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# Development of the Irish eel fishery

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# INTRODUCTION

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Increasing awareness of the value of eel fishing led to a decision by the Minister for the Marine to formulate a national eel strategy. As a contribution to the necessary gathering of views and information, the principal authorities concerned convened an Eel Management Workshop on 7th July 1998 at the Royal Marine Hotel in Dun Laoghaire. The Workshop was co-hosted by an Bord Iascaigh Mhara (BIM), the Marine Institute (MI) and the Central Fisheries Board (CFB), and was attended by 100 participants representing all sectors, including the eel fisheries and co-operatives, eel farmers, eel processors and smokers, the regional fisheries boards and the state development and regulatory agencies from both sides of the border. It was decided to hold a workshop on eel to heighten awareness of this most intriguing and valuable resource in Ireland, and to establish the baseline data for a national strategy for the development of the Irish eel fishery to be announced by the Minister for the Marine and Natural Resources during 1998.

After the opening address by the Minister, Dr Michael Woods, the remaining speakers included both policy makers and the practitioners. Topics covered all the significant areas including case studies from the managers of the established eel fisheries on Lough Neagh, the River Shannon and Lough Erne, Irish eel culture and culture trends in Europe, aquaculture grant aid, the markets and proposals for a national strategy for the Irish eel industry.

The Lough Neagh fishery is perhaps the most famous wild eel fishery in Europe with all credit for its on-going success due to Fr Oliver Kennedy, Manager of the Lough Neagh Fisherman's Co-operative Society Ltd. The fishery is extensive and enormously important to the economic well-being of the locality with between 185 and 190 boats fishing every year, and 400 families around the lough shore deriving an income from actively fishing on the lough. The total catch of brown eel each year is in the region of 550 t and of silver in the region 200 t.

The River Shannon and Lough Erne are smaller fisheries with catches of 100 t and 50–100 t per annum, respectively. Both fisheries are subject to studies and efforts to increase their production. The Erne Eel Enhancement Programme under the management of Dr Milton Matthews was initiated in 1997 under the EU Special Support Programme for Peace and Reconciliation with the securing of initial phase 1 funding of £0.8m. The primary aims of this programme are to increase recruitment of glass eel and elver to the Erne, to determine the current status of eel stocks throughout the Erne catchment and to ascertain the potential for increased exploitation. The final aim of the programme is to develop a co-ordinated cross-border management plan for the fishery.

The biology and management of the eel populations of the Shannon fishery, which is under the ownership of the ESB, who have generated hydroelectricity on the river since 1929, have been extensively studied by scientists from University College Galway headed up by Dr Kieran McCarthy with ESB biological staff oftentimes working in close association with fishing crews.

The 1992–1994 programme of research and development investigated juvenile eel and recruitment, yellow and silver eel. From 1994 to 1998 surveys of stocks were continued with the adoption of new fishery management protocols. The paper presents a general review of the results of this research with an assessment of the status of the eel fishery and its future development potential. The results of the progamme on the status of the yellow and silver eel stocks suggest that the effects of the collapse of the juvenile eel stocking programme in the previous decades is now evident. Catch statistics for Lough Derg and for the silver eel weirs of Killaloe and Clonlara show a decline in catch per unit effort (CPUE) and yield.

It is suggested that, with glass eel fishing develop-

ments in the Shannon estuary, improvements to elver and bootlace eel traps, electrofishing of juvenile eel and possible re-stocking of farmed fingerlings, adequate provision can be made for stock enhancement and conservation of eel in the Shannon catchment. Further, experimental studies suggest that there is scope for increasing yields through allowing increased numbers of nets to be used by fyke-net crews and encouraging greater fishing effort, authorising long-line fishing linked to a quota system and extending the network of silver eel fishing sites and introducing new fishing techniques. The short to medium objective of this effort is to double or treble the current catches to achieve a target yield of 200–300 t.

Aqua Arklow Ltd is managed by Mr Declan Duggan and is currently Ireland's only eel farm. The farm is licensed by the Department of the Marine and Natural Resources, and had received financial support under the Operational Programme for Fisheries 1994–1999, which is administered by BIM. The farm, which is located in county Wicklow, only 40 miles south of Dublin, is a state-of-the-art facility with a production capacity of 60 t. The farm was designed and installed by the Dutch company HESY bv who have built most of the eel farms in Europe and have recently completed a large farm in Australia.

The two constraints in Irish eel culture identified in this paper are the availability of glass eel for culture and the market for the end product. Due to a perceived lack of infrastructure for capture of glass eel in Ireland, 85% of requirements were imported from the UK in 1998.

Mr Richard Donnelly also of Aqua Arklow Ltd. outlined a proposal for the development of glass eel fisheries in Ireland, a theme also addressed by Dr Christopher Moriarty later in the Workshop. At the present time no glass eel fishing takes place outside the Shannon, Erne and Bann systems, even though there are many other suitable locations. Re-stocking of these fisheries is vital for the maintenance/improvement of their fishing yield and also, most importantly, eel culture is totally reliant on supplies of wild-caught glass eel as a source of stock for ongrowing. As outlined later by Dr Per Bovberg of the Danish Institute for Fisheries Technology and Aquaculture (DIFTA), the survival of glass eel to fingerling stage in culture is much greater than in the wild, therefore arguably it is a more effective use of this resource, especially for re-stocking of farmed fingerling as mentioned as a possibility by Dr Kieran McCarthy earlier.

Mr. Donnelly outlines the main methods of glass eel capture in Ireland including the use of hand nets, conical nets and PVC pipe traps. A proposal for the establishment of other glass eel fisheries is put forward with the results of studies on the rivers Ballisodare, Moy and Corrib discussed. It is proposed that the glass eel caught from these systems be sold at a price of £100 per kg packaged and delivered both for farming and re-stocking purposes.

BIM aquaculture grant schemes are discussed in some detail by Ms Lucy Watson of BIM's Aquaculture Development Division. The value of Irish aquaculture output at first sale was £55m in 1996 with an estimated 2,800 people engaged in aquaculture yielding 34,930 t of product. The current funding for aquaculture comes under Operational Programme for Fisheries 1994–1999. This is to be replaced post 2000 by a new Community Structural Fund agreed within the framework for Ireland and the Commission. Albeit that there will be a continuance of funding for aquaculture it is likely that the levels of grant aid will be reduced.

As at the time of going to press, EU grants to aquaculture projects are available at a rate of 35% of eligible costs for all projects. The combined BIM and EU grant aid varies from 40% to 45% of total eligible investment expenditure depending on the nature of the project. BIM assistance for eel culture may include feasibility studies including site location, business planning and technology investigation, also elver collection, pilot and full-scale commercial operation.

The current production of farmed eel in Europe is estimated at 8,000 t with an estimated 3000 t farmed in the Netherlands and 2,000 t farmed in Denmark. According to Dr Per Bovberg of DIFTA, the technology is constantly being advanced with improvements in production parameters including feeds and feeding methodology, water quality and also product diversification and better marketing resulting in improving profitability. It is reported that improved nursing of glass eel and elver with better feed and feeding practic-

es and optimisation of water parameters results in improved survival of glass eel to fingerling stage. A farmer now expects a survival rate of 2,500 good fingerlings per kg of glass eel or elver, substantially up from 1,600-2,000 survivors a few years ago. Other noteworthy technological advances include grading machines, new types of biofilters, e.g. fluidised bed filters and an increased focus on reducing unnecessary power consumption.

Eel markets were touched on by a number of speakers, but were more comprehensively covered by Ms Barbara Byrne of BIM's German Office with Mr. Peter Koch-Bodes, Chairman of the German Fish Retailers Association, answering specific marketing queries.

It was noted that up to 25,000 t of eel are consumed annually in Europe and the Japanese demand is estimated to be in the region of 100,000 t. At the present time most Irish eel is exported live to continental Europe providing no additional value. By far the biggest exporter of eel in Ireland is the Lough Neagh Fisherman's Co-operative with 60% of the catch of both brown and silver eel exported to Holland, 30% to north Germany and the remaining 10% to London. The total paid to fishermen each year in respect of their catch is in the region of £3.5 million sterling, while the total turnover is estimated at about £5.5 million. Fr Oliver Kennedy observed that prices in the Dutch and German markets have shown a marked decline in both the 1997 and 1998 seasons as a result of the high value of sterling and as a result of an oversupply of both wild and farmed product on the market. He sounded a note of caution saying that market for eel is not infinite or unlimited.

These sentiments were echoed by Dr Milton Matthews who called for a national market strategy to be developed to expand the market and to promote Irish eel both at home and abroad. He pointed out that smoked eel retail at approximately £30.00 per kg versus £3.50 per kg of live silver eel.

It would appear from comments made by Dr Per Bovberg that European eel farmers are making efforts to increase home market consumption in such countries as Denmark. He observed that the speciality product, kabayaki, or barbecued eel, is being produced in two factories in Denmark specifically for the Japanese market. These factories are co-owned with Japanese partners. The jobs created in these factories are important in local communities suffering cutbacks in the more traditional fisheries sector. He also highlighted the possibilities for developing special brands for accessing market niches.

Ms Barbara Byrne took an in depth look at the German market which is the destination for at least 30% of Ireland's wild eel. Total imports to Germany are estimated at 3,000 t with 50% of imports being live eel. The smokers have a preference for live product so that they can smoke using their own recipes. Italy, the Netherlands and Denmark provide the bulk of Germany's eel requirements. Frozen product comes from Denmark, Canada, Australia and New Zealand. European eel is considered to be of a much higher quality and is used for quality smoked products. Smoked eel is imported in the main from Denmark, the Netherlands, Greece and some small quantities are imported from Ireland. The prices vary depending on the size and origin of the eel. As an example the ex-factory price for 200–400 g product is £14.30 and the retail selling price is £17.90.

The main eel product on the German market is whole smoked eel. These silver eel are at the 'sharp nosed' stage of development, the shape of the head is characteristic of the appearance of the product.

There are four types of companies producing, selling and distributing smoked eel in Germany: vertically integrated companies such as Deutsche See, specialist producers with national and international distribution such as Gottfried Friedrichs, localised speciality producers such as Fiedler in Bremerhaven and finally, smaller wholesalers who smoke eel themselves for their own customers.

The two concluding papers at the Workshop proposed a national strategy for Ireland's eel resource and looked at the costs and benefits of a national eel programme.

Dr Paddy Gargan presented the Central Fisheries Board's policy on the management of eel in Ireland (the views of other State agencies were sought during preparation of the paper). The pa-

per examines each of the seven Fisheries Regions, identifying in each case the extent of the fishery, the present problems with the fishery and the potential for development. The findings of this regional focus are summarised. Common problems identified are licensing of long-line fishermen and eel dealers, and also legislation on close seasons. Lack of policy on the development of elver/glass eel fisheries is also noted.

The paper stresses the need for proper management of the fishery at both local and national level. It identifies the most productive waters from an eel fishery point of view as those of the four major catchments: the Shannon, Erne, Corrib and Moy. Against this, there is seen to be little potential for the development of a freshwater eel fishery in the rivers in the Eastern, Southern and Southwestern Regions. There is also seen to be potential for the development of an estuarine yellow eel fishery and for a glass eel/elver capture programme, particularly in the Southwestern Region.

Dr Gargan believes that, with proper management and regulation, the Irish eel fishery can generate increased employment and revenue. Management on a catchment basis, involving as a first step the assessments of stocks, is presented as the ideal case. Once stocks are estimated, a total allowable catch can be allocated per catchment. Licences can then be issued on the basis of a sound assessment of the exploitable stock in each catchment. Likewise an optimum recruitment number of elver for re-stocking or movement to other catchments could be set on a catchment by catchment basis This ideally should be undertaken by the Regional Fisheries Boards. Arrangements should also be made to supply elver to commercial eel farms. Eel fishing in estuaries is presented as another area requiring attention.

The paper concludes with a series of recommendations covering legislative changes required for proper future management of the fishery.

Dr Christopher Moriarty looks at the costs and benefits of a national eel programme. He argues that proper management of the fishery in the Republic of Ireland incorporating techniques known to be successful in Northern Ireland and elsewhere could increase the national yield of wild caught eel by a factor of four from 250 t to 1,000 t per annum simply by more effective exploitation of an existing habitat. This, combined with a possible 1,000 t from culture, could result in an annual yield of 3,000 t from the whole of Ireland. Dr Moriarty presents two possible programmes of work designed to increase productivity from the Irish eel fishery with resulting returns to the economy in employment and income generation.

The first plan presented involves an intensive three year study of the capture fishery with a seven year stocking programme at a cost of £7,820,000, with an annual yearly cost thereafter of £630,000. The calculated annual yield after the ten year programme is completed is £5m with a probability of £15m value added through processing. The second plan presented has an annual outlay of £240,000 and, while it could attain similar results, it would leave gaps in the knowledge required to operate with maximum efficiency.

The Workshop was drawn to a close by Mr David Griffith whose concluding remarks included reference to the fact that Lough Neagh is now a developed fishery, thanks to efforts by the Co-op and Fr Kennedy. Meanwhile, management advice for the development of the Republic's resource, such as that presented by Dr Moriarty, has not been acted upon. It is hoped that this is now going to change, and that the Workshop does indeed provide the starting point for a forward momentum for the effective development of the eel industry in Ireland.

# OPENING SPEECH

**DR. MICHAEL WOODS TD**

*Minister for the Marine and Natural Resources*

Ladies and Gentlemen, it is a great honour for me to be here today to open this Workshop on eel management. It is most important to bring together all relevant agencies and interested individuals to discuss the management of the valuable eel resource and options for its future development, and I thank the Central Fisheries Board, the Marine Institute and Bord Iascaigh Mhara for the time and effort they have taken to organise today's event.

The eel fishery section in this country is relatively underdeveloped, yet the potential return from it is very significant. The success of the Lough Neagh eel fishery is an illustration of this potential.

Today's programme is very comprehensive and illustrates very well the variety of issues which make up an eel management strategy. The seminar deals with each of these elements in turn. The eel fishery itself is the basic resource, and one which is estimated to have the potential for development as a fishery yielding at least £5 million per year to the fishermen. Interesting developments in the River Shannon, Lough Neagh and the Erne show the practicalities of protection and development of eel fisheries in specific case studies. The possibilities in eel culture are also discussed; the opportunities for specialist markets are looked at, and finally, the threads will be drawn together in the final session which looks at the way forward through a strategic national approach.

I am very pleased that such a comprehensive look is being taken at the eel resource. We have an inland fisheries resource of huge potential in this country, but often tend to think of this solely in terms of game and coarse fishing. Eel have been a small but often overlooked element of the resource, but deserve serious consideration in view of their potential value of perhaps as much as a £20 million industry when processing is included.

Eel are a highly valued and much sought-after species. The current catch is about 250 t and supports 150–200 part-time fishermen. Conservation of stocks, fishery development and eel culture all have a role to play in increasing catches in a sustainable way. There is an exciting export market for the product which can be tapped into, and I would also suggest that, in time, the domestic palate can be attracted to the product as well.

The conservation of stocks is a fundamental requirement and eel fishing is already regulated to a certain extent by means of restrictions on fishing methods and close seasons in some areas. The recent increase in exploitation may however require further measures to be introduced, and I am currently looking at the possibility of introducing national close seasons.

I am particularly interested to welcome participants from Northern Ireland to the seminar. You will see that both the Lough Neagh Eel Fishery, which is part of a fisheries co-operative, and the Erne Eel Enhancement Programme, which is a cross-border initiative between myself and my counterpart in Northern Ireland, figure prominently on the programme. The practical experiences of existing fisheries are very important in any discussions of eel management, and I believe it will be very interesting to hear more about these and the ESB's Shannon Fisheries later in the day. I have been informed that the capturing of glass eel at river mouths and distributing them throughout the lake systems is an important element in these programmes, and valuable research and experimental fishing is continuing with the object of deepening our knowledge and understanding of the species and its management.

The possibilities of eel aquaculture are also of great interest and I know that BIM's Aquaculture Development Division has supported various projects over the years. Ireland's first warm water recirculation unit for ongrowing eel was opened last year and it will be valuable to have the benefit of the Aqua Arklow's experiences and experiences and knowledge of our colleagues from Europe.

The development of the Irish eel resource in a sustainable way requires a recognition of problems and opportunities and an integrated approach to future development. I am conscious of the need to develop a coherent national policy on eel and therefore see the discussions and outcome of today's workshop as extremely valuable.

I am currently in the process of developing a national strategy document on this sector and both the report and recommendations on the sector which I have asked the Marine Institute to produce, and today's workshop will help considerably to inform my thinking on the subject and in bringing forward strategies for the development of this sector over the coming years.

It only remains for me to wish today's proceedings every success and to thank the organisers again for taking this initiative.

# DEVELOPMENT OF GLASS EEL FISHERIES IN IRELAND

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## Introduction

Recent developments within the aquaculture industry have greatly improved the efficiency and reduced the costs of operating warm water recirculation units for fish culture. This coupled with increased demand for eel, both in Europe where 15,000 t are consumed annually and in Japan where the demand each year is in the region of 100,000 t, has resulted in an increased number of eel farms in recent years. Due to the fact that it is not possible to spawn eel successfully in captivity all eel farm stock originates from the capture of juvenile eel in the wild.

No glass eel fishing takes place in Ireland outside the Shannon, Erne and Bann systems, despite the fact that there are many other suitable locations along the coast. The main migration of glass eel upstream occurs during the spring tides between March and May and suitable conditions for glass eel fishing may only exist for 2 to 3 hours on the highest flood tides during these months. With natural mortality rates of 67–95% between the glass eel and elver stage of the life cycle, much of the stock arriving into Irish estuaries is already lost. Therefore, harvesting of the glass eel and subsequent ongrowing in warm water recirculation facilities is proposed as a viable option for developing this industry.

## Main methods of glass eel capture

*Hand nets*

The hand nets used are square-framed, 30 cm in width made of aluminium. The mesh size is 0.5 mm. The dimensions of these nets are not crucial but the square frame allows easier access to eel migrating close to the bank.

*Conical nets*

Conical nets (0.5 mm mesh) similar to plankton nets can also be used along steep vertical walls where hand netting is not possible. The standard size net is 1 m in diameter tapering into a 1 m depth cone. The cod end of the cone is tied off with a piece of rope. The frame for this net is made with hard PVC piping.

*PVC pipe traps*

These traps, measuring 50 cm in length are cut from 15 cm diameter PVC pipes with a 0.5 mm mesh cone at the downstream end and removable cap at the upstream end, again with 0.5 mm mesh.

## Glass eel prices

Glass eel prices have been very volatile in the 1990s reaching values in excess of £300 per kg. But these were achieved only over very short periods and have become less common. An average price in 1997/1998 was £120 per kg. The majority of glass eel are sold to eel farms and these farms require excellent quality eel delivered in large quantities (>200 kg) in a single shipment.

## Current situation in Ireland

Glass eel and elver fisheries are operational on the Shannon, Erne and Bann systems. The stock captured here is used directly for re-stocking purposes. On the River Bann studies were conducted with the Lough Neagh Fishermen's Co-operative to examine the viability of glass eel fishing in 1995 and 1996.

The catch of glass eel on the River Bann for 1995 was 375 kg, representing 28% of the overall catch of juvenile eel from the river. This yield was achieved despite the fact that fishing did not begin

until mid-season (beginning of April) and that fishing methods were being refined during this period. Fishing in 1996 began in the first week in March. This was the earliest date on record that juvenile eel had ever been captured in significant quantities in the River Bann. The weight of eel, 2,505 kg, caught in 1996 was the highest recorded since 1988 with the glass eel catch representing 53% of this total. This would suggest that glass eel fishing is a viable and cost-effective operation at this location and does appear to substantially increase yields of juvenile eel from the system.

