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The Irish pollan, *Coregonus autumnalis*: options for its conservation

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The ecology of four relict Irish populations of pollan (*Coregonus autumnalis*) is compared with that of the species elsewhere, and used to advocate conservation. The threats to these populations from introduced/invasive species, habitat degradation, climate warming and commercial exploitation are summarized and the legislation governing conservation of the stocks is reviewed. Conservation options (legislation, habitat restoration, stock translocation and stock augmentation) are outlined and their practicality and efficacy considered. A preliminary search indicates that there are a number of lakes that appear to be suitable for pollan translocation.

Key words: *Coregonus autumnalis*; conservation ecology; legislation; eutrophication; translocation.

INTRODUCTION

Owing to its recent glacial history, Ireland has a depauperate native freshwater fish fauna of only 14 species, all of euryhaline origin. Human introductions have augmented the Irish ichthyofauna and today 25 species are found in Ireland's fresh waters (Griffiths, 1997). Of the native species, only one, the pollan *Coregonus autumnalis* Pallas is not found elsewhere in Europe (Whilde, 1993).

Ireland has more than 4000 loughs (lakes) >5 ha, but pollan occur in only four large lowland loughs. Two, Loughs Neagh and Erne, are in Northern Ireland whilst Loughs Derg and Ree are in the Republic of Ireland (Fig. 1, Table I). Typically, *C. autumnalis* inhabit low productivity river systems in Arctic Canada, Alaska and Russia, where they are referred to as Arctic cisco (Fig. 1; Morrow, 1980; Novikov *et al.*, 2000). These northern populations are anadromous, making long migrations downriver as juveniles to offshore feeding grounds and returning upriver to spawn as adults (Gallaway *et al.*, 1983). The Irish populations are found far to the south of the species' typical range and each population has been isolated from conspecific populations probably since the last glaciation (Ferguson *et al.*, 1978), giving adequate time for genetic differentiation in a group renowned for its phenotypic (Lindsey, 1981) and genotypic (Vuorinen *et al.*, 1991) plasticity.

Atypically, the Irish populations inhabit meso-hypertrophic systems in a temperate oceanic climate and, as demonstrated for numerous species found

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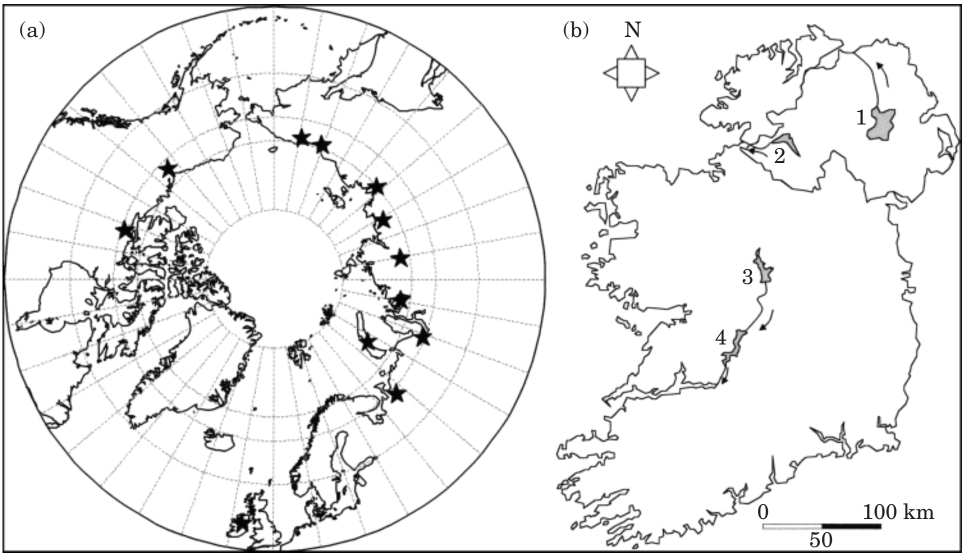

FIG. 1. Distribution of *Coregonus autumnalis*: (a) global distribution (note the disjunct nature of the western European populations, all found in Ireland, far to the south of the species typically Arctic distribution; (b) location of Irish pollan populations with efferent rivers: 1, Lough Neagh; 2, Lough Erne; 3, Lough Ree; 4, Lough Derg.

along latitudinal gradients (e.g. Arctic charr *Salvelinus alpinus* (L.), Griffiths, 1994), pollan ecology and behaviour contrasts markedly with that of more northern populations (Wilson, 1993). Pollan are entirely lacustrine and non-anadromous (even though all the populations have access to the ocean within 100 km), they can mature early and at a small size (1+ year, 210 mm), exhibit rapid growth rates, are short lived and, in comparison with northern populations, are of reduced individual size (Lough Neagh asymptotic length $L_\infty = 297$ mm, Harrod *et al.*, 2002; Yenisei River, Russia $L_\infty = 550$, calculated from Berg, 1962).

