Ireland’s changing freshwater habitats: anthropogenic impacts, fishery management problems and ecohydrological perspectives

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Abstract
The adverse changes to Ireland’s rivers and lakes, that result from deterioration in water quality, channelization and alteration of natural hydrological features, have impacted on the habitats of a variety of important fish stocks. These anthropogenic effects, and the recent changes in landscape management, which also threaten the other aspects of aquatic biodiversity of many Irish river catchments are reviewed. The importance of conserving ecotone features and of adopting an integrated ecological approach to monitoring of aquatic environmental change is discussed. Application of ecohydrological principles, for fish conservation and fisheries management is recommended. Further interdisciplinary studies and elaboration of new strategies for sustainable development of Ireland’s freshwater resources are required.

Key words: water quality; fish conservation; biocomplexity; ecohydrology; species introductions

1. Introduction

The lakes, rivers and other freshwater resources of Ireland are of considerable economic and ecological significance. Deterioration in water quality and habitat degradation, which increasingly impacted on these natural resources in the 20th century have lead to a greater appreciation of the need for effective monitoring, pollution control measures and habitat rehabilitation programmes. Conservation issues are increasingly important at local, regional and national levels. Likewise, EU legislation has regulated modifications to national regulations governing all aspects of environmental management. Development of inland fisheries and the natural resources, in a sustainable manner has also highlighted the need to appreciate the biocomplexity of river catchment management. Though significant advances have been made in the development of national water programmes, in research on Ireland’s aquatic ecosystems and in landscape management, the potential application of ecohydrology principles (Zalewski 2000) in freshwater research and management in fish habitat is only gradually being appreciated.

2. Ireland’s freshwater resources

Ireland’s north-western European location is reflected in its temperate maritime climate. Mean annual rainfall levels (which vary from about 750 mm in parts of eastern lowlands to more than 1200 mm in the western areas) and temperature regime (mean annual air temperatures ranges from 9.5°C in the north east to 10.5°C in the extreme southwest), combined with the islands ‘saucer-shaped’ topography, are reflected in the variety of surface freshwater habitats and wetlands that
are typical features of the Irish landscape (Keane 1986; Aalen et al. 1997). Lakes, and smaller standing water bodies recognised cartographically, make up about 2.4% of Ireland's land area. Various estimates of the numbers of such water bodies have been proposed, e.g. 4000 by Murray (1996) and Cabot (1999), and their combined surface area is estimated at 168,000 ha. Most of these standing waterbodies are small loughs or pools of less than 100 ha and only 23 exceed 1000 ha in area. Ireland's largest lake, Lough Neagh has a surface area of 38,300 ha, a maximum depth of 33 m, but its mean depth is only 8 m. Most Irish lakes are shallow, though some may have maximum depths in excess of 50 m, and most of the larger lakes are located in the lowland Carboniferous limestone that characterises the central low-lying area of the country (Murray 1996). The island's rivers include about 16,000 km of main channel and 10,000 km of tributaries and streams. Ground water resources, locally important for domestic and industrial supply, are of limited importance from a biodiversity perspective, reflecting the adverse effects of the Pleistocene glaciations on Ireland's biota. Karstic features in the geology of some limestone areas in central and western Ireland, e.g. the Burren area of County Clare, are important factors in the hydrology of temporary water bodies, such as those known locally as tur-loughs (Reynolds et al. 1998), which are of considerable ecological interest.

Peatlands are important natural features of the Irish landscape, in which natural deciduous forest cover was largely eliminated by the 18th century (Foss and O'Connell 1997; Neeson 1997; Sheehy-Skeffington, O'Connell 1998). Peatlands cover 17.2% of Ireland's land surface, the third largest proportion of any country in the world (Cabot 1999) and the ecology of the numerous small oligo-dystrophic loughs and some of the larger western Irish lakes is strongly influenced by the extent of the peatlands and their humic rich waters. Forestry development in Ireland, encouraged by State and EU grant aid has involved extensive coniferous plantations on economically marginal land like blanket bog areas (Neeson 1997). Commercial exploitation of peat, especially from the raised bogs which were themselves once important as proglacial lakes some 9000 years ago, has created numerous shallow water bodies of limnological interest (Reynolds et al. 1998; Sheehy-Skeffington, O'Connell 1998).