**Potential in Ireland**

A large number of river systems were examined around the coast of Ireland with a view to developing glass eel fisheries. From this study three sites, the rivers Ballisodare, Moy and Corrib, were of particular interest with good glass eel runs and good fishing sites. A conservative estimate of the yield from the three sites is 1,500 kg of glass eel per annum.

It is proposed that the eel caught from these systems would be sold at a price of £100 per kg packaged and delivered both for farming and re-stocking purposes. This would generate an annual income of £150,000 and provide part-time employment for 10 fishermen. A further 4 employees would be required to manage the collection, holding and distribution of the stock. If this quantity of glass eel were to be made available for farming, a further 20 jobs would be created in eel culture. The total production from farming these glass eel would be in excess of 250 t. The quantity of eel currently caught in the Republic of Ireland is *c.* 250 t. The export value of this increased production would be £1.5 million.

**Future trends**

The silver and yellow eel market is very competitive at present and with increased production of eel throughout Europe it is set to become even more so in the near future. The demand for premium quality eel favours farmed stock which are now achieving higher prices than wild eel. Farmed eel now constitute 80% of the European market. Therefore, if Ireland is going to compete in this market, the emphasis must be placed on producing a high-quality product. Ireland has a distinct advantage over most eel farming nations in having a good supply of glass eel stocks. If the eel industry is going to develop, these stocks must be used in a more productive manner.

# THE BIOLOGY AND MANAGEMENT OF RIVER SHANNON EEL POPULATIONS

T. K. McCarthy[1], P. Cullen[1] and W. O'Connor[2]

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## Introduction

The European eel, *Anguilla anguilla* (L.) is an indigenous and widespread species in Ireland's freshwater and brackish water ecosystems, which has been exploited by man from prehistoric times onwards. In the River Shannon catchment area archaeological evidence of ancient fishing weirs and folklore concerning eel fishing activities reflect the long-standing interest of the inhabitants of the region in the species (Went, 1950, 1974). Shannon eel fishery records, prior to the 1960s, are either absent or very incomplete, though some anecdotal observations by 19th century travellers in the area and occasional reports of eel exports from the region, do provide fascinating historical perspectives. Long-term analysis of the Shannon eel population trends and fishery yields is also complicated in respect of the 1960–1980 period by variations in the methods and extent of eel fishing permitted, extensive unrecorded unauthorised fishing and incomplete eel fishery records of juvenile eel stocked to the Shannon lakes (McCarthy *et al.*, 1994a,b,c). A long-term study of fyke-net captured yellow eel at Meelick Bay on Lough Derg has been undertaken (Moriarty, 1996a). Moriarty (1989) summarised earlier silver eel fishery records for the Killaloe eel weir on the lower Shannon and Shannon eel fishery records have also been regularly contributed to international reviews of eel fisheries in Europe (e.g. Moriarty, 1996b).

The ESB, who have utilised the regulated River Shannon discharge for hydroelectricity generation since the construction of the Ardnacrusha power plant in 1929, are currently the owners of the Shannon eel fisheries, having purchased the fishing rights from traditional eel fishermen because of complaints that eel stocks in the river system were seriously declining in the 1940s and 1950s and traditional long-line fishing for yellow eel was prohibited from 1968. In addition to being involved with the commercial exploitation of the Shannon eel stocks, the ESB has also been involved in the elver trapping and other juvenile eel stocking activities (Quigley & O'Brien, 1996). From 1968 onwards, in an attempt to conserve the eel stocks, authorised fishing of Shannon eel was largely limited to the major silver eel fishing weirs. In 1992–1994, following suggestions that eel stocks were improved and that scope for increased commercial development existed, the ESB initiated and funded extensive research and development of the fishery. This involved research and management programmes dealing respectively with (a) juvenile eel and recruitment, (b) yellow eel and (c) silver eel. Reports summarising the results of the 1992–1994 Shannon Eel Management Programme were compiled by Reynolds *et al.* (1994) and McCarthy *et al.* (1994a,b). From 1994 to 1998 surveys of the eel stocks were continued and various new fishery management protocols were adopted. Details of these have been summarised in a number of more recent reports (McCarthy & Cullen, 1995, 1996, 1998; McCarthy *et al.*, 1996; O'Connor, 1997).

Poor natural recruitment has been a general feature of European eel fisheries, indicating those of the Shannon and several other Irish river systems, in the past two decades. Furthermore, uncertainties about the future commercial prospects of the eel fishery in the Shannon have arisen from the combined effects of increased eel aquaculture in Europe and Asia, market instability and the apparent absence of a national consensus in respect of the future development of the eel industry.

Extensive data are now available as a result of the Shannon eel surveys undertaken since 1992 and the analyses undertaken on fishery records. In this paper we present a general review of the results of research on variations in Shannon eel population

structure, assess the current status of the eel fishery and discuss its potential development.

**The River Shannon catchment area**

The River Shannon, which rises at 120 m OD in the Cuilcagh mountains on the Cavan/Fermanagh border area, extends 250 km southwards, and discharges to an 83 km long estuary at Limerick, is Ireland's largest river system (Fig. 1). It drains an area of 11,700 km$^2$ (upstream of Limerick) which includes an estimated 41,000 ha of surface waters. Along its main channel length the gradient is extremely low. For example, it falls only 18 m on a length of 200 km south of Lough Allen. The catchment is generally low-lying and much of it is underlain by Carboniferous limestone. For this reason most of its numerous lakes have calcium-rich waters and are naturally mesotrophic or eutrophic in character. The ten largest lakes in the system are:

| | Area (ha) | | Area (ha) |
|---|---|---|---|
| Derg | 11,635 | Gara | 1,100 |
| Ree | 10,500 | Derravarragh | 1,000 |
| Allen | 3,500 | Owel | 950 |
| Sheelin | 1,900 | Key | 900 |
| Ennel | 1,200 | Boderg | 430 |

These contain about 90% of the total surface water of the catchment. Water quality in the area, reflecting national trends, has been deteriorating in recent decades and particular concerns have been expressed about the effects of nutrient enrichment. A recent review of the limnology and water quality in the Shannon catchment has been given by Bowman (1998).

The flow of the River Shannon is regulated by a number of control structures located at the outlets of Lough Allen, Lough Key, Lough Ree and at the Parteen regulating weir which is located 3 km downstream of the outlet of Lough Derg. The Parteen regulating weir diverts the main flow of the river down a 12 km headrace canal to the hydroelectric generating station located at Ardnacrusha, at a mean annual rate of 176 m$^3$ s$^{-1}$. A minimum 10 m$^3$ s$^{-1}$ is diverted down the old channel of the river. Seasonal variation in the regulated discharge is reflected in the flow rates through Killaloe, which is located at the outlet of Lough Derg. Flow rates here range from a summer average of 99 m$^3$ s$^{-1}$ to a winter average of 274 m$^3$ s$^{-1}$. Flow regulation affects the level of many of the lakes in the system and in the past regulation of the level of Lough Allen has clearly impacted on the structure and the biological communities of the littoral zone of the lake.

Water temperatures for the lower Shannon are compiled at the ESB salmon hatchery at Parteen, Co. Tipperary on a daily basis. A summary of these records is presented in Table 1. Water temperatures vary from year to year and during 1976–1997 values of mean annual temperatures have ranged from 9.8°C to 12.4°C. The corresponding range in yellow eel fishing season (May to September) mean water temperatures was 14.2°C to 17.5°C.

Locality data for glass ell, elver, yellow eel and silver eel fishing sites and zones, referred to in this paper, are summarised in Fig. 1.

**Recruitment to the Shannon eel fishery and stock enhancement measures**

Upstream migrating juvenile eel have been regularly trapped by the ESB in the lower River Shannon since 1959, for overland transport and stocking of lake and upper catchment river sites. Good catches made at elver and bootlace traps at Ardnacrusha and Parteen, respectively, were supplemented, especially in 1979–1985, with juvenile eel captured at estuarine tributaries such as the Rivers Feale and Maigue. However stocking levels progressively declined thereafter for various reasons, including the general effects of the European-wide decline in eel recruitment and restrictions imposed in respect of River Feale elvers/bootlace eel (which for several years were instead transported for stocking of a site in the Southern Regional Fisheries Board Region). The recorded yearly catches of elvers at Ardnacrusha (Fig. 2) illustrate the problems experienced in the early 1990s. Catches of bootlace eel at Parteen also declined, though not so dramatically. The collapse in natural recruitment to the Shannon system, perhaps reflecting the long estuarine route

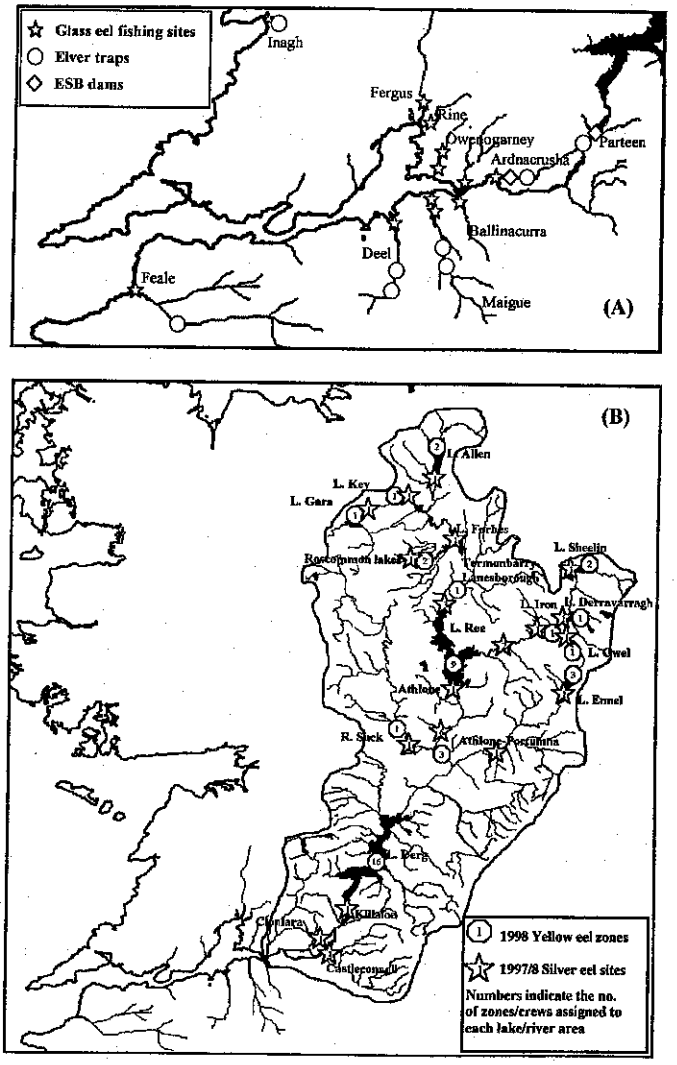


**Figure 1.** Maps of (A) the Shannon estuary and lower River Shannon showing the locations of glass-eel fishing sites and elever traps and (B) the River Shannon and its catchment area indicating the locations of yellow-eel fishing zones and silver-eel fishing sites. The number of zones/crews assigned to each lake/on each river section is indicated.

which juvenile eel ascending that river must travel, was much more extreme than that observed in the Rivers Bann and Erne, two other Irish river systems for which reliable elver trap statistics are available (McCarthy *et al.*, 1994c).

The movements of glass eel and elvers in the Shannon estuary, as evidenced by their catchability in a pilot-scale glass eel fishery and at fixed traps set at the tidal head of the main Shannon and selected estuarine tributaries, has been investigated in detail during the past two seasons (Fig. 1A). The general patterns of glass eel development and activity recorded were similar to those reported previously for these and other Irish locations (McGovern & McCarthy, 1992). The typical seasonal patterns of activity for glass eel, elvers and bootlace eel in the River Shannon system can be observed in respect of the recorded daily catches for 1997 (Fig. 3).

Glass eel arrive in the Shannon estuary in November, and movements were noted when water temperatures were as low as 3°C. Glass eel abundance increased during January and significant quantities of glass eel were present in the estuary during February and March of both years. The general re-

**Table 1. Water temperature (°C) of the River Shannon, recorded at Parteen salmon rearing station for 1976–1997**

| | Average | Min | Max | Degree days > 10°C |
|---|---|---|---|---|
| January | 4.9 | 2.0 | 8.2 | 0 |
| February | 4.8 | 1.0 | 7.8 | 0 |
| March | 6.3 | 1.0 | 10.0 | 0 |
| April | 8.9 | 5.5 | 13.5 | 65 |
| May | 12.5 | 8.0 | 18.2 | 358 |
| June | 15.7 | 12.0 | 22.0 | 470 |
| July | 17.7 | 14.5 | 23.0 | 547 |
| August | 17.8 | 14.0 | 22.0 | 550 |
| September | 15.6 | 13.0 | 20.0 | 467 |
| October | 12.5 | 9.0 | 15.7 | 357 |
| November | 8.9 | 5.0 | 13.0 | 66 |
| December | 6.3 | 3.2 | 10.1 | 0.5 |

lationship of glass eel activity to the semi-lunar tidal cycles was evident (Fig. 2). Other factors such as temperature and wind speed/direction also appeared to affect glass eel densities in the water column. Wind is thought to affect glass eel activity through its influence on water movements and tidal height. Glass eel abundance declined in April coinciding with the upstream migration of elvers, as evidenced by catches at the traps (Ardnacrusha, Adare) at the tidal head (Fig. 3). River temperatures exceeded 10°C at this stage. Discharge and water temperatures were found to be the most important factors influencing active upstream migration of elvers and small juveniles.

The cumulative estuarine glass eel catches for the 1996/1997 and 1997/1998 seasons comprised 480 kg and 396 kg, respectively, which were obtained by three (two-person) fishing crews that fished the

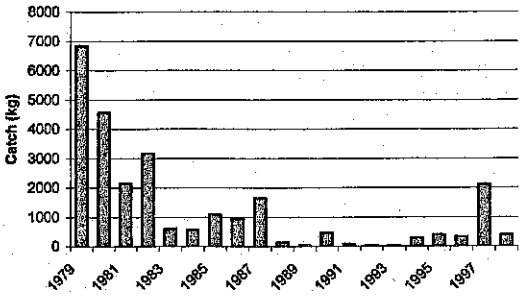


**Figure 2.** Yearly catches of elver made at the elver traps at the Ardnacrusha power station.

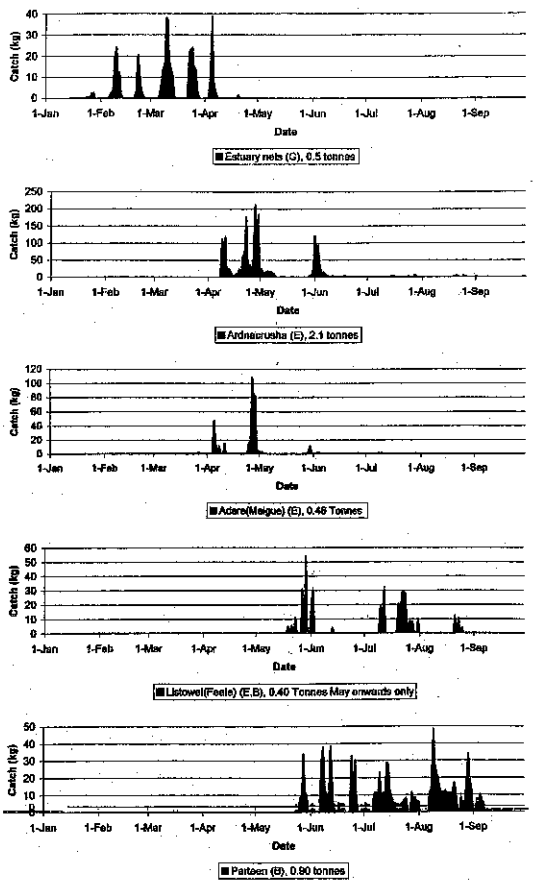


**Figure 3.** Patterns of daily catches of glass eels (G), elvers (E) and bootlace eels (B) at sites throughout the Shannon Estuary and lower River Shannon (1997 data).

five principal sites (R. Rine, R. Owenogarney, R. Maigue, Ballinacurra creek and Landsdown creek). The cumulative elver catches at the tidal head for the 1997 and 1998 season comprised 2,587 kg and 267 kg with identical effort. The CPUE values obtained in the estuary were broadly similar during both seasons; however, elver catches at the tidal head (Ardnacrusha, Adare) were an order of magnitude lower in 1998 than in 1997. Additional catches were made on the River Inagh: 188 kg elver trapped between 31 March and 10 April 1997 and 128 kg glass eel captured using a pull net in the tailrace of the Ardnacrusha power station between 9 April 1997 and 12 April 1998.

At Parteen weir, a bootlace eel trap operated on an annual basis captures upstream migrating juvenile eel ranging in size and age from 7.8. to 38 cm (mean = 11.5 cm) and 0 to 13 years (mean = 3.7 years) (O'Connor, unpublished data). Catches at this site declined from the late 1980s onwards but not so markedly as was noted in respect of the Ardnacrusha elver trapping operations; thus, in 1997 it was still possible to obtain 906 kg of these eel for the lake stock enhancement programme. Dense populations of eel, mostly small slow growing individuals, which ultimately migrate seaward as mature male silver eel have been shown by electrofishing to occur in the River Shannon main channel downstream of the Parteen regulating weir. McCarthy and Cullen (1995) demonstrated the commercial feasibility of harvesting these dense populations of juvenile eel, less than 20 g, for stock enhancement purposes.

A quantity (50 kg) of cultured fingerlings (Duggan, 1998) were stocked to Kilglass Lake in 1997. In 1998 a more systematic experimental stocking of Lough Ennel (150 kg) and a series of other river and pond sites (50 kg) were stocked with similar material. These experimental populations will be monitored annually.

**Stock assessment and development of a fyke-net yellow eel fishery in the Shannon (1992–1998)**

During the 1992–1994 review of the Shannon eel fishery, surveys of yellow eel stocks based on analysis of the catches of authorised fishing crews assigned to specified fishing zones were initiated. Initial results presented by McCarthy *et al.* (1994a) involved detailed monitoring of 8 and 16 crews in the 1992 and 1993 seasons, respectively. In subsequent years the numbers of crews and zones were increased and fishing activities were also recorded (McCarthy & Cullen, 1996, 1998; McCarthy *et al.*, 1996). A summary of the results of the fyke-net fishing surveys is given in Table 2.

A fyke-net CPUE (catch per unit effort) index based on the weight of eel (kg) per single fyke-net trap per 24 h fishing has been employed throughout the study. A steady decline in this CPUE has been noted (Table 2) in the case of Lough Derg since 1993, reflected also in the average catch per crew and total catch for this lake. However, in the upper catchment zones the fishing yields, etc., have varied irregularly during that period or increased in relation to the combined effects of more extensive fishing and more accurate reports from some fishing zones previously subject to intensive illegal fishing.