Coregonus autumnalis is relatively understudied in its Arctic Russian range (Novikov *et al.*, 2000) and several important features of the species ecology are unclear at present.

Although pollan conservation has been discussed principally with reference to the species' scientific worth, pollan are also important for socio-economic reasons. They have a long history of commercial exploitation (Thompson, 1856), and have played a significant role in Ireland's regional history. At the time of the Great Famine (1845–1850), after continued failure of the potato crop (Boyle & Ó Gráda, 1986), the Lough Neagh stock contributed to the livelihood of ' great numbers of the lower classes ' (Anon., 1849). Only 50 years later, over 450 t of pollan were being exported annually to Britain (Wilson, 1993), and the fishery employed a significant proportion of the local population, influencing patterns of marriage and settlement around the lake (Anon., 1985).

Today, the Lough Neagh commercial fishery primarily exploits European eel *Anguilla anguilla* L. and provides employment and income for about 400 individuals in one of the most deprived regions of western Europe. Coregonid fishes support major fisheries throughout the Northern Hemisphere (Bodaly,

TABLE I. Some characteristics of the pollan loughs

	Limnology[a]						% contribution to fish community[d]		
Lough	Altitude (m)	Surface area (km^2)	Maximum depth (m)	Mean depth (m)	Mean TP[b] ($mg\ m^{-3}$)	Maximum Chl.a[b] ($mg\ m^{-3}$)	Pollan	Roach	Total number of fish in catch
Neagh	15	383	34	8·9	173	93	26	58	2604
Erne	46	109	62	11·9	59	—	0·3	55	3368
Ree	38	105	35	6·2	47	42	0·6	73	3691
(+ZM)[c]					(35)	(15)			
Derg	33	117	36	7·5	43	72	0·3	79	2929
(+ZM)[c]					(32)	(9·6)			

[a]Limnological features: L. Neagh (Wood & Smith, 1993; Harrod *et al.*, 2002); L. Erne (Gibson, 1998) and L. Derg and Ree (Bowman, 1998, 2000).
[b]TP, Total phosphorus concentration; Chl a, chlorophyll a concentration.
[c]After colonisation by zebra mussels.
[d]Fish community structure, Harrod *et al.* (2002).

1986; Luczynski, 1986) and sustainable, scientifically managed pollan fisheries have the potential to provide employment and income. Coregonid fishes have been successfully cultured throughout much of their range for several decades (Luczynski, 1986) and pollan could provide a source of native fish for sustainable aquaculture. The continued survival of the Irish populations of *C. autumnalis* is therefore of importance for both scientific and socio-economic reasons.

Conservation of freshwater fishes within the British Isles has only recently become an important issue (Maitland, 1974). As part of this increased concern, the conservation status of several native fishes of the British Isles, including pollan and the coregonids native to mainland Britain [vendace, *Coregonus albula* (L.) and whitefish, *Coregonus lavaretus* (L.)] became an issue (Winfield, 1992). A number of recent reviews have been published suggesting that pollan were threatened or endangered (Maitland & Lyle, 1991; Whilde, 1993; Winfield *et al.*, 1994; Quigley & Flannery, 1996). However, these studies included very little contemporary information. Harrod *et al.* (2002), in quantifying the current status, noted that pollan, while formerly common, now contribute less than 1% of survey catches in three loughs (Loughs Erne, Derg and Ree), and 25% in Lough Neagh (see Table I). Hence, Lough Neagh possibly represents the last viable population of *C. autumnalis* in Ireland. Although detailed scientific baseline data are not generally available, anecdotal descriptions of fish community structure indicate that pollan have recently undergone negative changes in all four Loughs, and after 10 000 years of salmonid dominance, these waters are now dominated by introduced cyprinid and or percid fishes. These changes have occurred against a background of habitat degradation due to human development within catchments (gross cultural eutrophication) and the establishment of an array of invasive species in each lake [e.g. fish, roach *Rutilus rutilus* L. and the alien macroinvertebrates, *Gammarus tigrinus* Sexton, *Gammarus pulex* L., *Crangonyx pseudogracilis* Bousefield (Dick, 1996*a*) and zebra mussels, *Dreissena polymorpha* Pallas, whose recent rapid spread in Ireland (McCarthy *et al.*, 1997; Rosell *et al.*, 1999)] mirrors the North American situation (Griffiths *et al.*, 1991). Today, European populations of *C. autumnalis*, a cold-adapted fish found typically in Arctic, low productivity waters, inhabit lakes whose abiotic and biotic environments are changing at an unprecedented rate. These conditions contrast with those that the species encountered either in its evolutionary past or elsewhere in its distribution and are likely to compromise its future conservation. Because of their limited distribution, the European populations are extremely vulnerable to extinction through chance events (e.g. pollution and disease), which could eliminate entire populations. In this study, the existing situation regarding conservation of pollan in Ireland is reviewed, and practical actions are detailed for the continued conservation of this endangered fish.

