English Lake District, having been apparently lost during this century from the Castle and Mill Lochs in southwest Scotland (Maitland & Lyle, 1991a, 1991b).

Provisional estimates of population abundance or densities of the two British populations derived by echo sounding were given by Mubamba (1989) for the late 1980s, and by Winfield *et al.* (1994a) for the early 1990s. Both surveys suggested populations of several tens of thousands of individuals in both lakes, but they both also revealed an inconsistent recruitment of vendace in Bassenthwaite Lake.

There are no long-term records of any kind of the population dynamics of vendace in either Bassenthwaite Lake or Derwentwater.

4.4 Limiting factors

4.4.1 Lack of suitable lakes (Importance: high)

The abundance and distribution of vendace in Britain are undoubtedly limited primarily by the restricted number of lakes which meet the essential requirements of this species for a thermal refuge from relatively high summer temperatures, and an availability of clean gravel areas for egg spawning and incubation through the late winter and early spring. It should also be noted that Britain lies towards the southern geographical distribution of this species and any upward shift in lake temperatures associated with long-term climate change is likely to have a major adverse effect on their local survival.

4.4.2 Eutrophication-induced degradation of habitat (Importance: high)

Eutrophication may adversely affect coregonid populations through two distinct mechanisms. Firstly, the decay of accumulated dead algae in the late summer may cause near or complete anoxia in the hypolimnion, leading directly to the mortality of fish. Secondly, the accumulation of a layer of algal-derived material on spawning grounds may lead to poor survival of eggs, and hence unsuccessful recruitment.

4.4.3 Introduction of roach (Importance: unknown, possibly high)

The roach, a cyprinid fish of high competitive ability (see review by Persson, 1991), has recently been introduced to both Bassenthwaite Lake (Mubamba, 1989) and Derwentwater (Winfield, 1992). In addition to potentially out-competing vendace for zooplankton, young roach may also have an adverse effect by disrupting the established nature of the fish-zooplankton-phytoplankton axis, resulting in an acceleration of eutrophication (see review by Winfield & Townsend, 1991). It is stressed that these extreme outcomes of roach introductions are only possibilities, and whether or not they occur as a consequence of a given introduction depends on the result of a complex series of local interactions.

4.4.4 Introduction of ruffe (Importance: unknown, possibly high)

The ruffe, a percid fish which remains relatively active at low water temperatures (Bergman, 1988), has recently been introduced to Bassenthwaite Lake (Winfield, 1992), and appears likely to colonise Derwentwater in the near future via the connecting River Derwent. Elsewhere in the U.K., the introduction of this species has given cause for concern because it consumes considerable numbers of coregonid eggs (specifically *Coregonus lavaretus*) as they lay exposed on clean gravels during the late winter and early spring (Adams & Tippett, 1991).

5. Resume of conservation action to date

Prior to the late 1980s, the British vendace populations had been remarkably little studied. While some information on the now extinct populations of Scotland was given by Maitland (1966a), Maitland (1966b) and Maitland (1967), the extant English populations of Bassenthwaite Lake and Derwentwater had not been the subject of any scientific publications. Consequently, and understandably given this lack of fundamental information, most conservation action relating to

vendace has since been aimed at assessing their current status, fundamental ecology, and producing recommendations for future direct conservation action *per se*.

As part of a wide study of fish conservation issues within National Nature Reserves, some information on the ecology of the vendace of Bassenthwaite Lake and Derwentwater and recommendations for their future management were produced by Maitland & Lyle (1991a) and Lyle & Maitland (1991) under contract to the then Nature Conservancy Council. The findings of this study have also been published in the forms of Maitland & Lyle (1991b, 1992a and 1992b). Attempts by the same authors to establish new vendace populations in Loch Earn and Doune North Pond in Scotland, using eggs stripped from Bassenthwaite Lake fish in 1988, are briefly reported in Maitland & Lyle (1990).

The collection of detailed ecological information on the Bassenthwaite Lake and Derwentwater vendace was beyond the scope of the above study, but some such information was obtained by Mubamba (1989) although it has never been published. Nevertheless, this Ph.D. thesis contains invaluable data on the population biology, diet, reproduction and other aspects of these two vendace populations during the late 1980s.