During these surveys these CPUE values for the catches of fyke-net crews have been regularly monitored in respect of variations in population characteristics, such as eel ages, lengths, weights and condition. In Fig. 4 length frequency distributions of eel captured in Lough Derg and Ree during 1992 and 1998 are presented. The typically negatively skewed frequency distribution, reflecting the combined effect of net mesh dimensions and eel population structure, shows that in the case of the two major Shannon lakes broadly similar sized eel have been captured in both lakes throughout the survey period. The slight, though significant, difference between the 1992 and the 1998 Lough Ree data does not represent a progressive shift in population structure and probably reflects the sort of unpredictable variations observable from year to year in most wild fisheries. It is clear, however, from the illustrated size frequency distributions (Fig. 4), and other unpublished data that no evidence of overfishing, as would be indicated by extensive removal of large eel from the stock, has been occurring in these lakes. Consistent between-site differences in eel sex ratios and their typical size frequency distributions were noted in respect of other Shannon fishing zones. For example, eel in Lough Ennel and Sheelin, which are typically female, were generally larger than those found downstream of the Parteen dam in the River Shannon at Castleconnell

**Table 2. Overall results of fyke-net yellow eel surveys (1992-1998) in the Shannon catchment area.**

| | | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|
| Number of crews | L. Derg | 4 | 6 | 15 | 15 | 14 | 17 | 16 |
| | L. Ree | 4 | 3 | 8 | 6 | 6 | 8 | 9 |
| | Overall | 8 | 16 | 36 | 37 | 33 | 46 | 43 |
| Total catch (t) | L. Derg | 8.9 | 30.6 | 39.2 | 36 | 22.8 | 25.4 | 16.3 |
| | L. Ree | 3.5 | 5.6 | 6.4 | 7.4 | 7.5 | 19.2 | 15.3 |
| | Overall | 12.3 | 44.7 | 54.8 | 52.1 | 42.2 | 51.4 | 44.5 |
| Mean daily CPUE | L. Derg | 0.55 | 0.57 | 0.44 | 0.32 | 0.25 | 0.21 | 0.15 |
| (kg eel per fyke-net trap) | L. Ree | 0.18 | 0.30 | 0.20 | 0.26 | 0.22 | 0.28 | 0.19 |
| | Overall | 0.41 | 0.49 | 0.23 | 0.35 | 0.23 | 0.21 | 0.16 |
| Average catch per crew (t) | L. Derg | 2.2 | 5.1 | 2.6 | 2.4 | 1.6 | 1.5 | 1.0 |
| | L. Ree | 0.9 | 1.9 | 0.8 | 1.2 | 1.3 | 2.4 | 1.7 |
| | Overall | 1.5 | 2.8 | 1.5 | 1.4 | 1.3 | 1.1 | 1.0 |

where the dense population was predominantly composed of smaller male eel.

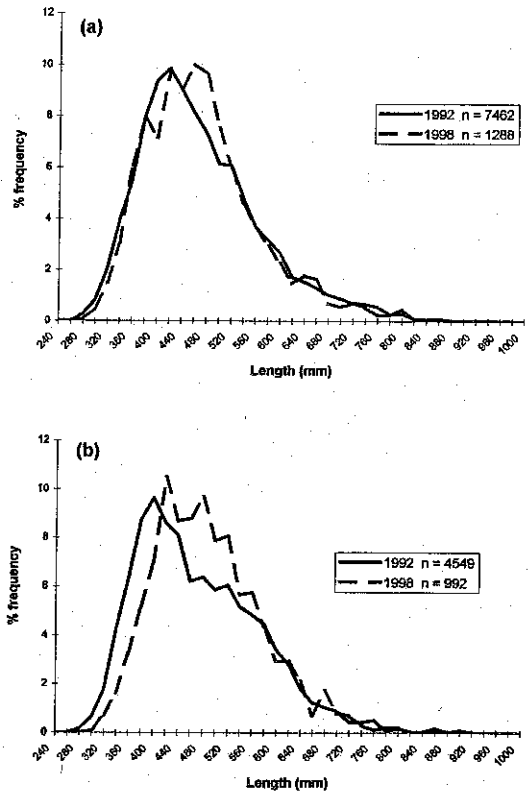


**Figure 4.** Length frequency distributions of yellow eels captured on (a) Lough Derg and (b) Lough Ree during 1992 and 1998.

In order to provide an independent assessment of eel stocks in various Shannon yellow eel fishing zones experimental long-line fishing surveys were undertaken in 1992 and 1993, using alternative bait types (earthworm or perch fry) and full details of catches, bycatch (non-target fish species), storage/transport related mortalities, etc., were recorded (McCarthy *et al.*, 1994a). For comparative purposes most of the areas previously fished were again surveyed by long-line fishing in 1997 and one zone on Lough Derg was repeatedly fished by this method during that season. Full results of this research will be presented elsewhere. However, some general results are summarised in Figs. 5 and 6.

In Fig. 5 the size-selective nature of sampling methods employed in the Shannon yellow eel surveys is illustrated using overall data for the 1992–1994 studies (McCarthy *et al.*, 1994a). As can be seen, lake shoreline electrofishing captured smaller eel on average than were captured in fyke-nets, which were in turn smaller than those captures by long-line fishing. Interestingly, in the case of the long-line fishing significantly larger eel were captured when lines were baited with perch fry rather than earthworms. The efficiency with which long-line fishing can be employed in the capture of yellow eel is illustrated by the re-

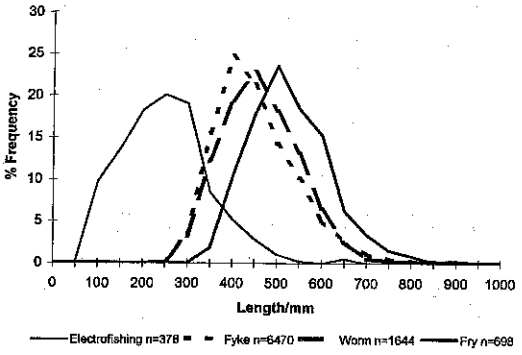


**Figure 5.** Length frequency distributions of eels captured by four different fishing methods: electrical fishing, fyke netting, long-line baited with earthworms and long-line baited with perch fry.

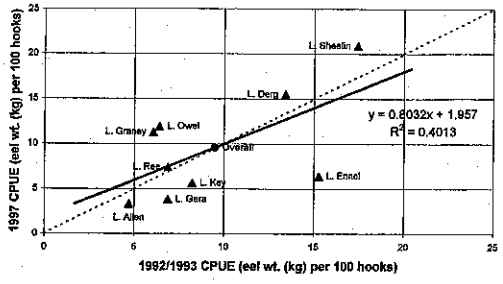


**Figure 6.** A comparison of catches per unit effort indices (kg of eels per 100 hooks) recorded during the 1992/1993 and 1997 experimental long-line surveys of nine Shannon lakes, together with the results of a regression analysis of the data.

sults of both the 1992/1993 and 1997 surveys. Thus, for example, in 1992/1993 the mean rate of capture recorded in a survey, using a total of more than 46 km of lines with 23,126 baited hooks was 37.6 eel per 100 hooks (9.5 kg per 100 hooks) though considerable variation was noted between sites.

In general, the results of the 1997 surveys paralleled those noted in 1992/1993. A comparison of the overall results for nine fishing areas which were fished during both the 1992/1993 and 1997 surveys is presented in Fig. 6. The slope of the linear regression analysis describing the relationship between the original and 1997 re-survey results suggests a slight overall downward shift in population densities. Attempts to relate the long-line CPUE values to corresponding fyke-net CPUE values for these nine lakes was complicated by the unreliable nature of fyke-net fishing crew records in some of the midland lake zones. However, a significant correlation was, for example, demonstrated in respect of mean annual fyke-net CPUE values for 1993 to 1998 for eight lakes (Loughs Allen, Graney, Gara, Key, Ennel, Ree, Derg and Sheelin) and the corresponding 1993 CPUE (kg/100 hooks) long-line indices for those lakes (McCarthy and Cullen, 1998). Long-line surveys provided a unique opportunity to document the distribution of eel within particular lakes. In Fig. 7 the variation in eel capture rates along a Lough Allen long-line can be seen to reflect lake bathymetry. Likewise specific distributional patterns in the bycatch of bream, roach and pike (which was exceptionally heavy on that particular day due to late lifting of the line in stormy conditions) can also be noted. In general bycatch levels were very low relative to fyke-net fishing, and only six trout were accidentally captured in the 1992/1993 long-line surveys while none were captured in 1997.

The growth rates of eel in the Shannon system exhibit considerable variation, as can be seen in Fig. 8, with faster overall growth being evident in respect of some exclusively female midland lake populations (e.g. L. Owel) and slow growth being a feature of the densely populated, largely male, populations of the lower River Shannon reaches (e.g. Castleconnell). The slow overall growth pattern and late maturation is typical of eel in Irish inland waters generally.

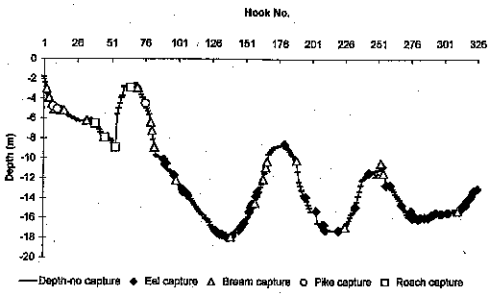


**Figure 7.** Depth profile of a long-line set on Lough Allen (September 1992) showing the occurrence of eels and other by-catch species captured along the line.

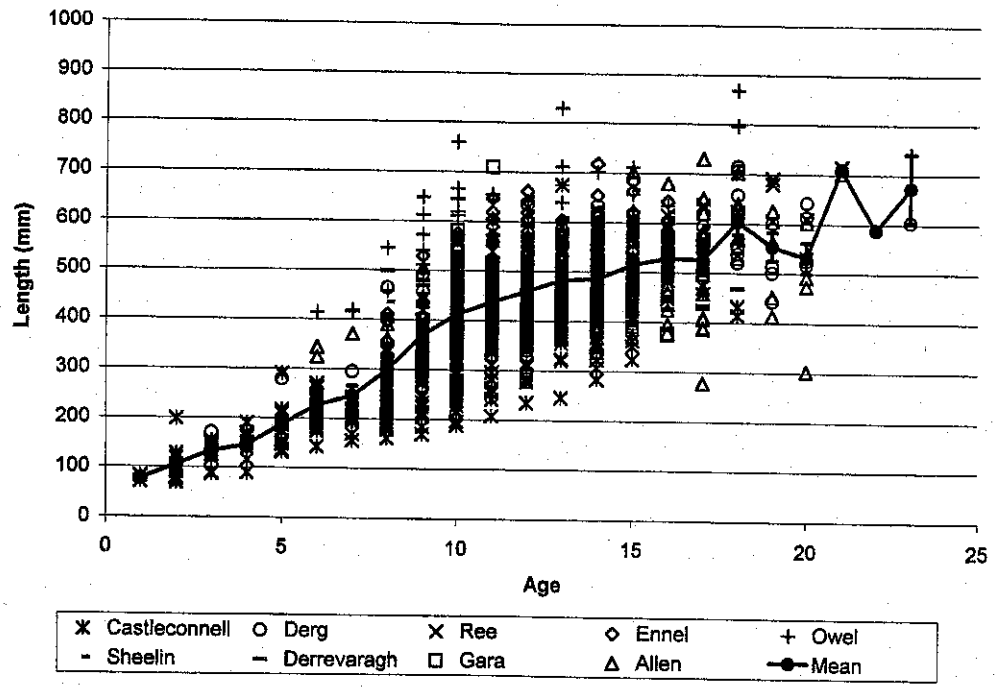


**Figure 8.** Scatterplots illustrating the length at age relationship for nine River Shannon lakes, along with the overall average.

**Shannon silver eel populations**

The downstream migrating silver eel populations of the Shannon were investigated in detail during the 1992/1993 and 1993/1994 fishing seasons (September–March), with particular reference to the major ESB operated fishing weirs at Athlone, Killaloe and Clonlara. A network (Fig. 1) of additional experimental fishing sites was established and from 1993/1994 these have also been monitored. Extensive data are now available concerning the daily, seasonal and between-year variations in catches for the fishing sites, based on records of the authorised crews and analyses of catch characteristics (McCarthy *et al.*, 1994b, McCarthy & Cullen, 1998). Variation between sites in respect of population characteristics, such as sex ratios and timing of migrations, have been recorded and an extensive tagging programme has provided information on the rates of downstream migration, the effects of environmental factors on migration rates, efficiency of fishing weir operations and extent of escapement to the sea (McCarthy *et al.*, 1993).

Lunar periodicity of silver eel migrations tends to be more obvious in respect of upper Shannon sites than is usually the case at Killaloe. Environmental factors such as wind speed/direction, rainfall and discharge influence the timing and extent of silver eel migrations in the Shannon system (McCarthy *et al.*, 1994b). However, in the case of the lower Shannon, as for example at Killaloe, the regulation of the flow for hydroelectricity generation usually results in a delay in the silver eel runs and efficiency of weir operations so that largest catches are typically made in mid-winter. The effects of artificial lighting on eel capture at Killaloe has also been demonstrated (Cullen *et al.*, 1994)

In the past decade a steady decline in the annual catches of silver eel at the Killaloe eel weir has been recorded (Fig. 9). A similar trend was noted in respect of Clonlara, further downstream. However, at Athlone and some other well-documented upper catchment sites, this phenomenon has not been demonstrated (Fig. 9). A shift in the sex ratio of silver eel, reflecting a decreased number of male eel has been observed (Fig. 10a) and analysis of commercial records (Fig. 10b) has confirmed this trend. Eel assigned to the very small category for sales purposes are exclusively male,

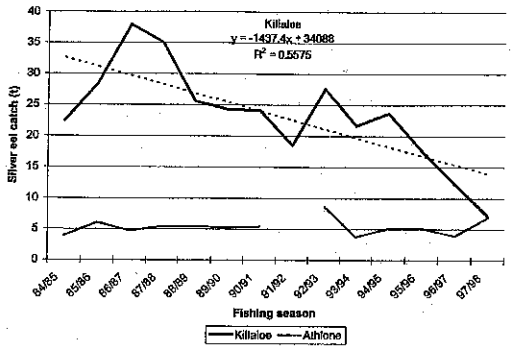


**Figure 9.** Total catch of silver eels recorded from the eel weirs at Athlone and Killaloe for the fishing seasons of 1984/85 to 1997/98.

less than about 43 cm in length, are easily distinguished as is evident from the bimodal size frequency distribution illustrated in Fig. 10a. The longer-term pattern of variation in lower Shannon silver eel population sex ratios is summarised in Fig. 10c. Consistent between-site variation in the silver eel population characteristics, such as sex ratios and age/size frequency distributions, have been noted. For example, some upper catchment lakes, such as Loughs Owel, Ennel and Sheelin, have almost exclusively female populations whereas at other sites, e.g. Castleconnell in the lower Shannon, the majority of silver eel sampled have been males. Age frequency distributions for male (mean = 11 years) and female (mean = 15 years) silver eel sampled in 1993 at Killaloe are given in Fig. 11.

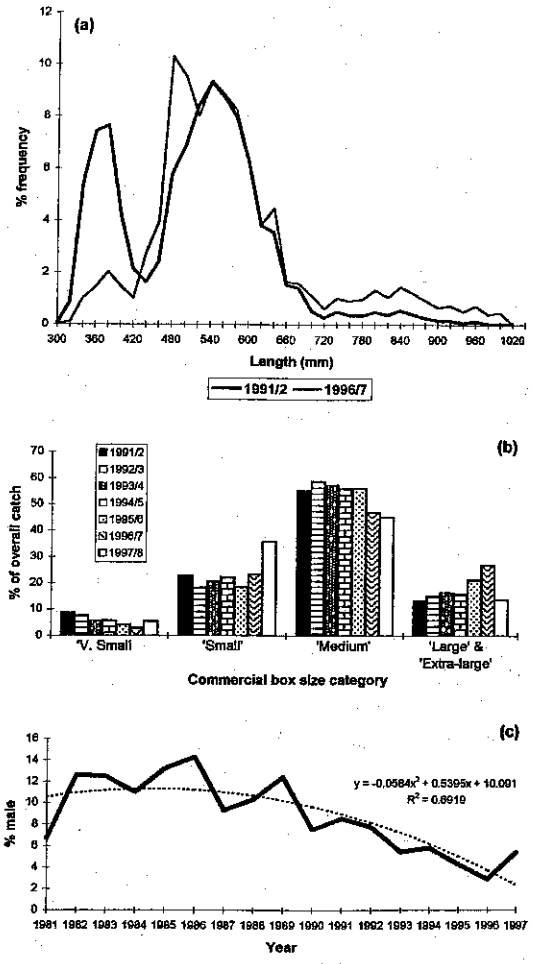


**Figure 10.** (a) Reconstructed length frequency distributions of all silver eels captured at the Killaloe eel weir during the 1991/2 and 1996/7 fishing seasons. (b) Percentage of the Killaloe silver eel catch in each of the four size classes used for grading of eels for the 1991/2 – 1997/8 seasons. (c) Percentage of males in the Killaloe weir silver eel catch between 1981/2 and 1997/8.

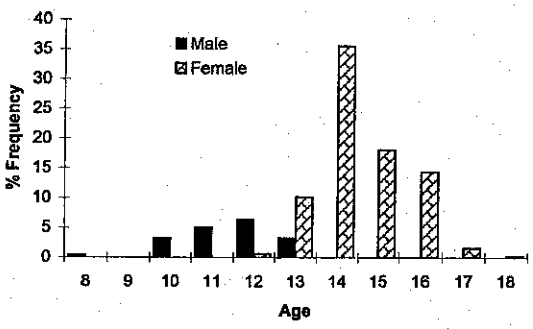


**Figure 11.** Age frequency distributions of silver eels (n=234) sampled at Killaloe.

## Overview and conclusions

The general characteristics and dynamics of the various component populations that represent the eel stocks exploitable by man in the Shannon system have been well documented in recent years as a result of the extensive research programmes undertaken on the eel of both the river catchment and its estuary. Many of the Shannon research results can also be usefully applied in the analysis of other Irish eel stocks, just as the model represented by the management of the Lough Neagh eel fishery (McCarthy *et al.*, 1994c; Kennedy, 1998) can as-

sist in eel fishery development throughout Ireland. In addition to the details presented in this paper a large volume of, as yet mainly unpublished, data exists concerning the parasitic diseases, feeding habits and migratory patterns of Shannon eel (e.g. Clarke *et al.*, 1993; Purcell and McCarthy, 1993) will also be of interest to researchers on other eel populations. Many practical developments in eel fishery research and management also have originated from earlier work undertaken on the Shannon eel fishery such as the pioneering work undertaken (O'Leary, 1970) on elver trap design or the development of specialised fishing techniques for capture of silver eel in the lower River Shannon (McGrath *et al.*, 1976).

The results of the 1992–1998 research programmes on the status of the Shannon yellow eel and silver eel stocks, suggest that the effects of the documented collapse of the juvenile eel stocking programme in the previous decades are now becoming increasingly evident. Analyses of catch statistics for the fyke-net yellow eel fishing crews in Lough Derg and for the silver eel weirs of Killaloe and Clonlara clearly show progressive declines in CPUE and yield (Table 2, Fig. 9). Excessive fishing effort would be expected to result in selective removal of large yellow eel, as for example occurred in the Dutch IJsselmeer (Dekker, 1987), and this would become apparent in size frequency distributions. Clearly this has not occurred in Lough Derg (Fig. 4) despite the decline in CPUE from 1993 to 1998.

Interpretation (Quigley & O'Brien, 1996) of earlier records of silver eel catches in the Shannon, stated to be 69 and 65 t in 1908 and 1927, respectively, and evaluation of the effects of the river regulation on declining catches, stated to have averaged 9.6 t in the 1940s and to have improved to approx. 47.3 t in the 1980s, following stock enhancement measures initiated in 1959, is complicated by variation in fishing effort and the extent of undeclared upper catchment fishing. Construction of three additional fishing weirs at Clonlara (1966, 1981 and 1982) and significant modifications to the Killaloe eel weir (1982) were among the changes in the fishery undertaken by the ESB. Contrasting variations in silver eel sex ratios which reflect population densities (Tesch, 1977) have been related to stock enhancement in the Lough Neagh fishery (Parsons *et al.*, 1977) and to declining natural recruitment in the Burrishoole system (Poole *et al.*, 1990). The consistently higher percentages of males in the Lough Neagh silver eel fishery suggest that sustained and intense stocking produced overall population densities higher than those ever achieved in the Shannon, where female eel have predominated even during the years of maximum catches (e.g. 1982 catch: 75.6 t, 12.6% male).