CONSERVATION OF THE POLLAN

SUMMARY OF THREATS TO POLLAN

Habitat degradation

During recent decades the pollan loughs have undergone cultural eutrophication as a consequence of phosphorus inputs from discharges of municipal waste and agricultural activities. Diffuse agricultural inputs are now the greatest loading factor in the Lough Neagh catchment (Foy *et al.*, 1995). Cultural eutrophication is a worldwide problem and has been implicated in the loss [such as of *C. albula* (Maitland & Lyle, 1991)] and decline (Nümann, 1972) of several coregonid populations. The ecological consequences of lake eutrophication are diverse (Smith *et al.*, 1999) and may impact pollan through direct or indirect pathways, such as reducing concentrations of dissolved oxygen due to increased productivity and by intensifying competitive asymmetries between roach and perch (Persson, 1991). Although each lough differs with regard to trophic state and current water quality (Table I), inputs of nutrients continue to rise in all the loughs (Foy *et al.*, 1995; Bowman, 2000; Zhou *et al.*, 2000) and probably pose the principal threat to the future survival of pollan.

Invasive species

Worldwide, lake ecosystems have undergone significant and far-reaching changes following the introduction of exotic species (Hall & Mills, 2000). Dick (1996*b*) has documented the success of various species in invading Irish freshwater ecosystems, and many of these species have the potential to threaten the survival of pollan stocks either through competition, predation or by modifying environmental conditions (Winfield, 1992).

Roach have undergone considerable expansion in the British Isles over recent decades (Maitland & Campbell, 1992), and there have been repeated suggestions that the introduction of roach has been a causal factor in the reported declines in pollan (Whilde, 1993; Rosell, 1997), presumably through interspecific competition for cladoceran prey. Roach are capable of depressing populations of other species in lake systems e.g. perch, *Perca fluviatilis* L. (Persson, 1991). Kirkwood (1996) demonstrated considerable dietary overlap between juvenile pollan and roach for both planktonic and benthic food in Lough Neagh, especially during the sensitive first summer. However, the existence, intensity or indeed direction of any negative interactions between juvenile pollan and roach is currently unclear.

Zebra mussels have recently been recorded in three pollan loughs, and only Lough Neagh is currently free from invasion (McCarthy *et al.*, 1997; Rosell *et al.*, 1999). Although first reported in these systems <5 years ago, they are now abundant and have been associated with improvements in water quality in Loughs Derg and Ree, for example by reducing chlorophyll *a* concentrations (Bowman, 2000) (Table I). Zebra mussels, by reducing phytoplankton densities, have the potential to indirectly influence pollan populations. For example, it is likely that by controlling phytoplankton levels zebra mussels will influence the abundance, size structure and species composition of zooplankton populations. Although this has the potential to affect pollan of all ages [Lough Neagh pollan are largely zooplanktivorous during summer months (Wilson, 1984; Kirkwood, 1996)], it is most likely to have an impact on 0+ year pollan by modifying available resources for pollan fry. Pollan may also be affected by zebra mussel aggregations on spawning habitats. Pollan spawn over shallow, hard-bottomed areas that are colonized preferentially by zebra mussels and which may become unusable for pollan by the accretion of pseudofaeces.

Climate change

Although debate exists regarding degree, there is a wide agreement that anthropogenic modification of atmospheric gases will modify global climate in the near future (Intergovernmental Panel on Climate Change, 1996). It is likely that any increases in temperature will have detrimental consequences for the pollan, an arctic, stenothermal, species. The consequences of climate warming interacting with problems of eutrophication are best illustrated through the example of Lough Neagh.