In the 1990s, the only conservation action covering both the Bassenthwaite Lake and Derwentwater vendace populations has been that commissioned by the National Rivers Authority (NRA) and reported by Winfield *et al.* (1994a, 1994b and 1994c). However, the Bassenthwaite Lake population was also the subject of an investigation commissioned by North West Water Limited and reported in Winfield *et al.* (1994d). This vendace population now also enjoys further protection following the 1993 declaration of the Bassenthwaite National Nature Reserve.

Winfield *et al.* (1994a), which involved an extensive but detailed and quantitative study of all of the known *Coregonus* populations of England and Wales, provides information on the community ecology, population ecology, reproduction, diet, seasonal distribution (including quantitative echo sounding for the first time on British vendace populations), intraspecific variation and captive breeding for the two extant vendace populations based on work carried out largely in 1991 and 1992. Some of these results are already in press in the scientific literature (Beaumont *et al.*, in press), others are currently submitted, while all of them are also currently being prepared for inclusion in a series of NRA Research and Development Notes which will be more widely accessible to the conservation community. Winfield *et al.* (1994b) is an extensive literature review of the status of rare fish in Britain and, in particular, the biology of *Coregonus* species in the U.K. and the rest of Europe. Again, this information has been made more accessible by its publication in the form of a NRA Research and Development Report (Winfield *et al.*, 1994c).

Conservation research by Winfield *et al.* (1994d) was carried out largely in 1992 and 1993 and was concerned exclusively with the Bassenthwaite Lake vendace population. In addition to allowing the temporal extension and development of investigations of vendace community, population and distribution ecology, this study also facilitated examinations of spawning grounds and an attempt to study the ecology of young vendace.

Taken together, the above studies revealed that the vendace population of Bassenthwaite Lake may be threatened by eutrophication, through the agencies of deepwater near-anoxia and the siltation of spawning grounds, and by recent species introductions of roach and ruffe which may

out-compete young stages or consume eggs, respectively. Although the Derwentwater population is not threatened by eutrophication, the roach has recently been introduced to this lake and the arrival of ruffe from Bassenthwaite Lake, via the connecting River Derwent, seems inevitable.

Because of concerns over the above species introductions, a collaborative research programme by the Institute of Freshwater Ecology and the NRA was begun in January 1995 with the aid of addressing these problems.

6. Proposed action by English Nature

6.1 Policy and legislation

Action 1: Work with other organisations towards the development of appropriate policies and management plans to ensure the conservation of vendace in Bassenthwaite Lake and Derwentwater (Priority: high)

6.2 Site safeguard, land acquisition and management

Action 2: EN should consider the case for the designation of Derwentwater as a Site of Special Scientific Interest or a National Nature Reserve, on the basis of the presence of vendace, to give it similar recognition and protection to those enjoyed by Bassenthwaite Lake (Priority: medium)

Action 3: EN should object to any development proposals, agricultural developments, drainage/flood alleviation schemes or water abstraction proposals that may detrimentally affect Bassenthwaite Lake or Derwentwater with respect to the habitat requirements of vendace (Priority: high)

6.3 Species management, protection and licensing

No action yet appropriate, with the exception of appropriate contributions to catchment management plans (but see Action 8 below).

6.4 Advisory

Action 4: Promote sympathetic management of Bassenthwaite Lake and Derwentwater for vendace (Priority: high, essential)

It is vital that EN ensures that the management of Bassenthwaite Lake and Derwentwater is sympathetic to the needs of vendace. In addition to direct influences on this fish species itself, such efforts should also cover any activity within the water bodies themselves or their catchments which may influence key environmental factors such as oxygen levels or the availability of suitable spawning grounds. Such advisory activities should include contributions to present and/or future lake management plans.

6.5 International

Action 5: Promote European co-operation on vendace research conservation (Priority: high)

Although most concern over vendace conservation elsewhere in Europe is on fisheries rather than biodiversity grounds, many of the problems faced and expertise accumulated have a relevance to the situation in Britain. Moreover, the facts that the remaining U.K. populations have been isolated since soon after the last glaciation and have never been heavily exploited by fisheries, with implications for their population and genetic structures, means that they are themselves of considerable international conservation value. The establishment of a network of European fish biologists involved in vendace ecology and conservation would be very cost-effective and beneficial.