The development of glass eel fishing in the Shannon estuary, the improvements made to elver and bootlace eel traps in the Shannon and estuarine tributary sites, the demonstrated feasibility of electrically fishing juvenile eel from unexploited lower catchment sites for lake stocking, and possibly also the utilisation of farm reared eel fingerlings in lake enhancement programmes, are all indications that in future years adequate provision can be made for stock enhancement and conservation of eel in the Shannon catchment. In the case of eel fingerlings reared in intensive aquaculture systems (Duggan, 1998) special care will have to be exercised, as stressed by McCarthy *et al.* (1994c), to assure that careful monitoring of such stocked eel and research on their behaviour, maturation and heath status is undertaken. Improvements to Shannon eel stocks can also be achieved by facilitating upstream movements of juvenile eel through installation of elver passes, etc. Downstream migration of silver eel not captured commercially could also be improved in the interests of conservation, although, despite evidence that piscivorous birds such as cormorants can locally feed heavily on eel (Doherty & McCarthy, 1997), introduction of predator control measures does not seem to be warranted.

Despite the concerns expressed about the population trends evident in the Shannon eel stocks experimental studies suggest that there is considerable scope for increasing yields through for example: (1) permitting increased numbers of nets to be used by fyke-net crews in their designated zones and encouraging greater fishing effort, (2) authorising long-line fishing linked to a fishing quota system, (3) extending the network of silver eel fishing sites and introducing new silver eel fishing techniques. However, the prospect of producing yields, despite the suitability of Shannon habitat type and area, comparable to Lough Neagh seems unlikely. A short- to medium-term objec-

tive of doubling or trebling the current catches and achieving a total yield of 200–300 t would seem to be a more realistic target, than the 700 t target proposed by McCarthy *et al.* 1994c, due to the delays associated with development of the required stock enhancement programme. Attainment of larger yields and maximum biological productivity may also be prevented in the longer term by other problems such as the uncoordinated, slow development of the eel industry in Ireland, failure to implement the programme adopted previously by an *ad hoc* national elver management committee, and logistical problems, such as are evidenced by difficulties experienced in controlling unauthorised fishing, in a large complex catchment like that of the Shannon. Biological phenomena such as the introduction of foreign pest species such as oriental eel parasites, the swim bladder inhabiting parasite *Anguillicola crassus* (T.K. McCarthy, O. Naughton and K. Creed, unpublished data) recently discovered in the south-east and west of Ireland, the gill fluke *Pseudodactylogyrus anguillae* and *P. bini* (McCarthy & Rita, 1991; Copley & McCarthy, unpublished data) now found in the Shannon system will present new difficulties for eel fishery management. Likewise more general ecological changes associated with water quality problems (Bowman, 1998) or species introductions (McCarthy *et al.*, 1997b) may affect eel growth rates and production in the future.

Marketing of eel captured in the Shannon has been difficult in recent years, due to competition from non-European eel fisheries and the continuing expansion of eel aquaculture both in Europe and Asia, as well as to an apparent decline in demand for such freshwater fish products in several European countries. Further development of eel culture in Ireland seems to be likely, leading to conflicting demands for glass eel/elvers (McCarthy *et al.*, 1997a, Warren-Hansen, 1997). However, scope for harmoniously promoting the two sectors of the eel industry, at both regional and national levels, clearly exists. This could be linked to new eel product development and co-ordinated marketing. Likewise, the integrated development of intensive eel culture and the longer-term wild fishery development (extensive culture or ranching) through stocking with both harvested juvenile eel and cultured fingerlings, may ultimately prove to be the best strategy for optimally utilising the natural resources of the Shannon system.

**Acknowledgements**

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# THE ERNE EEL FISHERY

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The Erne catchment is divided approximately equally between Northern Ireland and the Republic of Ireland. Total annual reported catch from the Erne is 30–35 t of brown eel, the greater part of which is taken by long-line on Upper and Lower Lough Erne in Northern Ireland. An additional 10–15 t of silver eel is taken by wing-nets and coghill nets on the outlet of Lower Lough Erne close to the estuary at Ballyshannon. The eel fishery south of the border is very under-developed and may produce less than 10 t per year.

Current yield from the Erne has been estimated at 5 kg $ha^{-1}$ or 56 kg of adult eel per kg of stocked elver. This is in sharp contrast to yields of 17 kg $ha^{-1}$ or 314 kg of adult eel per kg of stocked elver for Lough Neagh, which produces a total annual catch of 600–800 t. Previous study has shown Erne eel to be amongst the fastest-growing in the country, exceeding those recorded in Lough Neagh. Based on production levels of 17 kg $ha^{-1}$ for Lough Neagh, the average annual input of 1.3 t of elver to the Erne should yield an annual catch of 200 t yellow and silver eel.

This paper describes a major cross-border endeavour, the Erne Eel Enhancement Programme, initiated in 1997. Funded under the European Union's Special Support Programme for Peace and Reconciliation, it aims to determine the current status of the eel fishery, to maximise recruitment of juvenile eel to the system and to provide an integrated management plan for the future expansion of the Erne eel fishery.

## The Erne Catchment

At a length of over 96 km the River Erne is the second longest river system in Ireland. Rising in Slieve Glah, 6 km southeast of Cavan town, it flows through Lough Gowna, and then in a north-westerly direction through Lough Oughter to Upper and Lower Lough Erne before entering the sea at Ballyshannon, Co. Donegal (Fig. 12). Straddling the border between Northern Ireland and the Republic of Ireland, the Erne drains an area of 4,375 $km^2$, representing the fourth largest catchment in Ireland. The Erne lakes have a total area of 33,000 hectares of which approximately 15,000 ha are in the Republic.

The Erne system is dominated by Upper (34.5 $km^2$) and Lower Lough Erne (109.5 $km^2$), both situated within Co. Fermanagh in Northern Ireland. The Lower Lough itself is split into the Broad Lough to the north, which reaches a depth of 62 m, and the Narrows to the south which contains some of the richest eel fishing grounds within the lough due to the numerous shallow bays and inlets. The flooded drumlin terrain of the Narrows continues through into Upper Lough Erne (maximum depth 21 m) before radiating out to form a multitude of small lakes, channels, bays and islands contained in the Cavan–Monaghan area. The Environmental Research Unit (Castlebar, Co. Mayo) has identified over 1,000 lakes on the Erne system (Anonymous, 1993).

An extensive review of current and previous scientific studies of Lough Erne is provided by Gibson (1998).

## Hydro-generation on the Erne

A major feature of the Erne system is the presence of two hydroelectric power stations located at Cathaleen's Fall, Ballyshannon and at Cliff, Belleek which were commissioned in the early 1950s. Erection of dams at Cathaleen's Fall (height 27 m) and at Cliff (height 18 m) necessitated provi-

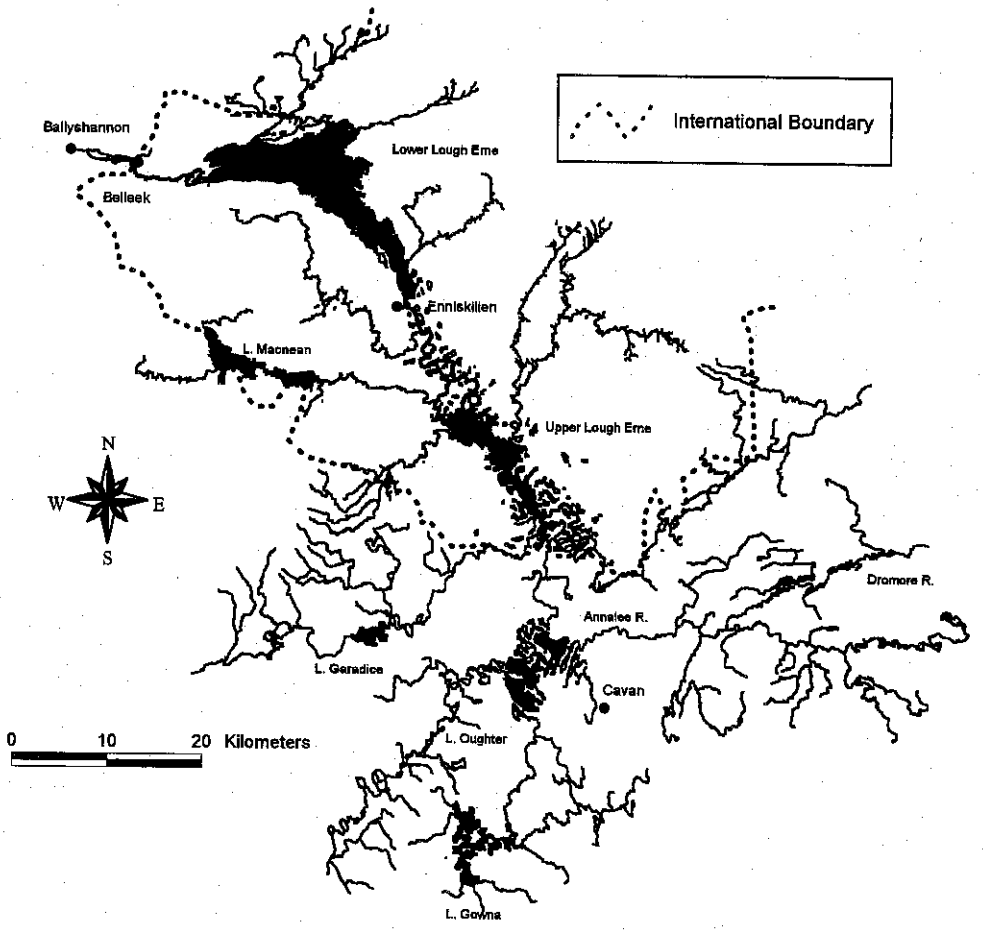


**Figure 12.** The Erne system.

sion for upstream movement of migratory fish including salmon, sea trout and eel through the construction of salmon passes and elver ladders at both dams. Water levels are tightly regulated within a band of approximately 1 m to meet the differing requirements of farmers, navigation traffic and electricity demand (Lawrence, 1992). The average flow rate through the stations is 92 $m^3/s$, which can rise to over 400 $m^3/s$ during major flooding. Downstream migration of silver eel is primarily through the generation sets. There is some evidence of turbine-related mortality, though this has not been quantified. Research has failed to develop effective means for diverting downstream migrating silver eel away from turbine intakes.

### The elver fishery

Following construction of the dams at Cathaleen's Fall and Cliff, elver ladders running in a series of zigzags from the bottom to the top of the dams were installed to provide passage for upstream migration. Although elver were recorded from the tops of the ladders, it is likely that the arduous climb resulted in significant losses. During the 1960s the ladders were replaced with elver boxes located downstream of the dam at Cathaleen's Fall. Exceptionally large elver runs, of over 4 t, were recorded in 1982 and 1994 (Fig. 13).

Each collection box is comprised of a ramp, approximately 70 cm wide, containing rubble and straw ropes to provide a climbing substrate. Clumps of heather are placed over the ramps to prevent predation by gulls and herons, which become active in the estuary during the elver run. A steady flow of water from the top of the ramps is maintained to attract elver up the entrance ramps

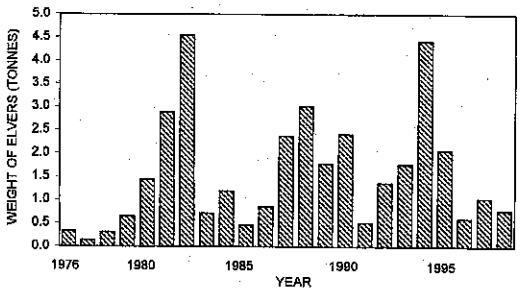


**Figure 13.** Elver catches at Cathaleen's Fall, Ballyshannon.

to the collection boxes. During the height of the run the boxes may collect in excess of 100 kg of elver per day.

Elver captured in the boxes are collected by Electricity Supply Board (ESB) staff and transported overland by the Department of Agriculture for Northern Ireland (DANI) for stocking out within Upper and Lower Lough Erne. A comprehensive record of elver catches at Cathaleen's Fall has been kept by the ESB and DANI since 1960 providing a long-term dataset of elver recruitment into the Erne. The presence of the dam means that additional recruitment into the system is extremely unlikely. Additional stocking of elver imported from outside of the Erne has not been carried out.

A steady decline in the numbers of glass eel and elver to the coasts of Europe has been reflected in generally declining elver catches to the River Shannon and the Bann since the early 1980s (Moriarty and Reynolds, 1997; Rosell, 1997). In contrast, the elver run to the Erne has remained relatively stable with a mean catch of 1.3 t per annum. Catches of 4 t and 4.5 t were taken in 1982 and 1994, respectively (Fig. 13).

The elver run generally extends from April to June, but varies greatly from year to year depending on air temperatures, rainfall and electricity generation regime. Water temperature of at least 10–11°C is required before elver will actively migrate. High daily discharge rates (range generally varies from 0 to 120 $m^3/s$), particularly in association with hydro-generation at night, may delay the commencement of the elver runs in certain years. Due to the location of Cathaleen's Fall at the limit of tidal influence, many of the elver in the earliest run to the boxes are in the earliest stage of pigmentation. The elver and bootlace eel run may extend into June or even July. The appearance of bootlace eel (10–22 cm, 5–10 g) in the catches is a reliable indicator that the year's elver run is drawing to a close. Once catches decline below 1–2 kg per week, the attractant water flows to the boxes are stopped. Small numbers of bootlace eel are known to migrate upstream through the salmon pass at Cathaleen's Fall during late summer.

## The brown eel fishery

The reported catch of brown eel from the Erne, of approximately 30–35 t per year, is regarded as being a gross underestimate due to under-reporting and illegal fishing. It should perhaps be doubled to give a more realistic estimate (Rosell, 1997). Based on an average production rate of 17 kg per hectare for Lough Neagh, the average annual input of 1.3 t of elvers to the Erne should be yielding about 200 t of adult eel per annum. At present the Erne produces 56 kg of eel per kg of stocked elver. In comparison, Lough Neagh returns 314 kg of eel per kg (Rosell, 1997).

Studies carried out by Moriarty (1973) showed eel from the north Cavan lakes to have rapid growth rates (mean length of 51.5 cm at 10 years), with the majority of the population maturing before 12 years and none exceeding 16 years. Erne eel were found to have faster growth rates and to mature earlier than those from Lough Neagh.

*Northern Ireland*

The Department of Agriculture for Northern Ireland (DANI) controls the fishing rights in Northern Ireland and has full discretion in relation to the issuing of permits for eel fishing. Licences are issued as a matter of course by the Conservancy Board for Northern Ireland, which is also responsible for fisheries protection.

The traditional method of eel fishing on Upper and Lower Lough Erne and Lough Macnean is longlining. The season extends from 1 May to 9 January. In 1998, 26 licences were being fished and each licence holder had a nominated helper. A cap on the number of licences had been introduced and there was a waiting list. Although there is considerable variation in the degree to which li-

cences are fished, a long-line boat containing 1 to 2 individuals, may fish up to 3 to 4 lines of 300 to 500 hooks per line. Restrictions on the size of boat (less than 6.1 m length), type of hook, and the taking of undersize eel (less than 30 cm) apply. A variety of baits are used through the season including earthworm, lugworm and perch fry. (The use of fry as bait is legal only in Northern Ireland.)

Of the two lakes, Lower Lough Erne is perhaps the most productive, and therefore supports the most consistent catch effort through the season. Fishermen traditionally fish either the Upper or the Lower Lough and there is little interchange between the two. Within Lower Lough Erne much of the most productive water is located within the Narrows due to the long shoreline, numerous bays and the movement of silvering eel through from the upper catchment.

Fyke-nets are also fished on both Upper and Lower Lough Erne, but to a much lesser degree. The season is short, running from 1 May to 31 July. Fyke-nets are not fished in the late summer to avoid impinging on the silver eel fishery.

Captured eel are held in marked keep boxes stationed around the lake edge. Dealers collect catches from agreed points around the lough either once or twice per week depending on the size of catches. Undersize eel are graded at the lakeside and returned to the water at the point of sale. Although the legal limit for undersize eel is 30 cm, market demands dictate that few eel under 40 cm are accepted by dealers.

*Republic of Ireland*

The eel fishery south of the border is very underdeveloped and may produce less than 10 t per year. Authorisation is granted by the Department of the Marine and Natural Resources (DOMNR), and licences are then issued by the Northern Regional Fisheries Board. Approximately 30 long-line and 5 fyke-net licences are issued annually. The number of long-line licences was capped in 1998 at the previous year's level. A small proportion (<15%) of the licences issued each year are held by people living within the Erne region with the majority of the remainder from Northern Ireland or the midlands.

Although a number of the larger lakes in the Republic (including Oughter, Gowna, Garadice) support fishing throughout the season, many of the waters in the Cavan–Monaghan area are small interconnecting lakes. Unable to support fishing throughout the season, many are fished intensively by long-line for 1–2 weeks each season and left 'fallow' until the following year. Fyke-nets are more commonly used in the Republic, but many are fished on a part-time or recreational basis rather than as a primary commercial enterprise. Many of the fishermen are reluctant to fish fyke-nets more than once or twice per week. A generally low fishing effort, the lack of stocking, prevalence of illegal fishing and under- reporting of catches all contribute to a lower output than should otherwise be possible.

The Northern Regional Fisheries Board carries out protection of the eel fishery. Staffing and resources for protection of the numerous, scattered lakes of this section of the Erne remain wholly inadequate. It is likely that significant amounts of eel captured, either legally or otherwise, are sold outside the catchment with no reports of catches. Historical records and local knowledge indicate catches to be a fraction of what was obtained previously.

**The silver eel fishery**

The annual catch of silver eel from the Erne is estimated at 10 to 15 t. The greater part is taken by a series of wing-nets on the outlet of Lower Lough Erne, and coghill nets at Roscorr Bridge, both situated in Northern Ireland, and Belleek weir, which spans the border. All are situated upstream of the ESB power-generation stations. The catch commences in late August/early September and continues to the first week in January. The main run is concentrated around October–November and is strongly related to lunar cycle, water temperature and weather. Catches are also influenced by the flow regime through the ESB power stations at Cliff and Cathaleen's Fall, with generation between dusk and mid-night encouraging migration of silver eel.

The silver eel fishery in the Republic is in decline. Of 11 silver eel weirs fished over the 1970s only 4 were in operation in 1998, some of them in need

of renovation. Catches appear to have declined significantly during the 1990s. The catches from the Upper Erne catchment are predominantly composed of large female eel averaging 60–90 cm in length.

**The Erne Eel Enhancement Programme**

The Erne Eel Enhancement Programme was initiated in 1997 under the European Union Special Support Programme for Peace and Reconciliation. Total funding of £0.8 million was secured under Phase I of the programme, which will extend to December 1999 (Fig. 14).

The programme has served to bring together the various agencies, North and South, to develop an integrated management strategy to realise the full development potential of the Erne eel fishery. A Joint Erne Eel Management committee and Scientific Advisory committee have been established to oversee the development of the eel fishery on the Erne. The primary aims of the programme are:-

*(1) To maximise recruitment of glass eel and elver to the Erne*

A central element of the current research programme will be to ascertain the potential for increased recruitment of juvenile eel to the catchment through the active capture of glass eel in the Erne estuary. Extensive glass eel fisheries exist in France, Spain, Portugal and Great Britain where eel are captured for direct human consumption, or for stocking to inland waters or eel farms. Glass eel are known to be present in estuaries for several months prior to their active upstream migration into fresh water. During this time they may suffer high mortality rates due to predation. Early collection and overland transport may be utilised to maximise survival at this critical stage of development. A variety of capture methods including hand netting and active trawling is currently under investigation.