Ireland's freshwater resources have been increasingly exploited since Mesolithic human populations first colonized this island about 8000 years ago. Their river and lake shore settlements reflected the importance of inland waterways for navigation purposes; the potential safety of lake island habitation sites and the food sources provided by the fish stocks and aquatic bird life in these waterbodies (Aalen et al. 1997; Mitchell, Ryan 1998; O'Sullivan 1998). The locations of modern towns and villages in Ireland often reflect the historical patterns of lake shore and river bank settlements.

3. Pollution and degradation of fresh-water habitats

Comprehensive long-term data sets on water quality in the Republic of Ireland are available as a result of surveys conducted by the Irish Environmental Protection Agency (formerly An Foras Forbartha and Environmental Research Unit, (Bowman and Clabby 1998)) Water quality is currently assessed by the EPA at 3200 locations at least once in every three years by biological sampling of invertebrate assemblages, and at 2100 of these sites chemical sampling is undertaken. The classification system employed is primarily biological and sites are assigned to 4 categories ranging from A, unpolluted waters to D, seriously polluted. A recent review (Stapleton et al. 2000) indicated that most (44%) recorded instances of serious pollution were attributed to sewage discharges, the remainder to agriculture or industry in roughly equal proportions. In the respect of the lesser, slight (B) or moderate (C) levels of pollution most instances were attributed to agriculture. The overall assessment of river quality, based on 13,000 km of channels surveyed for 1995–1997 was as follows: Class A, 67%; Class B, 18%; Class C, 14% and Class D, 1% (Stapleton et al. 2000). Regional variation in river water quality has been continuously noted, with conditions being generally poorer in eastern areas of the country. Though some improvements, due to increased monitoring and implementation of control measures, have been noted the proportion of river channel affected by slight or moderate pollution has increased from 10% in 1971 to 47% in 1995–1997. Even in areas of western Ireland deemed as near pristine in earlier surveys, the proportions of sites showing high biological diversity has declined considerably over the past two decades. Phosphate measured at 1600 locations in Irish rivers and streams by EPA in 1995–1997 show that a 30 µg dm⁻³ P standard has been exceeded in just over half of the sites.

The most extensive threat to water quality of Irish lakes is eutrophication (Allott et al. 1998; Stapleton et al. 2000). The classification scheme used to monitor water quality changes in lakes in the Republic of Ireland is a modification of a scheme proposed by the OECD (1982) which involves measurements of annual lake-wide (means, minima, maxima) variation in total phosphorus, chlorophyll a, and water transparency. Recent EPA assessments (Stapleton et al. 2000) of lake water quality involved 124 water bodies.
surveyed in 1995–1998 and the proportion of lakes assigned to different categories were as follows: oligotrophic (48%), mesotrophic (32%), moderately eutrophic (6%), strongly eutrophic (6%), highly eutrophic (4%) and hypertrophic (4%). In this survey 80% of the lakes, which included 18 of the 23 larger lakes and reservoirs (750ha) were classified as oligotrophic or mesotrophic and it was estimated that about 60% of the national total lake area was investigated.

Long-term trends in lake water quality are less clear cut than in the case of Irish rivers and streams but serious concern still are expressed about diffuse, mainly agricultural, sources of enrichment. Improvements in water quality in large River Shannon lakes have been attributed to recent upgrading of waste water treatment plants at several locations. However, it also is recognised that the recent colonization of some of the lakes by dense populations of zebra mussels has resulted in dramatic improvements in water transparency and chlorophyll a levels, due to their filter feeding effects on phytoplankton populations (McCarthy et al. 1997; Bowman 2000).

The recognition that use of the modified OECD classification scheme has limitation, in so far as detection of early signs of enrichment in large oligotrophic Irish lakes was concerned, lead to a recent study of six major western Irish lakes (McCarthy et al. 2001a, b). Likewise, the need to monitor habitat degradation in respect of fisheries and wildlife management has given rise to a series of on-going research projects which aim to develop new monitoring protocols (unpublished data). Palaeolimnological studies, including analyses of microfossils, chlorophyll a and nutrient levels in cores have confirmed that anthropogenic activities have contributed greatly to the eutrophication of Irish lakes in the past century (Murray 1998).