6.6 Future research and monitoring

Action 6: EN should commission or otherwise support research on the spawning ecology of vendace in their last two remaining U.K. sites (Priority: high, essential)

Research reviewed above has documented the status in the early 1990s of the vendace populations of Bassenthwaite Lake and Derwentwater and research now in progress is investigating the likely effects of recent species introductions. However, no work is currently in progress or planned on the spawning conditions, and scope for their improvement, for vendace in these two lakes, even though circumstantial evidence gives considerable cause for concern with respect to Bassenthwaite Lake. It is recommended that such work is given the highest priority.

Action 7: EN should commission or otherwise support a monitoring programme for vendace in their last two remaining U.K. sites (Priority: high, essential)

There is at present no consistent monitoring of the vendace population of Derwentwater, while monitoring of the population in Bassenthwaite Lake began only in May 1995 by IFE for a three year period under commission to NRA, North West Region in response to the 1991 Urban Wastewater Treatment Directive of the EC. It is recommended that this monitoring is supported in the longer term, and that a similar activity is begun as soon as possible on Derwentwater, preferably on an annual basis. The research reviewed above has shown that a suitable monitoring programme based on quantitative echo sounding, coupled with limited netting for biological samples, is now feasible.

Action 8: EN should commission or otherwise support a survey of potential sites for the establishment of new or replacement vendace populations (Priority: medium)

While conservation of their native habitats is undoubtedly the most appropriate way to conserve the vendace populations of Bassenthwaite Lake and Derwentwater, it is appropriate to prepare contingency plans for deployment if local extinction seems imminent. One course of action is to identify suitable sites, preferably within the natural catchment, for the establishment of further or replacement vendace populations. Such work could be done in large part from the scientific literature, but would also require the collection of new or current key environmental data. It would of course be essential to ensure that no other conservation concerns would be

compromised by such establishments of new populations.

Action 9: EN should commission or otherwise support a feasibility study to investigate the potential for captive breeding and keeping of vendace in Britain (Priority: medium)

As a last resort, contingency plans should also be made for the captive breeding and even keeping of vendace from Bassenthwaite Lake or Derwentwater. The technical aspects of such a programme have already been reviewed in the research described above, but consideration should be given at this stage to the logistics of where such programmes could be carried out. As such, this work would be largely a desk study involving discussions with numerous bodies within or allied to the water industry, and appropriate zoological institutions.

6.7 Communications and publicity

Action 10: Promote the importance of vendace and their conservation (Priority: medium)

The public profile of vendace, even in the Lake District, is remarkably low and would benefit from an increased appropriate effort in EN's routine communications and publicity programme. Such activities should include efforts to increase the awareness within the angling community of the potential, and usually unpredictable, consequences of species introductions. The production of appropriate posters and leaflets would be highly beneficial.

7. Action plan review

This action plan will be monitored annually by EN and NRA in conjunction with fish ecology specialists.

References

Adams, C. E. & Tippett, R. 1991. Powan, *Coregonus lavaretus* (L.), ova predation by newly introduced ruffe, *Gymnocephalus cernuus* (L.), in Loch Lomond, Scotland. *Aquaculture and Fisheries Management 22:* 239-246.

Beaumont, A. R., Bray, J., Murphy, J. M & Winfield, I. J. (in press). Genetics of whitefish *Coregonus lavaretus* and vendace *Coregonus albula* in England and Wales. *Journal of Fish Biology.*

Bergman, E. 1988. Foraging abilities and niche breadths of two percids, *Perca fluviatilis* and *Gymnocephalus cernuum* under different environmental conditions. *Journal of Animal Ecology 57:* 434-453.

Hamrin, S. F. 1986. Vertical distribution and habitat partitioning between different size classes of vendace, *Coregonus albula* in thermally stratified lakes. *Canadian Journal of Fisheries and Aquatic Sciences 43:* 1617-1625

Hamrin, S. F. & Persson, L. 1986. Asymmetrical competition between age classes as a factor causing population oscillations in an obligate planktivorous fish species. *Oikos 47:* 223-232

Jacobsen, O. J. 1982. A review of food and feeding habits in coregonid fishes. *Polskie Archiwum Hydrobiologii 29:* 179-200.

Lelek, A. 1987. *The Freshwater Fishes of Europe. Volume 9. Threatened Fishes of Europe.* Wiesbaden, AULA-Verlag. 343 pp.

Luczynski, M. 1986. Review of the biology, exploitation, rearing and management of coregonid fishes in Poland. *Ergebnisse der Limnologie 22:* 115-140.