Lough Neagh is a highly eutrophic lake (Table I) and has reduced oxygen concentrations during summer months. For example, C. Carter & D. Griffiths (unpubl. data) reported concentrations in inshore surface waters <80% saturation in the summers of 1998 and 1999, dropping to 60% on occasion. The trend of rising phosphorus inputs reported by Foy *et al.* (1995) is likely to continue with a consequent increase in eutrophication and decrease in oxygen saturation. Currently, Lough Neagh water is normally re-aerated by wind action but if calm weather persists for 3–4 days in summer, productivity is sufficiently high for eels *Anguilla anguilla* L. caught on benthic long lines to die of asphyxiation (M. Quinn, pers. comm.).

The mean annual temperature for Lough Neagh is 10° C and water temperatures is rarely 18° C in the summer. With temperatures predicted to rise by 1·4–5·8° C over the next century (Intergovernmental Panel on Climatic Change, 2001) there will be a further reduction in the oxygen carrying capacity of water and therefore an increased period when oxygen concentrations are low. For example, oxygen saturation concentration at 21° C is only 94% of that at 18° C and at 24° C 89%. If it is assumed a Q_{10} of 2 for oxygen consumers but no change in productivity, the time to a given oxygen concentration, such as that producing death by asphyxiation in calm lough waters, at 21° C will drop to 77% of that at 18° C and at 24° C to 59%: the eel observations suggest that severe deoxygenation will occur far more rapidly and for longer in the future. The Shannon lakes are, like Lough Neagh, eutrophic, unstratified, and wind-stirred and probably pose similar environmental challenges to pollan. In contrast Lower Lough Erne, while showing signs of enrichment (Zhou *et al.*, 2000), has a much larger deep area and is thermally stratified (Gibson, 1998). Pollan occupy deep waters in this lake and the consequences of climate warming would be probably less severe.

Dabrowski (1985) concluded that Lough Neagh pollan expended 51–66% of their energy budget on respiratory costs in a summer with a maximum-recorded temperature of 21° C. It seems likely that this percentage would increase at higher temperatures. The upper lethal temperature for whitefish has been suggested to be about 22° C (European Inland Fisheries Advisory Commission, 1994), and *C. autumnalis*, with its ' high arctic ' distribution, is likely to be more stenothermal than most coregonids. Accurate predictions of the effects of warmer summers on pollan will require information on how consumption, activity and respiration rates change with temperature.

Commercial exploitation

Pollan are probably subject to less human exploitation today than for many years. The Lough Erne fishery has been closed, owing to the decline in pollan.

The commercial pollan fisheries for pollan on the Shannon, while still open, have disappeared, presumably because catches are low. Lough Neagh fishermen exploit largely eels, using long-lines and purse seines because of the greater financial returns (*c.* £4·00 kg^{-1} *v.* *c.* £0·50 kg^{-1}). This contrasts with the situation at the turn of the century, when over 455 t of pollan were exported to Britain in a single season (Wilson, 1993). Pollan are still taken in considerable numbers on Lough Neagh, especially during the eel closed season, during periods when eel yields fall below acceptable levels for the effort invested and during early summer when 0+ year pollan are taken illegally to bait long-lines.

STATUTORY PROTECTION

The precarious conservation state of the pollan has been discussed for at least a decade (Winfield & Wood, 1990), and has developed alongside a global increase in awareness of biodiversity conservation (Holdgate, 1991; United Nations Conference on Environment and Development (UNCED), 1992). This increased awareness led to a series of international and national initiatives that reflected concerns regarding loss of species and their habitats.

Within the U.K. and Ireland, statutory nature conservation has been directed largely by legislation originating from International or European conventions. Reflecting a concern that human activities were destroying habitats and causing species' extinctions, signatories to the 1992 International Convention on Biological Diversity (ICBD) (UNCED, 1992), which included the U.K. and Republic of Ireland, committed themselves to producing legislation to protect and enhance biodiversity. At the same time, the European Community released Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna & Flora. This directive, widely known as the Habitats Directive, requires Member States to take measures to maintain or restore natural habitats and species at a favourable conservation status in the Community. As part of this, the directive aims to produce a network of protected Special Areas of Conservation (SACs) that host representative types of natural habitat or vulnerable species (which are listed in Annex II of the directive). Although considered endangered in Europe (Whilde, 1993) and with very restricted national distributions which are isolated in relation to the natural range of the species pollan were, inexplicably, not included in Annex II where the only coregonid afforded protection was the houting *Coregonus oxyrinchus* L. (they were included in Annex V, which lists species whose exploitation in the wild may be subject to management measures).