Apart from eutrophication, Irish inland waters have been affected by a variety of other anthropogenic changes in water quality. Localised discharge of a variety of toxic substances, for example metal pollution in the vicinity of mines and occurrence of synthetic organic compounds such as pesticides and PCBs in surface waters have been reported (Stapleton et al. 2000). Ireland's geographical location at the western edge of Europe and the southeastern/western direction of the prevailing winds have protected its lakes from artificial acidic rainfall. However, acidification has been reported in small poorly afforested bogland lakes western Irish catchments. This phenomenon has been attributed to the ability of the trees to filter pollutants at low concentrations and to exchange processes that occur at the roots of trees (Stapleton et al. 2000). Changes in patterns of land use have also affected water quality in other ways. For example, commercial peat extraction has resulted in siltation effects in various midland river sites and lakes like Lough Derg in the Shannon system. Likewise, degradation of upland blanket bog, especially in western Ireland has resulted from sheep over-grazing. The erosion of peat, resulting in siltation and changes in stream water chemistry have adversely affected salmonid fisheries (Allott et al. 1998; Sheehy Skeffington, O'Connell 1998). Physical and chemical changes attributed to forestry developments in such areas are also of concern to fishery managers.

The decline of several threatened species of freshwater fishes in Ireland, including Arctic char Salvelinus alpinus L., pollan, Coregonus autumnalis Pallas 1776, and brook lamprey Lampetra planeri Bloch 1784 have been attributed to declining water quality (McGarrigle et al. 1992; Whilde 1993; Harrod et al. 2002). However, other factors such as effects of recent fish species introductions may also have been involved (Doherty, McCarthy 2000; McCarthy et al. 2001a).

Channelization, or arterial drainage, of Irish rivers, was extensively undertaken on Irish rivers in the 20th century, primarily with a view to limiting adverse effects of flooding on agriculture production. Legislation (e.g. The Arterial Drainage Act, 1945), excluding the channelization schemes from provisions of earlier fisheries protection acts was enacted and despite widespread opposition from anglers and fishery owners extensive damage was done to salmon and trout stocks (Anon 1975). McCarthy (1985) reviewed the adverse effects of channelization and made recommendations for their amelioration. The un-economic nature of the changes produced and the increased appreciation of the environmental damage caused by arterial drainage schemes in Ireland, has lead to costly habitat restoration programmes.

Increased knowledge of fluvial hydrosystems, and of the importance of physical habitat components, in enabling better management of riverine fisheries (Potts, Amoros, 1996; O'Grady, Duff 2000). Bank protection and restoration measures; use of a variety of instream structures; pool restoration, as well as restoration of naturally variable flow regimes have been employed to produce significant improvements in smaller salmon and trout populations in western Irish river systems such as the River Moy and River Corrib catchment areas. Improvements to riparian habitats, which had been seriously degraded by either overgrazing or tunnelling effects of dense afforestation, are resulting in improvements in environmental conditions and fish stocks (O'Grady, Duff 2000). Riparian ecotone restoration, in addition to reduced on nutrient inputs to streams, affect feeding patterns of salmonid in Irish streams. Non-aquatic insects can seasonally be of great value in the diet of brown trout in western Irish streams (Walsh 1988).
Regulation of several major Irish rivers for hydropower generation on migratory fish stocks has to some extent been overcome, through stocking of hatchery reared juveniles, for Atlantic salmon or by overland transport and stocking of elvers captured in lower reaches, for European eel (O’Farrell et al. 1996; McCarthy, Cullen 2000). However, global changes in climate and in marine environmental conditions may well be the major threat to these species in Ireland.

4. Discussion

Anthropogenic impacts on water quality parameters, physical conditions and hydrodynamics of Irish freshwater habitats are of increasing concern. The adverse effects of such environmental changes of fish communities and biodiversity in general are well documented. Through expenditure of national, EU and private funds, environmental projects which aim to monitor and reverse such trends are being implemented. Environmental economics are now important considerations in respect of a wide range of local, regional and national policies. Significant advances have been made in development of programmes for the management of freshwater resources though: implementation of catchment management plans; extended monitoring programmes; improved funding for ecological research and increased involvement of “stake holders” in decision making and protection of natural resources. However, despite use of increasingly sophisticated technology (e.g. remote sensing, GIS and Internet accessible databases) expensive environmental programmes can suffer from being too narrowly focused or from a failure to explore the biocomplexity of the problems affecting the aquatic ecosystems being managed.