Lyle, A. A.. & Maitland, P. S.. 1991. The status and conservation of British freshwater fish: survey of freshwater fish in National Nature Reserves. *Institute of Freshwater Ecology Report to Nature Conservancy Council.* 44 pp.

Maitland, P. S. 1966a. The fish fauna of the Castle and Mill Lochs Lochmaben, with special reference to the Lochmaben vendace, *Coregonus vandsius. Transactions of Dumfries and Galloway Natural History Society 43:* 31-48.

Maitland, P. S. 1966b. Present status of known populations of the vendace, *Coregonus vandesius* Richardson, in Great Britain. *Nature 210:* 216-217.

Maitland, P. S. 1967. Echo sounding observations on the Lochmaben vendace *Coregonus vandesius. Transactions of Dumfries and Galloway Natural History Society 44:* 29-46.

Maitland, P. S. & Lyle, A. A. 1990. Practical conservation of British fishes: current action on six declining species. *Journal of Fish Biology 37 (Supplement A):* 255-256.

Maitland, P. S. & Lyle, A. A. 1991a. Conservation of freshwater fish in the British Isles. *Institute of Freshwater Ecology Report to Nature Conservancy Council.* 95 pp.

Maitland, P. S. & Lyle, A. A. 1991b. Conservation of freshwater fish in the British Isles: the current status and biology of threatened species. *Aquatic Conservation 1:* 25-54.

Maitland, P. S. & Lyle, A. A. 1992a. Conservation of freshwater fish in the British Isles: the status of fish in National Nature Reserves. *Aquatic Conservation 2:* 19-34.

Maitland, P. S. & Lyle, A. A. 1992b. Conservation of freshwater fish in the British Isles: proposals for management. *Aquatic Conservation 2:* 165-183.

Mubamba, R. (1989) The Ecology of the Coregonid Fishes in the English Lake District. Unpublished Ph.D. Thesis. University of Wales. 428 pp.

Persson, L. 1991. Interspecific interactions. In: Winfield, I. J. & Nelson, J. S. (Eds) *Cyprinid Fishes - Systematics, Biology and Exploitation.* Chapman & Hall, London. pp 530-551.

Pokrovskii, V. V. 1961. Basic environmental factors determining the abundance of whitefish. *Trudy Soveshchanii 13:* 228-234.

Resetnikov, J. S. 1988. Coregonid fishes in recent conditions. *Finnish Fisheries Research 9:* 11-19.

Sterligova, O. P., Pavlovskij, S. A. & Komulainen, S. P. 1988. Reproduction of coregonids in the eutrophicated Lake Sjamozero, Karelian ASSR. *Finnish Fisheries Research 9:* 485-488.

Winfield, I. J. 1991. Fishes, waterfowl and eutrophied ecosystems: a perspective from a European vertebrate ecologist. *Memorie dell'Istituto italiano di idrobiologia Dott. Marco de Marchi. Milano 48:* 113-126.

Winfield, I. J. 1992. Threats to the lake fish communities of the U.K. arising from eutrophication and species introductions. *Netherlands Journal of Zoology 42:* 233-242.

Winfield, I. J. & Townsend, C. R. 1991. The role of cyprinids in ecosystems. In: Winfield, I. J. & Nelson, J. S. (Eds) *Cyprinid Fishes - Systematics, Biology and Exploitation.* Chapman & Hall, London. pp 552-571.

Winfield, I. J., Fletcher, J. M. & Cubby, P. R. 1994a. Status of Rare Fish, Project Record Volume 1. *Institute of Freshwater Ecology Report to National Rivers Authority.* 244 pp.

Winfield, I. J., Fletcher, J. M. & Cragg-Hine, D. 1994b. Status of Rare Fish, Project Record Volume 2. *Institute of Freshwater Ecology Report to National Rivers Authority.* 108 pp.

Winfield, I. J., Fletcher, J. M. & Cragg-Hine, D. 1994c. Status of rare fish - a literature review of freshwater fish in the U.K. *National Rivers Authority, R&D Report 18.* 62 pp.

Winfield, I. J., Fletcher, J. M. & Cubby, P. R. 1994d. Ecology of the vendace, *Coregonus albula*, in Bassenthwaite Lake. *Institute of Freshwater Ecology Report to North West Water Ltd.* 62 pp.

Zuromska, H. 1982. Conditions of natural reproduction of *Coregonus albula* (L.) and *Coregonus lavaretus* (L.). *Polskie Archiwum Hydrobiologii 29:* 1-28.

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