During March 1998 glass eel experts from the University of Porto, Portugal were invited to the Northern Regional Fisheries Board, Ballyshannon to demonstrate the use of the *Tela* net for the capture of glass eel in the Erne estuary. *Tela* nets are used extensively on the River Minho estuary on the border between Spain and Portugal, where annual yields of 10–30 t of glass eel are taken and

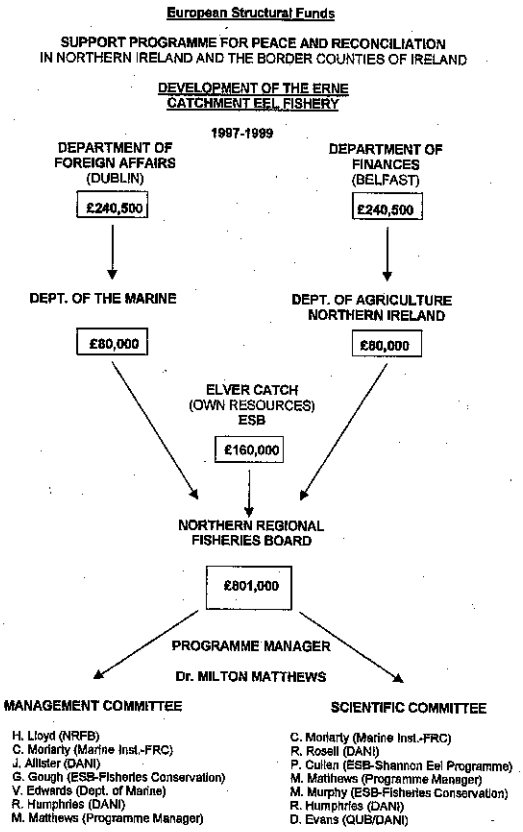


**Figure 14.** Administration of the Erne eel project.

exported to Spain for the restaurant trade or re-stocking. Yields of up to 40 kg per boat per night have been achieved (Weber, 1986).

The *tela* net, comprised of 2 mm mesh, is set at night across an incoming tidal stream. Floated wing nets, anchored at the extremities, funnel migrating glass eel to a pocket located at the centre of the net where they are removed by means of a *rapetta* dip net. Early trials carried out on the Erne estuary suggest that the method may be readily adaptable to Irish waters, providing additional material for re-stocking, as well as giving valuable information in relation to the movement and development of glass eel within the estuary. All glass eel captured at Ballyshannon have been used

for re-stocking into the Erne.

*(2) To determine the current status of eel stocks throughout the Erne catchment and to ascertain the potential for increased exploitation.*

An extensive fyke-net survey of the Erne catchment was initiated in July 1998 and will continue from May to September 1999 under Phase 1 of the Erne Eel Enhancement Programme. Six two-man crews, three stationed in Northern Ireland and three in the Republic, are currently providing, for the first time, a detailed account of the current status and distribution of eel stocks throughout the catchment. Weekly samples of eel are taken to determine age, growth and feeding patterns from different sections of the catchment. Placement of observers with survey fyke-net crews and commercial long-line fishermen will provide much needed information on the current exploitation levels on the Erne and will enable capture efficiency of fyke-net and long-line to be compared. Establishment of the current status of eel stocks in the Erne will provide the necessary baseline data against which future management and enhancement measures may be measured.

Periodic samples of the silver eel catches taken by commercial fishermen are also being examined to determine the timing of the silver eel run, sex ratio and age at migration. A tagging programme initiated in July 1998, using Floy tags to mark early silvering eel, is currently providing detailed information on the pattern and timing of silver eel migration through the system following recapture of tagged eel in the commercial catches on the outlet of Lower Lough Erne. Recaptures have already been recorded from Upper and Lower Lough Erne, Lough Oughter, and the Dromore system in Co. Cavan.

*(3) To develop a co-ordinated cross-border management plan for the Erne eel fishery.*

The ultimate goal of the current programme is to provide the scientific basis on which a viable management plan for the Erne eel fishery may be developed for the creation of additional employment within the industry. At present, captured eel from the Erne are exported live to continental Europe providing no additional value to the area. Until recently the demand for eel in Europe, which has been estimated at 25,000 t per year, has exceeded supply maintaining high market prices. The added value of smoked eel is such that they retail at approximately £30.00 per kg versus £3.50 per kg for live silver eel. With the growth in eel farming over the past 10 years the demand for eel is now being met and prices have dropped accordingly. It is now imperative that a national market strategy be developed to expand the market and to promote Irish eel both at home and abroad.

## Acknowledgements

This study was carried out under the Erne Eel Enhancement Programme, which is funded under the EU Special Support Programme for Peace and Reconciliation. The authors also wish to acknowledge the input from the members of the Erne Eel Management and Scientific Committees, and the assistance of the ESB staff at Cathaleen's Fall, Ballyshannon.

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# THE COMMERCIAL EEL FISHERY ON LOUGH NEAGH

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Although I wish to express my appreciation of the kind comments of the Minister and the Chairman, I must at the outset make it clear that I do not pretend and cannot claim to be an expert on anything. I am not a scientist, nor a biologist – marine or otherwise – merely a pragmatist who found himself faced some 25 years ago with a situation where local people were being seriously disadvantaged and sought help and advice, with a view to righting the injustices from which they were suffering.

At that time the local Parish Priest, in his sermon one Sunday describing the recruitment of the Apostles, emphasised that Our Lord did not choose wealthy or privileged or educated people - but "ordinary ignorant fishermen". Since about 60% of his congregation were fishermen, it was not exactly the most tactful of comments. I must hasten to add that my experience of over thirty-five years involvement with the fishing community around Lough Neagh has led me to the conviction that there are no longer any "ordinary ignorant fishermen". Instead they are resourceful and display a remarkable ability to find a way round any regulations designed to restrict or control their activities.

## Lough Neagh

Most of us remember from the Geography lessons at Primary School that Lough Neagh is the biggest inland lake in these islands. It is roughly 16 miles from north to south and approximately 10 miles from east to west – about 157 square miles in total area. It has now become internationally recognised as a major source of quality eel for the European market, where the Lough Neagh wild eel is accepted as having the perfect fat content for smoking.

Ancient Irish folklore attributes the origin of Lough Neagh to a local Ulster Giant – Finn MacCool – who is also associated with the Giant's Causeway. The story is that Finn awoke one morning in a vile mood – quite possibly as a result of over-indulging in some of the native Tyrone brew on the previous evening. To relieve his feelings he picked up a boulder from the centre of Ulster and cast it into the Irish Sea. The crater it left filled with water and became Lough Neagh, while the rock which fell into the Irish Sea became the Isle of Man. While geologists may well dispute that theory, I have, at times during the last thirty years, when myself under pressure, wished that Finn Mac Cool had found some alternative way to release his pent-up anger.

Lough Neagh, however, whatever its true origin, has become one of the greatest natural assets of our province, and a source of income to many.

## Annual catch

The eel fishing season on Lough Neagh opens on 1 May each year and continues until 10 January in the following year. In practice the brown eel fishing season is determined by weather conditions and water temperature. When the temperature of the water drops in late autumn the brown eel descends into the mud to hibernate, at which stage continued fishing for brown eel is no longer viable!

The peak months for brown eel fishing on the Lough are therefore June, July and August with fishing declining from mid-September. During the peak period, the daily intake of fresh-caught eel at the Co-operative's premises in Toome is between 7 and 10 t. Numerically this can represent in the region of 67,000 eel each day.

Silver eel are caught at the eel weirs at Toomebridge and downstream at Kilrea as they migrate to

return to the sea on their way to the Sargasso Sea to spawn, the theory being that all European eel spawn in the Sargasso Sea. The main catch of silver eel is from mid-September until early December, the catch being influenced by moon phase and weather conditions.

Total catch of brown eel each year is in the region of 550 t and of silver eel in the region of 200 t. It is principally from the catch of brown eel that fishermen derive their livelihood.

**Fishermen**

Since the Co-operative Society now has the title to the commercial eel fishery on the lough it is responsible for granting permission to fish. In recent years between 185 and 190 boats have been granted licences each year. Since each boat has normally a two-man crew, about 400 families around the lough shore derive an income from actively fishing on the lough. Fishermen are self-employed, and are responsible for their own boats and tackle.

**Previous background**

There is evidence at New Ferry, on the River Bann downstream of the fishery at Toome, of there having been commercial fishing for eel there since about 2000 BC – for which reason I cannot claim the credit for introducing commercial fishing for eel in the Lough Neagh area. The commercial eel fishery on Lough Neagh has therefore had a long and frequently chequered and troubled history.

The present title derives from the mid-1600s when Charles I, in return for unspecified favours received, granted the bed and soil and eel fishery of Lough Neagh to the Earl of Donegal from whom it devolved to the Chichester family and currently to the Shaftesbury Estate. The Co-operative Society holds a lease of the eel fishing rights from the Shaftesbury Estate.

On the basis of that title, there has always been a Company operating the eel weirs at Toomebridge and downstream on the River Bann, whose main interest has been in the maximum catch of silver eel. Inevitably it accepted that there were fishermen around the Lough shore fishing during the summer months for brown eel.

The Company issued licences to a limited number of fishermen and purchased eel from them. Since the more brown eel caught by fishermen inevitably resulted in a lesser catch of mature silver eel at the weirs, the company by patrolling the Lough, seizing gear and equipment, sought to restrict the catch by fishermen to a minimum.

This basic conflict of interest was the root of all the animosity between the then Company and the fishermen. The records of Petty Session Courts around the Lough are evidence of persecution and prosecution. Families living around the shores of the Lough understandably insisted that they had a moral right to earn a living by fishing.

With a view to establishing its exclusive right to the Eel Fishery on the Lough and the River Bann, the Company took proceedings at different times. In one such proceedings, in the early 1900s, the case went for decision to the House of Lords. Tim Healy, who represented the fishermen in that case, subsequently summarised it in a book called *Stolen Waters* which represents an authentic history of the Lough Neagh Eel Fishery up to that time.

The outcome of the case was not absolutely conclusive, since it appeared to concede the title to the Eel Fishery on the River Bann and in the immediately northerly part of the lough to that Company without being definitive about the remainder.

Fishermen continued to fish, some with permission from the Company and others without. Some sold their eel to the Company while others either sold them to local merchants or sent them directly to buyers in Billingsgate Market in London. Eel at that time were packed in wooden boxes and sent by train from local stations to Larne Harbour from where they crossed by ferry to Stranraer and onwards by train to London.

In the late 1950s the firm of Kuijten from Sparrndam near Amsterdam began to purchase the bulk of the silver eel catch at Toome. They realised the overall potential of the fishery, which was not be-

ing fully exploited, and combined with the four main eel-wholesalers in Billingsgate to acquire the Company at Toome and form Toome Eel Fishery (N.I.) Ltd.

The Directors of that Company then informed local fishermen and fish merchants that they would no longer buy eel directly from them as they had previously done, but that all eel caught must be sold to the Company at Toome at a price determined by it.

When local fishermen sought alternative buyers for their catch, Toome Eel Fishery (N.I.) Ltd. took proceedings in the Northern Ireland High Court against named fishermen and a London merchant. The decision of those proceedings in 1963 was that Toome Eel Fishery (N.I ) Ltd. had the exclusive right to the eel fishery on Lough Neagh and the River Bann.

The practical effect of that judgement was that local fishermen

(1) could only fish if granted permission by the Company,
(2) under the provision of regulations made by the Company,
(3) had to sell their catch to the Company at a price determined by it.

In the light of that decision fishermen felt that the regime, which the Company proposed to introduce and enforce strictly, would result in their no longer having an opportunity to earn by fishing on the Lough.

Since a substantial number of fishermen lived in the district of the parish at Toome for which I was responsible, I was approached by them for advice. At that time I knew nothing about eel fishing – and there are those who would suggest I haven't learnt much since. It appeared to me that a situation, where a private company could control the fishing rights over an area of water the size of Lough Neagh, was unacceptable and anachronistic.

Since, however, the Courts had decided that that was the legal position, there seemed to be no alternative but to take effective steps to have that injustice remedied. In effect, a private company had an absolute monopoly over one of the most productive wild eel fisheries in Europe and could, and probably would, administer it in its own interests and to the disadvantage of the families, which had always lived on the shores of the Lough and traditionally fished its waters.

**Trade Union**

At a meeting of fishermen held in May 1963, I recommended that the existing Lough Neagh Fishermen's Association should be re-organised, all fishermen should be encouraged to become members of it, and that it should be registered as a Trade Union. The Association was registered as a Trade Union on 24th November 1963 and undertook to represent the fishermen in negotiation with the Company and with the Department of Agriculture. In joint discussions with the Company and the Department it sought to negotiate changes in the fishing regulations and the system for issue of licences.

**Formation of Co-operative**

In 1965 one of the five share-holding companies in Toome Eel Fishery (N.I.) Ltd proposed to sell its 20% holding in that Company. Since one of the remaining share-holders had already an option on another share-holding, the other two directors were concerned at the possibility of his acquiring a majority share-holding. They therefore suggested that the Fishermen's Association should acquire the available share.

Since it appeared that this would represent a positive step towards the fishermen eventually achieving total control of the fishery, it was decided to make an offer, subject to investigation. The purchase of that one-fifth share was concluded in 1965 at a cost of £83,000 which was a substantial sum in those days – especially in view of the fact that the Association did not have any funding available.

It was decided to form a Co-operative Society to purchase and administer the shareholding. Fishermen and local people, who recognised this as an opportunity to assist in remedying the injustices

from which fishermen had suffered for generations, subscribed approximately £43,000.00 and were allocated shares in the Co-operative, which was duly registered on 24th May 1966.

The balance of the purchase price of that share-holding was raised by a loan from the Ulster Bank which was repaid through the profits from the Society's share of the silver eel catch in the following seasons.

The purchase of the share-holding gave the Society

(1) a right to appoint a director to the Board of Directors of the Company
(2) a one-fifth share in the catch of silver eel at the weirs.

**Marketing of eel**

In practice the Co-operative decided to undertake the marketing of their catch on behalf of fishermen on a non-profit-making basis. Although initially the principal outlet continued to be Billingsgate market in London, as the years progressed it developed alternative and more lucrative markets on the continent.

In recent years approximately 60% of the catch of both brown and silver eel are exported to Holland, 30% to north Germany and the remaining 10% to London. The total paid to fishermen each year in respect of their catch is in the region of £3.5 million sterling, while the total turnover is about £5.5 million.

While, under the previous regime, the total profits of the Fishery were enjoyed by the share-holding companies and their Directors, who were based in England and Holland, the full profits of the fishery are now shared locally by fishermen and the share-holding members of the Co-operative. In addition to the payments made to fishermen for their annual catch, the Society for many years past has paid its members each year share interest and dividend at a combined rate of 27%.

In December 1971 the Co-operative realised its objective of acquiring total control of the fishery, when it purchased the remaining 80% share-holding. By that achievement the Co-operative succeeded in bringing to reality the dreams of previous generations of fishermen.

During the following years the Co-operative availed of its influence within the Company to encourage the other share-holders to consider disposing of their share-holding and retained some of the profits from the sale of its share of the silver eel catch to help finance that project, should the opportunity present itself.

As a result of that pressure, and the fact that public attention was focussed on the injustice of the privileged monopoly which the Company enjoyed, it decided in 1967 to cease purchasing brown eel from fishermen and to remove from the fishing regulations the insistence that all eel caught must be sold to the company. Since the company through its share-holding companies had a strangle-hold on the major market outlets for eel, this was intended to create chaos.

In each year since it undertook the marketing of their catch of eel, the Society had retained part of the proceeds of the sale of their catch. That fund was used to fund the outright purchase of the Company: fishermen were, by agreement, issued shares in the Co-operative in relation to the share of the retention to which they would have been entitled.

As a result of that distribution of shares, all those actively involved in fishing at that time became share-holding members of the Society with an interest, therefore, in its continued viability and profitability. Thus the long-standing conflict of interest between the brown and silver eel fishery was potentially resolved.

Prior to the Society's obtaining control of the Fishery, the maximum number of licences issued to fishermen was in the region of 150. Since the Society's object was to allow fishermen the maximum opportunity to earn a living by actively fishing on the Lough, the number of licences issued was increased. Due consideration, however, was given to the need to control the intensity of fishing to preserve stocks. At a time the number of licenses issued was in excess of 200. Currently in the region of 185 Boat Owners' Licences are issued each year, all of which are fished intensively.

The statistics of brown and silver eel catches since 1972 show a substantial change in the balance of brown and silver. The substantial increase in the annual catch of brown eel is reflected in a corresponding decline in the silver eel catch. This development is carefully monitored with a view to ensuring that the total catch of brown and silver eel each year is within acceptable limits.

**System**

The 185 licences are held by fishermen scattered around the Lough shore, which touches 5 of the 6 Counties. There are obviously major concentrations of fishermen in certain areas. Fishermen are permitted to fish by either long-line or draft-net. A long-line by Lough Neagh standards may consist of 3,000 hooks. Lines are set in the afternoon or early evening, and lifted early next morning.

Eel are collected from the fishing quays around the shore next morning by agents acting on behalf of the Co-operative and transported in tanks on the lorry to the Co-operative's premises at Toomebridge. Each fisherman's eel are in a separate tank on the lorry and identifiable as the produce of that boat until arrival at Toome.

At Toome:

(1) Undersized or inferior quality eel are rejected and returned to the river,
(2) The boat is credited and a docket issued for the weight accepted,
(3) Eel are then graded to the size appropriate for the different markets and
(4) Packed ready for shipment.

Eel are packed in cardboard cartons, each containing 30 pounds (13.6 kg). All eel are now consigned by air, to London for the UK market and through Heathrow to Holland and Germany. In the absence of a dedicated freighter service, eel are carried on passenger services, using a variety of flights to achieve the required total capacity of 6 to 9 tons each evening. Flights currently used achieve an arrival time at Schipol of 18:30 h and 20:30 h each day.

Eel are collected from the airport that evening, taken back to their premises and prepared for smoking from 05:00 h next morning. In effect eel caught on Lough Neagh this morning, packed and shipped today, can be on sale as smoked eel in the holiday resorts around the IJsselmeer tomorrow afternoon.

**Management**

In view of the life cycle of the eel, which requires up to 14 years to reach maturity, it is imperative that effective steps are taken to avoid over-fishing.

For this reason:

(1) a restriction is imposed on the number of licences issued,
(2) a quota is placed on the quantity of eel accepted from each boat each day.

While the maximum daily quota will ordinarily be 8 stone (51 kg), this is flexible. If market demand is poor, the quota is reduced with a view to maintaining an acceptable price, rather than face reductions through over-supply. Account is also taken of the *total allowable catch* in relation to *stocks*.

In the years when the natural elver recruitment has been below normal, the Society purchased elver from other sources to sustain the stock of eel at a level which should maintain catches at an acceptable intensity.

**Market demand and prices**

Since approximately 90% of the total annual catch of Lough Neagh eel is exported to Holland and Germany, prices returned from these markets have shown a marked decline in both the 1997 and the current season as a direct result of the high value of sterling.

Returned prices have also been adversely affected by the increased quantity of both wild and farmed eel on the market. At present prices reflect a drop of between 25% and 30% as compared to the 1996 season. It is unlikely that this will improve in the near future. It must be stated that contrary to pop-

ular belief the total market for eel is not infinite or unlimited.

Those with practical experience in marketing what is a specialised product will confirm that:

(1) the overall market is contracting and
(2) it is being over-supplied from both wild and farmed sources.

As a result of the attractive prices available for eel some years ago, more and more rivers and lakes, which had previously not been fished, have been fished intensively for eel. At the same time there has been a growth in the number of eel farms in Holland and Denmark in particular and advances in eel aquaculture have resulted in increased production.

The overall effect is that the market is currently being over-supplied from both wild and farm sources with prices being deflated as a consequence.

The apparent scope for export to the Far East is at present being adversely affected both by the declining economy and gross over-production by Chinese eel farms. The quality of farmed eel from China is suspect; because of the decline in the demand in Japan in particular they are being offered in Germany at low prices.