Interdisciplinary studies, which have been previously difficult to undertake due to funding restrictions, are being initiated in respect of several Irish aquatic systems, including western Irish lakes like Lough Corrib. Previous studies on some oligo/mesotrophic western Irish lakes, while recognizing the need to continue established water quality monitoring programmes, identified ecological changes occurring which were not being indicated by changes in chlorophyll a, total phosphorus or water transparency levels. New monitoring protocols were recommended involving: documentation of localized enrichment effects on littoral communities; analysis of lake outlet communities; investigation of flora and fauna of high conservation status; and a generally more broadly based ecological assessment of the lakes (McCarthy et al. 2001 a, b). Classical open water limnological studies can be of limited value in investigation of shallow lakes or of the unusual calcareous water bodies that occur in the karstic limestone areas of western Ireland (Reynolds et al. 1998; Scheffer 1998). Reliance on monitoring systems based largely on hydrochemistry or simple biotic indices, is unnecessary and may allow serious environmental degradation to occur undetected.

Increased knowledge of the importance of riparian ecotones in reduction of nutrient inputs to streams and research illustrating how allochthonous organic inputs affect community structure (Giller et al. 1998) have lead to a better understanding of the need for landscape ecological approaches to Ireland’s aquatic ecosystems. Likewise, the importance of water borne nutrients to river flood lands like the Shannon callows (Heery 1993) and to turloughs in western Ireland is increasingly appreciated.

The EU-supported Rural Environmental Protection Scheme (REPS 2000–2006) currently being undertaken in Ireland highlights the need for integrated policies for landscape management. In 1994–1999 some 45,500 farmers had joined the REPS Scheme, with approximately 33% of the utilisable Irish agricultural area being farmed under REPS guidelines (Rath 2000; Regan 2000). The major ecological changes attributable to some non-indigenous species, such as zebra mussels Dreissena polymorpha (Pallas 1771) and roach Rutilus rutilus L., accidentally introduced into Ireland (McCarthy et al. 1997; McCarthy et al. 2001 a) indicate the importance to consider factors other than anthropogenically induced physical or chemical changes to habitats in monitoring environmental changes. Likewise, reliable knowledge of aquatic ecosystem processes and species requirements are important in habitat restoration projects, such as those been undertaken on western Irish salmonid rivers (O’Grady, Duff 2000). Ecological studies that focus exclusively on simple trophic interactions can fail to detect important changes in community structure. The potential interactions between waterfowl and fish, as revealed by studies on roach and tufted duck Aythya fuligula L. in Ireland’s largest lake, Lough Neagh (Winfield et al. 1992; Wood 1998), and effects of the cestode parasite Ligula intestinalis on cyprinid fish dispersion and population dynamics in such lakes, illustrate the need for better knowledge of lake ecosystem dynamics. Dramatic changes in coarse fish stocks in some Shannon lakes, attributed by anglers to eutrophication, were shown to be due to identifiable diseases, physical damage and secondary infections associated with fish handling by anglers (McCarthy 1997).

The decline in Arctic char and pollan in Irish lakes in the 20th century has highlighted the need for fish conservation measures and focused attention on rare indigenous elements of the island’s fauna. Research on such species can be important
in biomonitoring and in the ecological analyses of some of Ireland’s more pristine lakes (Doherty, McCarthy 2000; McCarthy et al. 2000). Focusing on conservation of the simple fish communities of lakes like Lough Mask, which still contains large numbers of char, may serve to protect these valuable water resources. Designation of one or other of the large western lakes, already state owned, like Loughs Mask or Corrib as a new biosphere reserve could facilitate interdisciplinary research as well as achieving such conservation goals.

The global decline in water resources and the recognition that established mechanistic-hydrochemical approaches to water management were not adequate for sustainable use of freshwater systems, has lead to elaboration of ecohydrological principles (Zalewski 2000). This approach can potentially lead to improved water quality, more effective restoration of the habitats and more effective interdisciplinary research programmes. A network of regional centers for the promotion of this approach to water management could be provided at National and European levels. Establishment of such new links in management and research of inland waters could lead to innovative approaches to global environmental problems. Improved understanding and more effective use of freshwater resources may, in the event of rapid global climate changes, assume increasing importance in the 21st century.

5. References