The U.K. and the Republic of Ireland, as independent governments, respond individually to international commitments and national concerns (including wildlife conservation) by formulating national legislation and strategies. Although each government has recognized that the European populations of *C. autumnalis* are endangered (Whilde, 1993), currently their only protection is through restrictions on commercial fisheries in Northern Ireland (Table II). The lack of protection afforded to pollan contrasts with the situation elsewhere in the British Isles where *C. lavaretus* and *C. albula* are protected by the United Kingdom Wildlife and Countryside Act 1981.

TABLE II. Summary of the statutory protection afforded to the Irish populations of *C. autumnalis*

Irish RDB	European legislation	National wildlife legislation	National BAP
Endangered[1]	Habitats Directive[2]: Annex V	ROI[4]: Unprotected	ROI[6]: In preparation
	Bern Convention[3]: Annex III	UK[5]: Commercial species:	UK[7]: Priority species

[1]Whilde (1993).
[2]EC Directive 92/43/EEC Annex V—species whose exploitation must be subject management.
[3]Council of Europe Convention on the Conservation of European Wildlife and Natural Habitats (Berne Convention).
[4]Republic of Ireland Wildlife (Amendment) Act 2000.
[5]Northern Ireland Fisheries Act (1966) and subsequent amendments: places restrictions on minimum length, mesh sizes, and closed season.
[6]At the time of writing the Republic of Ireland BAP was in preparation (P. Buckley, pers. comm.).
[7]United Kingdom Biodiversity Action Plan (UKBSG, 1995).

CONSERVATION ACTION TO DATE

The requirement for prompt conservation action for the Northern Ireland populations has been recognized through the inclusion of pollan as a priority species in the United Kingdom Biodiversity Action Plan (United Kingdom Biodiversity Steering Group, 1995). This response to the ICBD identified 116 U.K. species whose conservation was considered a priority. A Biodiversity Action Plan (BAP) was published for each, providing a formal, government-endorsed framework for long-term conservation: they assessed current status; detailed threats to survival and set fixed objectives for conservation by named partners. Although the BAP identified statutory bodies charged with fulfilling these conservation objectives, no specific funds for conservation action have been provided. The key features of the pollan BAP are summarized in Table III.

Although the pollan BAP is a welcome response from the U.K. Government, it has serious shortcomings that constrain its use as a framework for the conservation of pollan. Adequate management of the Lough Neagh fishery is not possible at present: there are no estimates of stock size, no catch returns made for any of the commercially exploited fish in Lough Neagh, no measures of fishing effort, and no catch limits so there is little likelihood of any stock-based sustainable management of the Lough Neagh pollan in the short term. Furthermore there is a marked reluctance by the fishermen to subscribe to any framework which could possibly curtail their freedom to fish. At present regulations control fishing gears, mesh size and fishing times and seasons but for gillnets there are no limits on the number of licenses issued. The BAP assumes implicitly that the Lough Neagh population is not under threat. However, during the 1990s the stock underwent major shifts in population structure that have been linked to a loss of larger fish from the population and it experienced several years of poor recruitment, raising fears that the population was in decline (Harrod *et al.*, 2002).

In a predominantly rural economy where agricultural soils are saturated with phosphorus from diffuse (agricultural) sources (Tunney *et al.*, 1998), there is little

TABLE III. Summary of the United Kingdom Biodiversity Action Plan for Northern Ireland pollan populations (UKBSG, 1995)

Current status	Two U.K. populations
Factors causing decline	Eutrophication Competition with introduced roach Commercial exploitation
Current action	Regulation and management of commercial fishery Management of water quality
Action plan objectives and target	Maintain the Lough Neagh population at a level suitable for sustainable harvesting Maintain viable pollan populations in Lower Lough Erne Restore Upper Lough Erne population by 2005
Proposed actions	Seek appropriate level of fishery protection for U.K. pollan populations Co-operate with Republic of Ireland authorities to ensure cross-border water quality management strategy is appropriate for pollan
Site safeguard and management	Reduce the trophic status of U.K. pollan lakes Consider providing statutory protection to pollan habitat in Lower Lough Erne
Species management and protection	Seek the co-operation of Lough Neagh commercial fishermen to monitor commercial catches Consider the potential for culturing and reintroducing pollan to Upper Lough Erne
Advisory	Increase public awareness of pollan and its conservation requirements
Future research and monitoring	Provide quantitative assessments of Lower Lough Erne stock