**Future development**

The Co-operative Society, when it acquired control of the Fishery in 1972, inherited premises constructed in 1960. Since these were quite inadequate in the light of the changed manner in which the Co-operative administered the Fishery, it undertook in November 1996 a Capital Programme which resulted in the total replacement of the previous buildings and facilities. While these buildings have not yet been fully equipped, the intention was to make more than adequate provision for future development and diversification.

The capital investment of some £3.5 million is a token of the Society's determination to ensure that it is in a position to continue to refine its marketing strategy to take account of changing circumstances.

**Success**

Those who are objective observers, and have no direct involvement in the eel industry, regard the progress made by the Lough Neagh Fishermen's Co-operative as one of the major successful community enterprises in the recent troubled years. It is an indication of what can be achieved by a previously disadvantaged community, through a local initiative founded on the principle of self-help.

It is both anxious and willing to assist and support developments elsewhere, but must understandably be concerned to ensure that these do not in any way detract from what has been achieved by a local community to redress the injustices from which it previously suffered through its own determined initiative and enterprise.

# EEL CULTURE IN IRELAND

**DECLAN DUGGAN**

*Aqua Arklow Ltd., Croghan Industrial Estate, Emoclew, Arklow, Co. Wicklow*

Aqua Arklow Ltd. was officially opened 18 April 1997 and is grant aided by the Government and the European Union. We wish to take this opportunity to thank the organisations and individuals who have been invaluable in assisting the development of the company to date – to name but a few: Bord Iascaigh Mhara, Department of the Marine and Natural Resources, the ESB fisheries conservation board and many other fishery board officials and staff.

The production unit is designed as a 60 t unit containing the latest technology and installed by the Dutch company HESY bv. who have built similar plants worldwide. At present the company employs 6 people and indirectly provides work to others including processors in Ireland and ongoing work to local suppliers and contractors. The system is housed in a standard industrial insulated building 22.5 x 37.5 m and has very low waste discharge due to the design of the system. This enables the plant to be installed in virtually any particular area and easily complies with the various planning and environmental laws. Water temperature is kept at 25°C for optimum growth levels.

Any elver sourced in Ireland are transported by small tanker with an oxygen supply. Unfortunately, due to lack of infrastructure for glass eel capture in Ireland, 85% of the 1998 intake came from the River Severn in the UK. These eel are inspected by the Ministry of Agriculture in the UK and certified disease free before importation. Quality is of the utmost importance in sourcing of glass eel and ensuring that mortality is kept to a minimum. Eel larger then 0.3 g are unsuitable due to the risk of carrying freshwater parasites.
A supply of 300 kg of glass eel is required to produce 60 t of market size (150 g) eel.

Eel are held in a special quarantine system before introduction to the glass eel system and are treated with salt or formaline to eliminate any possibility of common parasites. After 24–48 hours they are transferred to the glass eel system and feeding commences. After 6 weeks they are graded and fast growers transferred to the fingerling unit. From then on the eel are graded approximately every 6 weeks and eventually transferred to the ongrowing system. In grading they are pumped from the tank through a mechanical grader and are weighed and distributed to different tanks according to size.

Eel are initially started to feed on cod roe. Many soon graduate to dry feed: specialised eel feed imported from Holland and designed to ensure optimum fat content for smoking. They are fed by auto feeders at specified intervals according to the size of eel. The amount of feed given is carefully calculated and formulas are designed to ensure optimum feeding and maximum growth rates

Overfeeding quickly pollutes the water, giving severe problems in biofiltration and consequent ill-health among the eel. Regular and efficient grading is vital to ensure optimum conversion ratios and prevent cannibalism. Careful weighing during grading is essential to enable accurate feed schedules to be calculated for each individual tank.

Eel are purged in fresh water without feeding for 7 days prior to sale to ensure optimum quality. Some salt is added to prevent any fungal outbreaks and oxygen injected to the water supply. Aeration is also provided to eliminate any carbon dioxide. Over 3 t can easily be held in one tank.

Eel are exported live in specially designed vivier trucks, most trucks carrying over 6 t of eel. Carefully designed systems, always with back-up and alarms, are utilised to ensure the cargo arrives alive and in top condition to the customer.

The PC plays an essential part in feeding formulas and for accurate predictions of stock production. Careful records are maintained on feeding, water quality and general husbandry. Mechanical main-

tenance schedules are most important also and strictly adhered to. A small laboratory is also utilised to examine eel on a regular basis and to maintain accurate records of water quality, etc.

The actual system consists of 4 independent recirculation units and the combined number of tanks is 24, ten of these being used for ongrowing. Each tank is self-cleaning with high level alarm, direct emergency oxygen supply, self-cleaning outlet and auto-feeder.

To maintain densities of up to 200 kg per square metre, up to 6 t of liquid oxygen is stored on site. This is automatically injected to the system water and is monitored on an ongoing basis, extra oxygen being added automatically as required, during peak demand at feeding time, etc.

Reliable pumps ensure that water is circulated and back-up pumps are also installed in case of any failure. UV light is utilised to kill any harmful pathogens and oxygen is efficiently mixed in the water by specially designed oxygen reactors

The system is controlled from a central panel and monitored 24 hours a day by a security company by means of alarms and modem. Staff work an 8-hour day and take it in turn to carry a mobile phone in case of alarm. The person on call carries the phone 24 hours a day, 7 days a week. Saturday and Sunday work involves about a total of 3 hours per day, again done on a rota basis.

A denitrification plant is presently being installed to ensure the company keeps up with the latest technical advances. This will ensure better use of available water and energy and save on replenishing water further. At present approximately 90–95% of the water is recycled.

# EEL CULTURE TRENDS IN EUROPE

**PER BOVBJERG**

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## Introduction

Eel farming in open ponds, as it is practised in the southern part of Europe (for example Italy), has existed for many years, but eel farming in recirculation systems, as it is practised in the Northern part of Europe (e.g. the Netherlands and Denmark), has been a commercial industry only for relatively few years. Following many trials (and errors) during the mid-1980s, production finally became profitable and today the technology is well-known and well-proven, so that means have been realised for further improvements.

The production of eel in recirculation systems has increased concomitantly, as it appears from the production figures (t):

| | 1994 | 1996 | 1998 (estimated) |
|---|---|---|---|
| Netherlands | 1,400 | 1,900 | 3,000 |
| Denmark | 914 | 1,250 | 2,000 |

Now that it seems as if the Dutch market, traditionally the main market for eel of 120–160 g, is becoming saturated, more innovations are introduced.

## An overall view of the trends

The general trends in intensive eel farming may be summarised and grouped as follows.

Production parameters:
- improved nursing of elvers (e.g. nursing, grading, feeding
- increased production-intensity by increased density
- improved feed types and improved feed conversion efficiency
- optimisation of water parameters and water quality

Technology and environment:
- reducing need for manpower (e.g. grading systems, automatic feeding systems)
- new types of biofilters (e.g. fluidised bed filters)
- denitrification filters for removal of nitrate
- in-line or end-of-pipe precipitation of phos phorus
- reduced water consumption
- focus on power consumption

Products and markets:
- product diversification
- kabayaki production
- certified and guaranteed quality

## Production parameters

*Improved nursing of glass eel/elvers*

In 1 kg of European glass eel, *Anguilla anguilla*, there are approximately 3,300 individuals (depending on origin). A few years ago, a farmer would have considered it quite satisfying if some 1,600–2,000 of these survived to fingerling stage, useful for production.

By improving on the general management, spending more time, feeding more often, grading earlier and using better feeds, in 1998 average survival might reach 2,500 good fingerling per kg of glass eel or elver.

*Increased production intensity by increased density*

In a recirculation system, where all the production parameters are quite constant throughout the year, yearly production can theoretically be calculated as 365 times the average density times the average

daily growth rate (specific growth rate SGR).

So,

daily production = avg. SGR (%/day) × avg. density (kg/m$^2$)
yearly production = 365 × avg. daily production

Even though attempts have, of course, been made to increase SGR, it has proven quite difficult (see below). The way to increase the production in an existing system has therefore mainly been to increase the density. The average density can today reach some 100 kg/m$^2$ (higher for bigger eel), and as the average growth rate is 0.7%, 350 × 100 kg/m$^2$ × 0.7% = up to 245 kg can be produced per m$^2$ tank area per year.

In a well-designed system approximately 50% of the in-house area can be tank-area.

**Technology and environment**

*Reducing need for manpower (e.g. grading systems, automatic feeding systems)*
As manpower, at least in Europe, is becoming increasingly expensive, the focus is constantly on the possibility of reducing the needs. Two of the most labour-intensive parts of eel farming are daily feeding and grading, normally done every seventh week.

Feeding used to be done by filling each of the feeding machines individually by hand. To-day, automatic feeding systems ("imported" from the poultry business) can take accurate care of this in a very short time. This had led to a reduction in man-power needed for feeding.

Additionally, grading also used to be a quite strenuous job. The eel in a tank were caught by net and graded in a machine. The gradings were transported back to the tanks in tubs. Today, all the eel in a tank are transported through a piping system to a grading reservoir. An air-lift elevates the eel to the grading machine, and the graded eel are collected in big nets and weighed and transported by fork-lift.

All in all, a farmer-operated system can produce some 40 t/year with only little assistance, and a 300 t farm can be operated with a staffing of only 4–5 persons.

*Improved feed types and improved feed conversion efficiency*

As mentioned above, it has proven difficult to increase the growth rate significantly, but on a European basis many feed companies are trying to produce and improve specialised feed recipes for eel, thereby improving on the growth rate. Up until now it has resulted in significant reductions in feed conversion ratios, whereby the capacity of the biofilters has supported increased production in existing systems.

*Optimisation of water parameters and water quality*

Poor water quality and variation in different parameters will result in reduced feed intake and reduced growth of the eel. Efforts are therefore constantly being made to optimise and stabilise relevant parameters.

*New types of biofilters (e.g. fluidised bed filters)*
Different types and constructions of biofilters are being developed and tested, and especially bed filters seem to be coming up. The aim is, of course, to reduce investment cost, reduce need for space, reduce operation costs, or improve capacity.

*Reduced water consumption*
Water is becoming increasingly expensive, so are the costs of removing or cleaning it. Additionally, as the farms are becoming bigger and bigger, logistic problems of distributing the water outlet on farmed land are increasing. When you reduce water consumption, some parameters such as nitrate and phosphorous, will increase in concentration (see below).

*Denitrification filters for removal of nitrate*
Even though nitrate is not considered very toxic to eel, practice seems to indicate that levels above 300–500 mg/l reduce growth. These levels are often reached, especially if water consumption is reduced. Specific filters, designed for removing nitrate by converting it into free nitrogen, are being developed and installed.

*In-line or end-of-pipe precipitation of phosphorus*
Reductions in the elevated levels of phosphorous are coming up, either in-line (reducing levels in the circulating water) or end-of-pipe (reducing environmental impact).

*Focus on power consumption*
Power is another variable cost, increasing in price. During the "early stages" of eel farming, focus has been on succeeding with the technology, and to get production rolling. Now, optimisation and reduction in, for example, power can be achieved. This is mainly done by optimising the pumps, and eliminating power consumption not really needed.

## Products and markets

*Product diversification*
The main part of the production is still eel in the size range 120–160 g, but more farms are now producing bigger eel, particularly for the German market. Increased efforts are also being made to increase home-market consumption in such countries as Denmark.

*Kabayaki production*
A special kind of product diversification is the production of the Japanese speciality, kabayaki. In Denmark, two such factories are already operating. The factories process the eel in Denmark and sell the product in Japan through Cupertino/licenses with Japanese partners. Of course, the market situation in Japan is not too good right now, but I am convinced that this will be a good and increasing business for Europe in the years to come. Additionally, the value addition in the factories creates jobs in areas, where competition and cut-backs in the traditional fisheries sector have caused reductions in jobs available.

*Certified and guaranteed quality*
By producing the eel in controlled conditions, the possibilities of developing special brands appear. Green labels, blue labels, ecological labels, organic farmed fish seems to be on its way, and can be another way of access to new markets or new market-niches.

## Concluding remarks

Even though the demand from the Dutch market seems filled and the Japanese market is difficult for the time being, the prospects for eel farming and value added production (especially kabayaki) seems good. The huge Japanese market for kabayaki is today mainly supplied from China, but Chinese eel production seems to be coming to a crisis in the years to come. Glass eel of the regional species *A. japonica* are scarce in supply and concomitantly prices are extremely high; imports from Europe of *A. anguilla* are not too successful and restrictions in the import can be foreseen. All in all, Chinese eel-production is expected to be reduced significantly, leaving a gap in the supply to the Japanese market. It is foreseen that this gap can be filled from an increased European production, leading to a further expansion in an industry already growing.

# EEL PRODUCTS AND MARKETS
## An overview of the market for eel in Germany

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### Eel imports into Germany

Total imports in four categories (Table 1) have been fluctuating around the 3,000 t level, about 50% of imports being live eel. Smokers prefer, if at all possible, to obtain eel alive, as they have their own special methods of killing the eel and emphasise that, to obtain the required quality and flavour of the smoked product, eel must be smoked immediately after being killed.

When live eel are not available, smokers will take frozen and around 30% of imports are in this category. As production of smoked fish in Germany is very high, imports of smoked eel are still low. However, this category shows a very gradual increase, from 3% in 1995 to 4% in 1997.

**Table 1. Total imports (t) of eel to Germany (data from Statistiches Bundesamt.**

| | 1995 | 1996 | 1997 |
|---|---|---|---|
| Live | 1,541 | 1,816 | 1,474 |
| Fresh or chilled | 701 | 479 | 418 |
| Frozen | 959 | 1,026 | 882 |
| Smoked | 99 | 117 | 118 |
| Total | 3,330 | 3,438 | 2,892 |

### Sources

The main suppliers of live eel to Germany (Table 2) are Italy, the Netherlands and Denmark, followed by Poland, Sweden and the UK.

In the frozen category imports (Table 3) are high from Denmark, Canada, Australia and New Zealand. Smokers appear to be interested only in the European eel for their quality smoked products. The European eel is considered to be of a much higher quality and achieves much higher prices.

The fresh or chilled category is becoming less significant, decreasing from 21% of imports in 1995 to 15% in 1997 (Table 4). The main suppliers are Denmark, the Netherlands and Sweden.

**Table 2. Main suppliers of live eel (t) to Germany.**

| | 1995 | 1996 | 1997 |
|---|---|---|---|
| Italy | 485 | 494 | 476 |
| Netherlands | 356 | 547 | 491 |
| Denmark | 214 | 287 | 209 |
| Poland | 107 | 56 | 10 |
| Sweden | 90 | 83 | 83 |
| UK | 86 | 66 | 50 |

**Table 3. Imports (t) of frozen eel by Germany.**

| | 1995 | 1996 | 1997 |
|---|---|---|---|
| Denmark | 192 | 144 | 104 |
| Canada | 136 | 65 | 114 |
| Australia | 164 | 193 | 223 |
| New Zealand | 127 | 142 | 124 |
| Netherlands | 53 | 36 | 62 |
| Ireland | 21 | 12 | 5 |
| Poland | 74 | 189 | 45 |
| Estonia | 11 | | 10 |

**Table 4. Imports (t) of fresh or chilled eel by Germany.**

| | 1995 | 1996 | 1997 |
|---|---|---|---|
| Denmark | 351 | 169 | 180 |
| Netherlands | 130 | 95 | 113 |
| Sweden | 84 | 121 | 63 |
| Poland | 85 | 68 | 8 |
| Estonia | 23 | 12 | 30 |

Smoked eel is imported from Denmark, the Netherlands, Greece, from other EU countries and also

from Poland. There are some Irish companies exporting smoked eel to Germany very successfully and it is being very favourably received, but the total quantities would still be very low (Table 5).

**Prices**

Wholesale buying ex-factory price (the prices the German smokers are getting for their products) and wholesale selling price are given in Table 6. The most popular sizes for smoking appear to be 300 g to 700 g liveweight. These sizes appear to achieve the highest prices, slightly less being paid for eel above and below these sizes.

Retail prices are shown in Table 7.

**Main eel products on the German market**

The best-known and most widely available eel product on the German market is whole-smoked eel, available at specialist fish counters and in the more upmarket food sections of department stores and (vacuum-packed) in the more upmarket supermarkets.

Eel for smoking whole have to be at what the Germans refer to as the *Spitzkopf* (sharp-nosed) stage of development as, in addition to the quality of the silver eel, the sharp-pointed head is a characteristic of the appearance of the product. Whole-smoked eel is also available in pieces.

Smoked eel fillets are gaining in popularity especially, as German producers and distributors point out, among younger consumers who would be less aware of the traditional product.

Canned products, such as smoked eel in aspic, eel fillets in dill sauce and, in the Hamburg area, a selection of eel soups are also found on the market. These products, however, tend to be made up from lower grade eel, often not the European species.

Some smokers are reported to be introducing lower grade, lower priced smoked products which are not made from European eel.

*Deutsche See* (leading German fish wholesalers) supply a selection of whole smoked eel products in seven size categories ranging from 175–250 g to over 1,200 g, three *bundaalle* (2 in bunch) from 125 g to 250 g and smoked eel fillets.

**Table 5. Imports (t) of smoked eel by Germany.**

| | 1995 | 1996 | 1997 |
|---|---|---|---|
| Denmark | 51 | 38 | 17 |
| Netherlands | 33 | 66 | 20 |
| Greece | 12 | 10 | 13 |
| Other EU | | 1 | 1 |
| Poland | | | 62 |

**Table 6. Wholesale prices per kg for smoked eel in Germany (£IR converted from DM at exchange rate of 2.52).**

| Weight (g) | Ex-factory price IR£ | Wholesale selling IR£ |
|---|---|---|
| 200 – 400 | 14.30 | 17.90 |
| 400 – 600 | 13.10 | 16.70 |
| 850 – 1,250 | 12.70 | 16.70 |
| Bundaall ( 2 in bunch) | 11.90 | 14.70 |

**Table 7. Retail prices in Germany (£IR converted from DM at exchange rate of 2.52)**

| | | IR£ |
|---|---|---|
| Smoked Baltic eel – vacuum packed | per kg | 31.30 |
| Smoked fillets of Baltic eel | per kg | 53.17 |
| Canned smoked fillets in aspic | 110 g can | 3.60 |
| Canned fillets in dill | 110 g can | 3.60 |

At the moment Deutsche See find that sales are approximately 80% larger eel and 20% smaller, sold in bunches of two tied together. The smaller eel can be used as raw material for smoked eel fillets.

**Types of companies producing, selling and distributing smoked eel in Germany**

These may be divided into four categories

(1) Companies such as Deutsche See/Nordsee group, who have complete vertical integration. They produce products themselves, in addition to buying in products. They are by far the largest wholesalers in Germany, with 30 depots throughout the country, supplying to retail chains and outlets and restaurants and catering establishments. They also have their associated chain of fish shops and restaurants.

(2) Specialist producers with national and international distribution, the best known being Gottfried Friedrichs in Hamburg. In spite of their size, Friedrichs seem to succeed in maintaining the traditional image of an upmarket, handcrafted product.

(3) The more localised speciality producers (and smoked eel still tends to be a speciality product associated with special areas in Germany and not subject to the huge pressure on price that can be a feature of the German market). These companies smoke eel as a speciality of their area, sell the products in their own retail outlets or restaurants and supply other outlets, sometimes only in their own area, in some cases over a wide area. Examples of these companies, who produce on average between 300 and 400 t of smoked eel annually, would be Fiedler in Bremerhaven and Bruns in Bad Zwischenahn. Bruns have also built up a very successful mail-order business and supply customers throughout Germany by mail.

(4) Smaller wholesalers who smoke eel themselves for their own customers, in addition sometimes buying in smoked eel.