chance of reducing phosphorus loadings in the short term. Again, there seems to be little likelihood of roach populations being controllable. It is not obvious how the Lower Lough Erne population can be maintained, given the uncertainty about the causes of the decline there. Finally, there seems to be little chance of restoring the Upper Lough Erne population by 2005 since no hatchery or strategy is in place; it should be noted that while it is not unreasonable to assume that pollan occurred in Upper Lough Erne there is no evidence that they did (Rosell, 1997).

The Republic of Ireland has yet to implement a formal plan for the conservation of biodiversity. Fisheries departments in the Republic of Ireland (like those in Northern Ireland) have traditionally directed resources towards exploitation of fishes and have ignored their conservation importance. A recent account of the state of the Republic of Ireland's environment detailed the status of its freshwater fish stocks (Stapleton *et al.*, 2000). This report provides detailed information on species of direct fisheries interest (e.g. salmonids and coarse fishes) but fails to refer to pollan, apart from suggesting that active conservation management plans are required for a number of endangered freshwater fishes, and makes no practical suggestions for the conservation of pollan. Conservation in the Republic of Ireland is further complicated in that conservation legislation and protection is very much a multi-agency problem with up to six individual bodies having some statutory responsibility for conservation of rare & threatened species (P. Buckley, pers. comm.).

Although the European populations of *C. autumnalis* are found in two separate political regions, the populations are located <200 km apart in a single biogeographic area. The threats to the future conservation of pollan are similar for each population (Harrod *et al.*, 2002), and therefore a strong argument exists for a pan-Irish approach.

CONSERVATION OPTIONS

An assortment of strategies are available for the conservation of threatened freshwater fishes e.g. Maitland & Lyle (1992). Here the most likely alternatives for pollan are reviewed.

LEGISLATION

Existing legislation is clearly insufficient to ensure the future conservation of pollan and there is a pressing need for the Irish populations of *C. autumnalis* to be subject to increased statutory protection. Elsewhere in the British Isles, both *C. albula* and *C. lavaretus* populations are protected from human interference under the U.K. Wildlife and Countryside Act. The omission of pollan from the equivalent legislation in Northern Ireland (Nature Conservation, Amenity, Lands and Wildlife Order 1985, 1989) and their habitats from Annex II of the Habitats Directive should be an immediate required action. However, simply relying on future legislation to protect pollan is impractical and total protection for pollan is probably undesirable since it would prevent exploitation of the Lough Neagh stock. Provided the population there remains healthy the pollan fishery should be maintained but it is suggested that any future legislation should set a framework for the fishery to operate under scientific i.e. stock-based management

It could be argued that there is little likelihood of increasing the statutory protection of pollan unless there is an increased awareness of pollan at a political level. This is extremely difficult to achieve for a species that is largely unseen, even by people in the communities around some of the lakes where it lives. An alternative view is that well publicized increased legal protection would increase public awareness and encourage the authorities to take action. Either way, pollan are extremely threatened in the short term and prompt, practical, action is required to conserve the Irish populations.

HABITAT RESTORATION AND CONTROL OF INTRODUCED SPECIES

Restoration of temperate lakes has generally involved the control of problem species and rehabilitation of water quality (Smith, 1998; Drenner & Hambright, 1999). Each pollan lough has undergone decades of cultural eutrophication originally due to point pollution of plant nutrients from sewage treatment works but increasingly through diffuse, agricultural, pollution. Even if there was to be total control of inputs there are still considerable quantities of phosphorus locked up in the sediments and improvements over a decadal time-scale are unlikely. In addition, the large size of the pollan loughs restricts options for restoring water quality through lake management techniques. Biomanipulation and control of introduced species such as roach and zebra mussels is impossible due to the size of the lakes and the prohibitive costs (Myers *et al.*, 2000), whilst removal or treatment of sediments is similarly not feasible.

TRANSLOCATION

Conservation ecologists commonly translocate threatened species in order to generate self-sustaining populations in case the original populations go extinct (Stockwell *et al.*, 1996; Fischer & Lindenmayer, 2000). This could be done following existing procedures utilized for other endangered fishes in the British Isles including coregonids and Arctic charr *Salvelinus alpinus* L. (Maitland & Lyle, 1992), that is to strip wild fish, fertilize eggs in the field and then return adults to the donor lake. Pollan would then either be introduced to the new water as fertilized eggs, as yolk-sac larvae, or as juveniles.