**Raw material specifications of German smokers**

The table below outlines *Deutsche See's* raw material requirements for their 'DS Gold' smoked eel products:

| Sizes 600–850 g and 850–1,200 g | | Sizes 200–400 g and 400–600 g |
|---|---|---|
| May–October/November | December–April | |
| Live wild *Anguilla anguilla* Spitzkopf (sharp nosed) Baltic eel, Blankaale (silver eel) | Frozen Baltic silver eel, quality as above *or* Live farmed eel (available all year round, which are comparable in quality to Baltic silver eel | Live farmed eel Spitzkopf *Anguilla anguilla* which are comparable to Baltic silver eel |
| | fat content about 20% | |

Apparently *Deutsche See* are able to obtain farmed eel in the larger sizes. One of the methods used by suppliers is to take wild eel between 120 and 150 g and raise them in farms to the larger sizes.

*Deutsche See* smoked eel provided the following chemical and physical analysis:

| | |
|---|---|
| Aqueous salt | 3.5–4.1% |
| Salt | 1.8–1.9% |
| Fat | Minimum 20%, optimum 27.6–36.4% |
| Moisture | |
| Benzo(*a*)pyrene | Adherence to legal requirements |
| Other foreign substances | Adherence to company's internal guidelines |

**Conclusion**

Opportunities exist, for instance, to test-market possible new products at in-house trade fairs held by German wholesalers.

# BIM AQUACULTURE GRANT SCHEMES

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This paper introduces the people that work in the Aquaculture Development Division of Bord Iascaigh Mhara, BIM, the objectives of BIM's Aquaculture Development Division, and the enabling grant schemes that facilitate the development activity of the Division. The paper will conclude with a look at what has been achieved in Irish aquaculture to date in terms of volume of production, value and employment. As I go through the presentation I will show how eel fit into this activity.

**The Aquaculture Development Division**

The Aquaculture Development Division was set up in 1989, bringing together all the functions in BIM related to aquaculture, apart from trade. Up until then the functions had been scattered among various divisions.

Currently the Division comprises three sections:

The Aquaculture Technical Section
The Environmental/Quality Section
The Projects Section

There are twenty-three people in total employed in the Aquaculture Development Division; however, this number is subject to seasonal fluctuation especially in the summer time when additional staff are taken on in head office and on the coast for specific project work.

Officers of the Aquaculture Technical Section provide specialist advice and practical assistance in the following areas:

Developing and evaluating new methods of growing fish and shellfish species and conducting trials for cultivation in new areas.
Technology transfer from abroad and within Ireland.
Carrying out environmental impact studies.
Carrying out feasibility studies.

Section Officers also produce technical advisory manuals, organise industry workshops and seminars, and represent BIM on industry organisations and discussion groups.

The objectives of the Environmental and Quality Section are to:

Promote environmental awareness within all sectors of aquaculture through provision of guidelines, codes of practice, workshops and direct advice on identifying suitable sites for aquaculture.

Establish links between the aquaculture industry, conservation groups, local authorities and government bodies on environmental issues.

Devise and promote measures to deal with external environmental factors which may affect the production of quality farmed finfish and shellfish.

In summary, the primary mission statement for the Aquaculture Development Division is to encourage, assist and facilitate the expansion of the Irish aquaculture industry in terms of volume, value and employment, and to ensure that such expansion is sustainable in terms of environmental impact, economic viability and species diversification.

*Financial assistance*

Financial assistance for projects is provided by the Aquaculture Grant Scheme which is the main instrument of BIM's policy for the industry. Since 1994, projects have been funded under the Operational Programme for Fisheries 1994–1999. £11m in grant aid was made available for aquaculture development under the Aquaculture Measure of the Operational Programme.

There are two grant types offered by BIM depend-

ing on the level of investment involved: commercial and pilot grants. Commercial grant aid applies to projects with a total investment of upwards of £40,000. Pilot projects are those of less than £40,000 investment, and are grant aided at a rate of 40%. Pilot projects do not qualify for EU aid. Under the commercial grant scheme, BIM provides grant aid to aquaculture projects at a rate of 5%. Projects concerned with the development of novel species, including eel, or with the introduction of new techniques may get an additional 5% giving a total BIM grant of 10%. A bridging grant of 20% recoverable from EU grants may also be payable.

EU grants to aquaculture projects are available at a rate of 35% of eligible costs for all projects. The combined BIM and EU grant aid will therefore vary from 40% to 45% of total eligible investment expenditure depending on the nature of the project.

**Financial assistance for eel culture**

There are a number of specific areas where BIM can assist with grant aid and technical support for eel culture. In the first instance BIM can assist feasibility studies. Feasibility studies can involve a variety of aspects including production, marketing and business planning. First and foremost a farm must have a site, and the site must have access to adequate quantities of water. Grant aid can be given for retention of a consultant hydrogeologist, sinking of a borehole and assessment of the quality of the water. Grant funding will also be considered for investigation of technology including retention of consultants and investigative trips to see and assess technologies currently in use on farms usually in Europe. A feasibility study might include all of the above-mentioned items plus a market investigation. In all events the terms of reference of a feasibility study should include a realistic business assessment of the viability of the project taking account of current technologies and a view of the market.

BIM can consider funding of elver collection for the eel farm subject to licences being in place. Elver collection licences are granted by the Department of the Marine and Natural Resources in consultation with the Regional Fisheries Board in whose area the permission is requested. BIM has in the past grant aided the investigation of suitable sites for fishing elver, purchase of equipment including elver traps and holding facilities. BIM has also supported the purchase of a trailer and the design and building of holding tanks for the trailer for the transport of elver. Travel and subsistence associated with elver catching trips are also eligible for funding in a feasibility study.

Once the feasibility study is complete and indications relating to the business proposition are positive, application can be made to BIM for setting up a commercial grow-out unit. In this situation eligible expenditure includes investment in new fixed assets excluding site costs. In this case BIM requires that a business plan is submitted.

The business plan should include a lot of detail on the proposed venture including:

(1) names of the principals, address of promoting firm, history, details of shareholders, names and addresses of directors

(2) the products/species to be farmed and the proposed technology

(3) the expected annual output and the revenue for each year of production

(4) the location of the farm including a map delimiting the area involved and indicating the size of the area in square metres

(5) copies of the licences, permissions and permits which have been received from regulatory and other authorities

(6) a list of all items indicating their capacities and specifying costs, and a timescale for the project.

(7) where juveniles are to be sourced.

Capital expenditure will need to be itemised and supporting estimates of costs supplied including:

(8) a detailed explanation on the finance to be raised, the share capital, grant aid sought and borrowings

(9) cash-flow statements including projected cash flows and balance sheets

(10) the management and technical control of

the venture including qualifications and experience of key personnel on the farm and

(11) the proposed marketing arrangements.

After approval for funding a formal letter of offer is issued with conditions under which the offer is made. If the offer is accepted a formal agreement is entered into between BIM and the applicant. Payments are made following on-site inspection and submission of certified accounts with a tax clearance certificate.

**Aquaculture output, value and employment**

In 1996, 2,800 people were engaged in aquaculture comprising an estimated 749 in finfish production and 2,051 in shellfish production on a full- or part-time basis. Jobs that aquaculture provides have certain added value because of their location in potentially low employment rural and coastal areas. Frequently aquaculture provides new or alternative jobs for those previously employed in the agriculture and fisheries sectors.

Irish aquaculture production has increased significantly from 18,327 t in 1988 to an estimated 34,930 t during 1996, an increase of 90%. The total value of aquaculture output increased from £15.2 m in 1988 to £55m in 1996, an increase of 260%. It is important to stress that the annual values given here hide the substantial price fluctuations that occur on a day to day or week to week basis. Irish industry representative agencies and bodies have had to make major efforts to sustain price levels. Price fluctuation is also a difficulty in eel culture, in elver supply and in end-product value.

From the comparative table below, it is clear that the unit value of shellfish has more than doubled in the period 1988 to 1996. This can be attributed to the fact that in 1988 shellfish production comprised mostly mussels. There are now higher value species within the product mix, and also the value of mussels has increased.

**Comparative values per t**

| | 1998 | 1996 |
|---|---|---|
| Finfish | £2,351 | £2,816 |
| Shellfish | £ 242 | £ 536 |

The 1996 value of salmon was 20% up on the 1988 values. Having said that, however, salmon prices are subject to price fluctuations as a result of the impact of supply on demand on the day. It is clear that both aquaculture production and value are increasing; however, the unit value is increasing at a greater rate than production output. This is attributed to a number of factors including the influence of increased salmon production and value of salmon which is more than five times the unit value of shellfish. An increased tonnage of shellfish, which includes shellfish species which are more valuable than mussels (scallops, oysters), and the increasing value of mussels have also contributed to the increasing value of aquaculture output over this time period.

The Operational Programme has one year further to run to the end of 1999. It will be replaced by a new Community Structural Fund, agreed within the framework for Ireland and the Commission post 2000. It is likely that the overall funding will be reduced. However, there will be a continuance of funding for aquaculture for the period 2000–2006.

# THE MANAGEMENT OF EEL IN IRELAND
## A Central Fisheries Board Policy Document

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### Introduction

The eel, *Anguilla anguilla* (L.), is an indigenous Irish species continuously recolonising freshwater habitats from its marine breeding area. It is widely distributed throughout the country and in many rivers, lakes and coastal areas it is the dominant fish species.

Archaeological evidence indicates a long history of eel capture by man in Ireland using eel spears and ancient fishing weirs. References to eel fishing abound in historical manuscripts, property titles and early natural history texts.

Eel are currently exploited using fyke-nets, long-lines and trap nets and these eel have a very high commercial value, often reaching higher prices per kg than wild salmon. Although eel are growing in importance as a commercial species there is lack of an explicit policy on eel management in Ireland. The criteria used for authorisation of eel fishing licences are unclear and sometimes inconsistent. This paper sets out to examine the present exploitation pattern and future potential of eel fishing in Ireland. The paper sets out Central Fisheries Board policy in relation to eel and also looks at the overall regulation and management of eel in Ireland and makes recommendations for the future management and development of the species.

### The Irish eel fishery

Irish freshwater eel are born in the Sargasso Sea and take one year or more to cross the Atlantic Ocean to reach the coast of Europe. At this stage they measure about 6 cm in length and are called glass eel. In spring they swim into rivers and travel upstream mostly at night and are called elvers. They grow slowly, increasing in length by 2 or 3 cm each year. Eel do not breed in freshwater but remain there for at least eight years while some remain for more than twenty. The eel while feeding and growing are known as "yellow eel". Prior to migration, eel takes on a silvery appearance and are called "silver eel". Silver eel migrate downstream in the autumn and swim across the Atlantic to the Sargasso Sea to spawn and die. The seaward migration takes place only once in the eel's life time and there is no evidence to suggest that young eel return to the river or even country from which their parents migrated.

There has been a significant decline in the numbers of glass eel arriving at the Atlantic coast of Europe over the last 15–20 years and it is not known whether this is a cyclical phenomenon or a general decline in stocks. An agreed report by experts from 10 EU Nations (Moriarty, 1996) states that many eel fisheries have declined in the course of the previous twenty years, the principal factors appearing to be recruitment failure and inadequate management measures. Notwithstanding the reduced numbers of glass eel present, the bulletin concludes that adequate glass eel exist for a greatly enhanced stocking programme.

The commercial fishery involves harvesting both yellow and silver eel. Yellow eel are fished for in lakes using fyke-nets or long-lines. Fyke-net fishing is the more commonly used method and involves using a wall of netting, about 5 m long, with a trap net at each end. Fyke-net fishing is practised extensively on Lough Corrib and Lough Derg and many smaller lakes. Long-lines consist of a fishing line about 2 km in length with a thousand hooks attached at intervals of 2 m. The hooks are baited daily with an earthworm or a small fish. When silver eel are migrating in the autumn they are caught in stocking-shaped nets called "coghill nets" which are attached to posts set in the river bed.

The current commercial eel catch in the Irish Republic is about 250 t involving about 150–200 part-time fishermen. About 800 t are caught on Lough Neagh where a large-scale elver re-stocking programme has been underway for over forty years. This fishery provides employment for some 400 people and 100 more in handling and processing. The catch of eel per hectare in L. Neagh is 18 kg compared to an average of 3 kg/ha in the Shannon and Erne lakes.

Eel are a highly valued and sought after species attracting around £3,000 to £5,000 per t at first sale. There is considerable potential for development of the eel fishery and the introduction of a comprehensive elver stocking programme in selected systems would significantly increase the catch and lead to the creation of both direct and indirect jobs in catching, processing and exporting eel. Research has shown that, if fully managed, the annual production in the Irish Republic could be increased to 1,000 t, with a value of £5 million and with potential for a processing industry bringing the total value to £20 million. There is an angling fishery for eel, largely confined to tourist anglers, which is believed to be growing in importance. Because of their high commercial value there is a large illegal fishery for eel concentrated mainly in the mid-Shannon and Erne fisheries.

**Exploitation of eel on a regional basis**

**Eastern Region**

*Extent of the fishery*

The largest fishery is the fyke-net fishery in the Slaney Estuary where about twenty fishermen catch approximately 10 t of eel annually. The tidal portion of the Boyne has been fished regularly in recent years and has recorded reasonable catches. Eel fishing takes place on Lough Ramor and the river Blackwater with a catch of some 7 t. The small lakes on the Glyde and Dee systems are fished with long-lines and fyke-nets and yield about 5 t of eel annually. The estuaries of the Liffey, the Broadmeadow and the Broad Lough are fished regularly for eel and the ESB contract fishermen to fish on the River Liffey.

*Present problems*

Eel fishermen on the river Liffey have been fishing in breach of their authorisations in recent years as they have been fishing in private fisheries. They do not report catches to the Eastern Regional Fisheries Board and considerable resources are employed to monitor their activity.

*Potential for development*

There is potential for development of estuarine eel fishing, particularly in the Slaney, Broadmeadow and Boyne estuaries and in Carlingford Lough.

**Southern Region**

*Extent of the fishery*

There are two significant eel fisheries in the Barrow/Nore/Suir catchment, the River Barrow silver eel fishery and the baited eel pot fishery in Waterford Harbour. Small numbers of fyke-nets are also fished on the Suir estuary. Little eel fishing has taken place on the River Blackwater in recent years. The total catch in the Region is estimated at 15 t.

*Present Problems*

There is currently no legislation to control the use of baited eel pots or fyke-nets in estuaries. In the Southern Region there is reason to doubt the validity of the eel pot licences issued. The extent of a Regional Board's power to refuse licences for novel and potentially damaging eel fishing methods in brackish or salt water is unclear.

*Potential for development*

In recent years the potential for development of the existing eel fishery has been hampered by a number of factors. There has been a marked reduction in the elver run in the Region and the stocks of both yellow and silver eel are reported to be significantly reduced. The average size of eel taken in the Waterford Harbour fishery is reported to be reduced in recent years.

A number of factors have contributed to an increased fishing effort on a reduced eel resource. These include an increased uptake of licences for

baited eel pots in Waterford Harbour in anticipation of compensation for closure of the sprat weirs and a significant increase in the number of eel pots used as a result of a new market for green crabs, (which are taken as a by-catch in the eel pots). Taking cognisance of these developments and having consulted with eel fishermen in the region, the Southern Regional Fisheries Board has drawn up and agreed a set of proposals for the rational management and development of the eel fishery in the Region which is summarised below:

- Eel pots to be defined as "scheduled engines" under the Fisheries Acts and a licence introduced for a maximum of 20 pots.
- Only 30 eel pot licences to be issued in the Waterford Fishery District.
- A close season from 1 Dec to 15 June to be introduced for eel pots in the Barrow/Nore/Suir estuaries.
- The number of fyke-net licences issued in Waterford estuary not to exceed the number (9) issued in 1996.
- A close season for fyke-nets and sprat weirs to be introduced.
- A minimum size limit for eel sale of 30 cm.
- A prohibition on the use of long-lines in the Region.
- An improved method of catch reporting to be introduced.
- Carry-out an eel population survey in the large river catchments in the Region to guide future development of the eel fishery.

**Southwestern Region**

*Extent of the fishery*

There is little history of eel fishing in the Region and over the last ten years the maximum number of eel fishing licences taken out did not exceed six. One licence is issued to fish the river Lee upstream of the reservoirs and catches have indicated moderate stocks.

*Present problems*

No problems exist at present as little eel fishing takes place. The Board policy is to prohibit long-line fishing, develop an elver fishery for transfer to other Regions and to develop an estuarine eel fishery.

*Potential for development*

Potential for the development of a viable eel fishery is limited due to the relatively slow growth rate caused by the predominantly acidic waters in the region. The rivers Lee and Bandon may have some potential to support a viable fishery. There is also some potential for the development of a fyke-net fishery on the Lee reservoirs. No other lakes or rivers in the Southwestern Region have potential for serious development as commercial eel fisheries. There is potential for the development of an eel fishery in estuaries (greater than 1,200 m in width).

The main potential for the eel fishery in the Region is the development of an elver fishery for the purpose of transferring elvers to more productive waters in other Fisheries Regions, having stocked out an adequate number in commercially important eel fisheries within the Region. This approach would maximise the benefit to the region and to the eel resource nationally.

**Shannon Region**

*Extent of the fishery*

The largest eel fishery in the State is operated by the Electricity Supply Board on the River Shannon. Three forms of fishing take place, for glass eel and elvers in the estuary and lower river, for silver eel on the River Shannon at Athlone and below Lough Derg and for yellow eel by fyke-net on Lough Derg and lakes upstream. The silver eel fishery takes approximately 35 t of silver eel annually. The ESB is issued with fyke-net licences by the Shannon Regional Fisheries Board, who in turn issue permits to private individuals to use these nets on their behalf. About forty 2-man crews operating 50 fyke-nets each are contracted to sell their estimated catch of 55 t to the ESB. The permits issued to these fishermen contain a number of conditions.

In recent years fyke-netting has expanded throughout the Shannon Region and ESB surveys

show that there is greater potential for expansion of this fishery. In the Shannon Region eel fishing also takes place on the Rivers Feale and Maigue and in Co. Clare rivers and lakes.

*Present problems*
The Shannon eel fishery is considerably underdeveloped at present while a large illegal eel fishery did exist, particularly on the midland lakes. In the last number of years considerable resources, including Garda involvement, have been put into trying to curtail the large-scale illegal eel fishing activity, particularly in the Mullingar area. This effort has met with some success but illegal fishing still takes place. The ESB has begun to licence fyke-net fishermen to fish on the midland lakes but regulation of the illegal fishery is hampered by lack of staff and resources.

Considerable improvement is required at the Shannon silver eel weirs to increase overall catch efficiency.

*Potential for development*
Moriarty (1984) estimated that the largest lakes on the Shannon system should be capable of giving a combined yield of at least 590 t of eel per annum based on an elver stocking rate of 350/ha. Despite this stocking requirement being reached on a number of occasions the annual yield never exceeded 76 t Moriarty (1990b), commenting on the very low yield from the Shannon in comparison to Lough Neagh, suggested that the difference between the two fisheries appears to depend entirely on fishing effort and concluded that the Shannon lakes contain a stock which cannot be fully exploited by the low intensity fishing effort.

Recently the ESB has carried out a major study of eel stocks on the Shannon catchment (McCarthy *et al.*, 1994a). This research has demonstrated that, while there is a commercial stock of adult eel in the Shannon, there is serious concern at the low level of elvers entering the system. The ESB has initiated a glass eel and elver stocking programme aimed at improving catching methods and survival rates, (Reynolds *et al.*, 1994).

The Shannon Board has drawn up recommendations to conserve, improve and commercially exploit, in a sustainable manner, eel in the Region. With regard to glass eel and elvers, the Board recommends estuary trapping and transfer of elvers in a number of small river catchments. Initially 50% of the elvers caught would be transferred upstream within their home river while the remaining 50% would be transferred to the main Shannon. Each river system will have an *optimum escapement number* of elvers agreed, which shall be transferred upstream before movement outside the catchment can be undertaken. This *optimum escapement number* will be based on the nationally recognised number of elvers necessary per hectare of catchment. Thereafter elvers will be transferred to the ESB up to a maximum of 4 t annually.