Although the establishment of back-up populations is probably the most practical option available to those wanting to conserve lake fishes in the British Isles, it is not without problems. Genetic diversity should be maximized to increase viability of these translocated populations (Leberg, 1990; Stockwell *et al.*, 1996). In the case of pollan, this is likely to involve obtaining gametes from as many individuals of both sexes as possible throughout the spawning period over several years. Spawning pollan are easily obtained in Lough Neagh but obtaining sufficient parent fish to maximize genetic diversity may be difficult in the other loughs. For example Rosell (1997) conducted extensive, sonar-directed, gillnetting surveys for pollan in Lower Lough Erne between 1992–1995 but caught only 21 specimens.

Maitland & Lyle (1992) suggested that two back-up populations should be established in each of the Erne, Neagh and Shannon (Derg and Ree) catchments. Although these regions include a large number of lakes, their individual suitability as introduction sites for pollan is uncertain, particularly since coregonid fishes have elevated habitat requirements (Alabaster & Lloyd, 1980).

Potential waters for translocations in Northern Ireland, were identified by a preliminary analysis of the Northern Ireland Lakes Database, which details characteristics of 614 lakes (Smith *et al.*, 1993). In the present study lakes were classified following a simple filter analysis (Fig. 2). Although pollan can survive in very eutrophic systems (such as Lough Neagh), lakes initially selected fulfilled the oligo-mesotrophic limits of the Organization for Economic Co-operation and Development trophic state classification, since these lakes were thought more likely to fulfil other habitat requirements of pollan (stages 1 and 2, Fig. 2). This reduced the number of lakes remaining to 131.

In order to establish a viable, self-sustaining population a lake should be large enough to minimize genetic effects of small population size such as inbreeding. Although the number of pollan constituting a viable population is unclear, a population of several thousand is probably needed to minimize inbreeding effects (Nunney & Campbell, 1993). Published estimates of natural densities of lake coregonids vary greatly (e.g. 2–223 kg ha^{-1}) but reported fishery yields of Lough Neagh pollan at the end of the nineteenth century were *c.* 12 kg ha^{-1} (Wilson, 1993), indicating that actual densities at the time were at least 10–20 kg ha^{-1}. Since a 200 mm pollan weighs *c.* 100 g (C. Harrod, pers. obs.) a 20 ha lake would

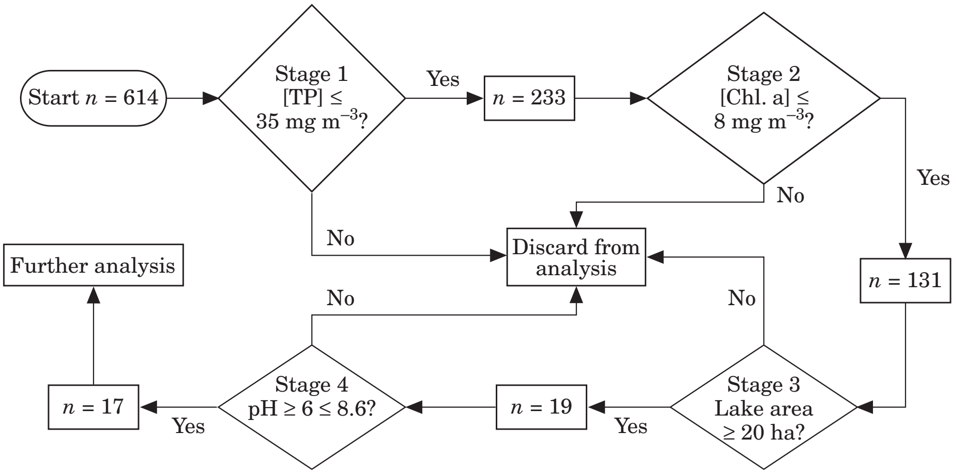

FIG. 2. Selection model for pollan relocation in Northern Ireland using data from the Northern Ireland Lakes Database (Smith *et al*., 1993).

TABLE IV. Summary of physical and chemical characteristics for the 17 loughs selected after filter analysis of the Northern Ireland lakes database

Variable	Mean (± S.E.)	Minimum	Maximum
Altitude (m)	147·6 (± 17·6)	45	285
Area (ha)	40·9 (± 4·85)	20	86
Soluble reactive phosphorus (mg m^{-3})	6·2 (± 0·68)	3	11
Total phosphorus (mg m^{-3})	19·9 (± 1·69)	8	35
Nitrate (mg m^{-3})	0·11 (± 0·033)	0·01	0·39
Silicate (mg m^{-3})	1·8 (± 0·50)	0·25	7·95
pH	7·5 (± 0·14)	6	8·27
Chlorophyll *a* (mg m^{-3})	4·8 (± 0·52)	1	8

support *c*. 4000 fish. By selecting lakes of 20 ha or larger, the range of potential waters was reduced to 19. Finally, this was further reduced to 17 after selection for pH, of <8·6, which was selected as an upper safe limit for coregonid eggs (Alabaster & Lloyd, 1980).

The physiochemical characteristics of the loughs remaining at the end of analysis are detailed in Table IV. Unfortunately, the database does not include information on a range of factors which are likely to influence the suitability of the loughs for translocations, including sufficient depth enough to provide temperature refugia during summer stratification existing fish community structure, and ownership and current management procedures. However, these factors could be assessed easily with desk and field studies. A number of the lakes identified are upland reservoirs. Establishing safeguard populations in reservoirs might be problematical for several reasons. First, during summer months, pollan, at least in Lough Neagh, are largely zooplanktivorous, selectively preying on cladocerans. This may subsequently affect water quality as algal populations are released from grazing pressure, which could impair reservoir operations. A further problem is associated with the suitability of reservoirs for spawning. Any drawdown of water levels during winter may lead to reduction in available spawning habitat or even eggs suffering mortality after being exposed to the air (Winfield *et al.*, 1998).

ENHANCEMENT OF EXISTING STOCKS USING HATCHERIES

Bodies involved in maintaining fish populations have commonly used hatcheries to supplement natural populations, or to maintain populations where natural reproduction does not take place such as due to habitat degradation (Waples, 1999). Hatchery augmentation of natural and introduced stocks of coregonids through the stocking of juvenile life stages has been practiced for over 150 years in Europe (Hamrin, 1986; Luczynski, 1986; Salojärvi, 1986; EIFAC, 1994) and North America (Todd, 1986*a*). However, there has been a long debate regarding the efficacy of these costly techniques in maintaining coregonid populations (Bodaly, 1986; Todd, 1986*a*, *b*). Waples (1999) reviewed the controversy surrounding hatcheries which extends beyond arguments regarding costs. The considerable genetic, ecological and disease risks associated with hatchery enhancement (Busal & Currens, 1995; Waples, 1999), combined with the elevated costs of this approach indicate that it is not a suitable approach for the conservation of pollan.

MONITORING AND RESEARCH

While some routine sampling has been carried out on the Lough Neagh and Erne pollan populations the knowledge of the Shannon populations is extremely limited and these lakes are in urgent need of investigation (Harrod *et al.*, 2002). Any future conservation action plan must include a monitoring component, providing information on the effectiveness of any conservation actions and the status of existing stocks. Monitoring should utilize standard assessment techniques, be standardized between lakes, and continued at a scale suitable to provide reliable evidence of stock abundance and change. However, this will be expensive because of the large size of the lakes.

Ferguson *et al.* (1978) resolved the uncertainty about the taxonomic status of pollan using electrophoresis. Their analysis has subsequently been confirmed by others (Bernatchez *et al.*, 1991; Bodaly *et al.*, 1991) using a variety of genetic techniques and markers. However no inter-population studies have been conducted and prior to any translocations there is a pressing need to establish the level of genetic differentiation between the pollan populations (Cross *et al.*, 1998).

CONCLUSION

Pollan populations represent an important biological resource for Ireland, but the conservation value of the species is not widely appreciated, and until recently, there was little governmental recognition of their precarious conservation status.

The present authors suggest that to effect the future conservation of pollan, a pan-Irish pollan conservation group, incorporating biologists and environmental managers at government and local levels, should be formed. This group would formulate a practical conservation action plan and oversee the short and long-term actions necessary for the conservation of pollan. Immediate actions should include an investigation of the extent of genetic differentiation between populations, the establishment of back-up populations, and monitoring of existing and any newly established populations. Longer term actions will include pressing for improved water quality, enlightened fisheries management, and governmental recognition of the conservation requirements of pollan. By including these features in a conservation action plan that clearly defines goals and monitors their progress, it should be possible to ensure the future survival of the pollan in Ireland and western Europe.

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