The Board is supportive of the ESB policy of issuing permits with conditions to fyke-net fishermen on the Shannon lakes. However the Board would favour an opportunity to comment on the suitability of prospective netsmen. With regard to silver eel fishing with coghill nets and weirs, the Board recommends that only traditional operators should be licensed until a comprehensive survey of eel stocks is carried out in non-ESB controlled waters. No authorisation is required for fyke-net fishing in estuaries and the Board recommends no new licences be issued pending completion of a stock survey.

As is the case in other regions no authorisation is required for long-line eel fishing. The Shannon Board strongly recommends a change in the legislation to enable conditions to be placed on a licence. It also recommends that the number of long-line licences should be capped at present levels (8) and be confined to the East Clare area pending the outcome of an eel stock survey. The Board supports the regime of a close season for eel and makes recommendations for close seasons for each fishing method. The Board also recommends a tightening up of the eel licence application process and recommends that fishermen should be required to maintain a catch register.

**Western Region**

*Extent of the fishery*
A considerable amount of eel fishing takes place, primarily on the Corrib catchment. Approximately twenty fyke-net fishermen operate on Lough Corrib while a small number of long-line fishermen fish Lough Corrib and Lough Mask. The yel-

low eel catch in the catchment is about 20 t. A silver eel fishery operates downstream of Lough Mask and the Central Fisheries Board also operates a silver eel fishery below Lough Corrib. This latter fishery takes an average of 10 t of silver eel annually. However, catches in recent years have been poor, dropping to as low as 4 t.

*Present problems*

Traditionally only a small number of long-line eel fishermen have applied for an authorisation to fish the Corrib system. However, since the recent judgement in the case of Hughes and Stewart versus the Northwestern Board there has been a large increase in licence applications. Fourteen applications for long-lines licences were made in 1997 compared to five in 1995 and the situation with regard to eel exploitation has become serious. Only two of the fourteen applicants are traditional long-line fishermen over a long period in the Western Region.

Intensive long-line fishing for eel took place on Lough Carra, at the head of the Corrib System in May 1997. No long-line fishing had been permitted on Lough Carra for the previous ten years by the Western Board in order to conserve stocks. As many as seven long-line boats intensively fished Lough Mask together from June to October 1997 and a considerable stock of eel was taken. No information is forwarded by these long-line operators to the Regional Board regarding catches, numbers or length of long-lines used. With the life cycle of the eel being eight to twelve years, this level of exploitation is not sustainable and the livelihood of traditional eel fishermen is seriously threatened.

In September 1997, long-line fishermen moved to Lough Corrib and began to fish intensively. It is likely that by the end of the year, very large numbers of eel were removed from Lough Corrib, seriously impacting on the numbers of yellow eel available to traditional fyke-net fishermen over the next five to seven years. Such intensive fishing will also seriously impact on the Central Fisheries Board silver eel fishery in Galway for the foreseeable future. This fishery has been an important source of revenue and catches in recent years have been particularly poor.

The decision by the Minister for the Marine and Natural Resources to introduce a by-law capping the number of long-line licences available in April 1998 was a very important measure in protecting eel stocks, particularly in the Corrib Catchment, and should result in a more rational exploitation of eel stocks on a sustainable basis.

*Potential for development*

Moriarty (1990a) undertook a survey of eel stocks in Lough Corrib to assess stock status since an earlier survey over the 1967–1969 period. Results revealed that a serious reduction in eel stocks had taken place in the south basin. This stock reduction has been reflected in the silver eel catch at the Galway Fishery which has been reduced by half since 1990.

Elver recruitment into the Corrib system has been very poor over the past decade and numbers have been too low to warrant effort at capture and transportation upstream. Concurrent with a reduced stock and a reduced elver run, and with no close season for yellow eel, there has been a sustained fishing effort, particularly in the lower basin.

The recent heavy exploitation by long-line fishermen has further impacted on the stock. Although the recent cap on the number of long-line licences available will help minimise further excessive exploitation of eel stocks, there is little potential for expansion and development of the Corrib Catchment eel fishery at present .

The Western Regional Fisheries Board has launched a comprehensive management strategy for the eel fishery in the Corrib system. As part of this plan, it is proposed to engage eel fishermen to undertake an eel survey to assess the status of stocks. A long-term management strategy will be drawn up based on the findings of the research survey.

**Northwestern Region**

*Extent of the fishery*

Limited eel fishing has taken place in the Region up to 1997. As a conservation measure, the Board had restricted the issue of long-line eel fishing licences to fishermen who held licences in 1994 and formally adopted this policy in 1995. The Board

has pursued a policy of restricting the issue of eel licences and only twelve long-line authorisations were issued in 1995 taking an estimated catch of 10 t.

*Present problems*
In September 1996 the Board successfully prosecuted two long-line eel fishermen for long-line eel fishing without an authorisation. The defendants appealed the conviction in March 1997 and were successful. After this judgement the Board had no option but to issue long-line eel fishing licences on request. However, the by-law introduced in April 1998, capping the number of long-line eel licences available, has resolved this issue.

**Northern Region**

*Extent of the fishery*
The major eel fishery in the Region is the long-line eel fishery on Lough Erne. In 1997, 26 long-lines were authorised north of the Border with a further 30 long-lines and 5 fyke-nets issued south of the Border. An estimated catch of 30–35 t of yellow eel is taken each year. An average of 10–15 t of silver eel are captured each year, the majority being taken at three coghill net fisheries operating at Belleek–Ballyshannon near the base of the Erne system. Glass eel and elvers are currently trapped at the ESB generation station at Cathaleen's Fall in Ballyshannon and transported overland by DANI for stocking out upstream.

*Present problems*
Development of the eel fishery on the Erne system has been somewhat hampered in the past due to the cross-border location of the fishery. Following the initiation of the Erne Eel Enhancement Programme in 1997 (funded under the cross-border Peace & Reconciliation Measure) it is hoped that a co-ordinated catchment management plan for the entire Erne system will be developed which will enable the full potential of the fishery to be realised.

As is the case on the midland lakes, a considerable illegal fishery operates on the Erne system. To date the eel fishery south of the border remains very underdeveloped with little or no regulated fishing taking place on the upper catchment. The vast majority of licence holders reside outside the Erne catchment. The number of silver eel weirs in the Cavan–Monaghan area has dropped from 11 to 4 reflecting the generally poor condition of this sector of the fishery.

Catches of silver eel from the larger-scale operations in the lower Erne are greatly influenced by the generation regime at the ESB generation stations at Cliff and Cathaleen's Fall. Little scientific data is available for age, sex ratio and final escapement of silver eel from the Erne system.

*Potential for development*
To achieve eel production of the Erne lakes similar to Lough Neagh with consequent employment creation of 150 people initially, an Erne Catchment Eel Fishery Development Project was drawn up in 1997. This is a co-operative North/South project aimed at undertaking research which will lead to the formulation of a management plan for the development of the fishery. The project estimates that if elver stocking were undertaken on a similar scale to Lough Neagh and productivity was similar, then the potential eel catch from the Erne lakes would be 726 t per annum requiring an annual stocking of 4.2 t of elvers. A research programme is underway covering areas such as glass eel and elver recruitment studies, yellow eel fyke-net surveys, monitoring of the existing long-line fishery and the silver eel fishery. A feasibility study on the provision of an eel smoking facility for the system is also to be undertaken.

The NRFB is currently investigating the potential for increased capture of glass eel in the Erne estuary to maximise recruitment to the Erne fishery. Only Board staff are involved in this aspect of the

*Potential for development*

There is potential for development of eel fishing on Lough Conn and a number of other lakes in the Region. The Northwestern Board favours the development of fyke-net fishing on conservation and management grounds and favours the introduction of a close season for brown and silver eel.

There is potential for development of an elver capture and stocking programme on the Moy, Ballisadare, and Owenmore rivers. The Board recommends no harvesting of elvers until a scientific assessment of stocks has been carried out.

programme. The NRFB is strongly of the opinion that any future exploitation of glass eel should be carried out by Board staff only as the high prices commanded by glass eel currently would likely lead to a significant illegal fishery should capture technologies become available to individual or commercial enterprises.

**Summary: present problems in the eel fishery**

A number of problems are common throughout all Regions with regard to the present operation of the eel fishery:

(1) A lack of sound scientific information on stock means that a planned and regulated expansion of the fishery cannot take place. Under-reporting of catches also hampers the development of sound management strategies.

(2) The recent judgement allowing long-line fishing to take place without the need for an authorisation is not conducive to sound management and regulation.

(3) Long-line fishermen are no longer subject to conditions in their licence. The Minister may amend or revoke an authorisation if a holder is convicted of an offence or has breached any of the conditions of the authorisation. It will now be difficult to convict a long-line fisherman of an offence as no conditions apply.

(4) Few Fishery Districts have a close season, mitigating against development of a sustainable annual eel harvest.

(5) On the major lake systems, large-scale illegal fishing takes place and there is lack of staff and resources to adequately control this illegal activity.

(6) There is no legislation regulating estuarine eel fishing, a fishery seen as having considerable potential.

(7) The absence of a national eel dealers licensing scheme leads to duplication and/or lack of consistency throughout each Region in which a dealer operates. Also the 1994 legislation does not specify the place where an eel dealer must operate.

(8) Another problem pertinent to the eel fishery is that licences are issued to applicants who reside outside the Fishery Board's jurisdiction in which they operate making regulation and management difficult.

(9) No legal size limit applies for the sale of eel leading to the potential for over-exploitation of juvenile stocks.

(10) There is a very high demand for elvers/glass eel and although a Section 14 Authorisation is required for the capture of elvers/glass eel, there is no national policy on the development of this fishery.

**Potential for development of the eel fishery nationally**

Recent studies by BIM the FRC, Forbairt and the ESB has all concluded that there is considerable potential for the development of the eel fishery in Ireland. This potential for increased yield will only be realised if the fishery is properly managed at both local and national level.

There is little potential for development of a freshwater eel fishery in the rivers in the Eastern, Southern and Southwestern Regions. There is some potential, however, for the development of an estuarine yellow eel fishery. There is also great potential for a glass eel/elver capture programme, particularly in the Southwestern Region, for transfer to more productive waters in other regions. Moriarty (1984) has indicated that at a stocking rate of 350 elvers/ha, a potential eel yield of 20 kg/ha could be attained compared to current yields of 2–3 kg/ha.

The majority of productive waters, from an eel fishery point of view, and consequently the waters with greatest potential for the development of an eel fishery are in four major catchments, i.e. the Shannon, Erne, Corrib and Moy. These are the catchments which should be targeted initially in which to introduce a proper management system for the development of a regulated and expanded eel fishery.

The great majority of the Irish eel catch is exported live to Continental Europe and only a small

amount of eel are smoked before export. There is potential for the development of a processing industry in Ireland, particularly if the annual yield can be increased.

**Collective view of Regional Boards**

There is general agreement among all Regional Fisheries Boards that the potential that exists for development of the fishery cannot be realised under the present management system. Proper control on the number and type of licences issued is the first step in developing a future management strategy. Stock assessment is required in order to set catch targets and guide an elver stocking programme. Additional resources are required to protect stocks from over-exploitation from illegal fishing. There is also agreement that many of our river systems in the South and Southwest have little potential and elver trapping and stocking into more productive lake catchments is desirable. A yellow eel fishery should also be developed in a number of large estuaries countrywide.

**Central Fisheries Board eel policy**

The Board believes that proper management and regulation of the Irish eel fishery can lead to increased employment and revenue generation. The yield per hectare in Irish lakes is six times less than that attained in L. Neagh and there is no reason why comparable yields cannot be achieved through adequate management initiatives. The fishery must be developed on a sustainable basis. In this regard the first requirement is to establish management on a catchment basis and then to assess the status of stocks in our major catchments. Following survey recommendations, a *Total Allowable Catch* should be set for each catchment to be divided among all fishermen in the catchment.

The number and type of appropriate eel fishing licences should then be set on a catchment basis, having regard to the exploitable stock available in each catchment. An increased protection effort will be required to enable development of the fishery on a regulated and sustainable basis. Moriarty (unpublished) has pointed out that for conservation reasons, all catchments below an agreed productivity level should be designated as eel sanctuary areas to produce breeding adults. As the great majority of eel caught are exported live, there is considerable potential for the development of a processing industry.

Survey results should determine the level of elver stocking required in each catchment which should have an *optimum recruitment number* of elvers agreed for transfer upstream before movement outside the catchment can be undertaken. This *optimum recruitment number* should be based on a nationally recognised number of elvers necessary per hectare of catchment. The policy is summarised below.

**Survey major catchments**

↓

**Determine eel stock levels**

↓

**Extrapolate for smaller catchments**

↓

**Determine exploitation level per catchment (Total Allowable Catch)**

↓

**Determine number and type of fishing licences**

↓

**Determine elver stocking rate per catchment**

↓

**Increase protection effort to regulate the fishery**

↓

**Designate catchments as sanctuary areas**

↓

**Develop an eel processing industry**

It will not be necessary to survey all catchments in order to implement the strategy outlined above. Currently much information is available or being collected on the Shannon, Erne and Corrib catchments and it will be possible following minor surveys to extrapolate data for other catchments. It is recommended that licences should be restricted to numbers issued in recent years until the TAC per catchment, the number of licences per catchment, elver stocking rates, etc. can be worked out. On-

going regular monitoring will be required to ensure that over-fishing or other factors which could effect eel stocks are not operating. For proper implementation, it will be necessary to fully cost the programme outlined above.

**The management of juvenile eel stocks**

Elver runs have been declining since the early 1980s throughout Europe. There is some indication of improved runs in the last two years but runs are still low in comparison to previous decades. Catches of yellow and silver eel have also been low in recent years and as a result there has been a growing interest in enhancement of eel stocks by capture of elvers and movement to headwaters. The introduction of commercial eel farming has also raised the question of capture and sale of elvers. Elvers in 1997 sold at £150,000/t, but considerable reduction in price has taken place since..

A feasibility study on elver management (McCarthy *et al.*, 1994b) was carried out for Forbairt to assess elver stocks and the prospects for a management programme to enhance the eel stock. This report recommended transfer of elvers from unproductive to productive catchments. Strategies for eel stock enhancement have been extensively studied by McCarthy *et al.* (1996). This study reviews and evaluates options which could be employed for eel stock enhancement as follows:

(1) Facilitating natural upstream movement, e.g. elver passes, opening sluices at appropriate times, removal of obstacles.

(2) Upstream overland transport of glass eel/elvers captured in estuaries/river mouths.

(3) Overland transport between unexploited and fished river systems, of glass eel/elvers.

(4) Importation of wild caught glass eel/elvers for stocking.

(5) Ongrowing native or imported glass eel/elvers in extensive culture systems.

(6) Ongrowing native or imported glass eel/elvers in quarantine/intensive culture systems.

(7) Control of environmental conditions to minimise natural mortality: predatory birds, trophic conditions, pollution, disease.

The report concludes that because of increased knowledge of glass eel/elver harvesting techniques, development of large-scale glass eel/elver fisheries is a possibility, for both direct stocking to lakes/ rivers as well as supplying stock to ongrowing facilities. As the majority of productive waters, from an eel fishery point of view, are in four major catchments, it will be essential that larger river systems be targeted for glass eel and elver stocking. As most eel fishing in the larger river systems (Slaney, Suir, Barrow, Nore, Blackwater) is in estuaries, these systems could be fished for glass eel/elvers upstream of yellow eel fisheries without affecting the current level of fishing.

The Board recommends that for a five year period the capture and distribution of elvers, as outlined by McCarthy *et al.* (1996), should ideally be undertaken by Regional Fisheries Boards. It is acknowledged, however, that there has been a history of private individuals involved in elver harvesting and provision for continuation of these traditional operators under Regional Board supervision will have to be included. The Boards would draw up a stocking policy on a catchment basis following completion of stock surveys. It has been estimated by Moriarty (1998) that 13 t of elvers per annum would be required. Arrangements would also have to be made to supply a proportion of elvers to commercial eel farms.

**Eel fishing in estuaries**

Research indicates that the great majority of eel do not ascend freshwater but remain in estuaries. Some fishing already takes place in Waterford Harbour and in the Slaney estuary but there is potential for the development of this fishery. This fishery will not impact on the freshwater eel fishery. Fyke-nets or baited pots are the suggested fishing method as long-lines may impact on other fish stocks.

**Eel farming**

Due to the high commercial value of eel, eel farms have been set up throughout Europe and the Far East in recent years. As it is not possible to breed eel in captivity, elvers have to be captured for on-rearing in these farms. Due to growing interest, BIM commissioned a manual in their *Aquaculture explained* series entitled "Eel farming in re-circulation systems" (Warrer-Hansen, 1997. The first commercial eel farm was set up in Ireland in 1996 and currently produces 40–60 t of eel annually. The CFB provided elvers captured at the Erriff Fishery for on-rearing at the facility and a proportion of these grown-on eel were stocked out into the Corrib catchment. The future policy of harvesting elvers for supply to such commercial rearing facilities will have to be considered in the overall context of elver stock management.

**Views of other bodies consulted**

In the course of preparing this policy paper, the views of the Marine Institute, the Electricity Supply Board, the Salmon Research Agency and An Board Iascaigh Mhara were sought.

*The Marine Institute* has a very similar view to that outlined in this paper with regard to the future management of the Irish eel fishery. They were involved in the consultation process leading to the preparation of the paper and made constructive suggestions which were incorporated into this draft. Their main concern related to the possible introduction of a close season. They believe that this would be a very expensive measure to enforce and would still likely be only a very crude means of conserving eel stocks. The Marine Institute agrees with the general policy outlined and are in the process of completing their own policy paper incorporating similar views which sets out a strategy for the eel fishery.

*The Salmon Research Agency* made a submission to the CFB on the management of eel stocks and the main points are outlined here.

> Considering the current limitations to the glass eel resource, care should be taken to ensure that over-exploitation of glass eel does not occur.
>
> As there is little known about the effect of timing of arrival and migration patterns of glass eel on growth rates and sex determination of the adult eel, intensive fishing of a discrete portion of any one glass eel/elver year class should be avoided.
>
> Management of water discharge rates may be required for optimising the migration and/or catch of glass eel/elvers in the larger systems with barrage impoundments.

With regard to yellow eel, the SRA believe that fishing should be limited to the exploitable stocks, that fishing effort should be limited and that reliable methods of monitoring both stock performance and total catch should be developed. Some implementation of measures to conserve silver eel spawning stocks are required. These objectives are very similar to those set out in this paper.

The SRA believe that eel culture has considerable development potential. However, the following issues will have to be seriously addressed: (1) glass eel/elver supply and how much can be used for culture and how much for re-stocking, (2) holding and transportation of glass eel/elvers and the risks involved, and (3) the importation of stocks and the disease risks.

Stock enhancement is also seen as important in order to maximise yield. Enhancement from on-grown juveniles is a promising development but some assessment must be made of the adaptation and performance of stocked eel. Implicit in any enhancement is the movement of fish and movement should be restricted to within catchments and no movement should take place from catchments with either crayfish plague or zebra mussels.

The SRA set out a number of areas on which future research should focus:

(1) Developing optimum utilisation of the glass eel and elver resource

(2) Assessment of the success of stocking out wild fisheries with on-grown eel

(3) Methods of assessing the effects of different levels of exploitation of juvenile eel and yellow eel

(4) Research on growth and performance in culture conditions

In general, the views of the SRA with regard to management of eel stocks are compatible with those outlined in this paper.

*An Bord Iascaigh Mhara* have been actively promoting investment in the intensive culture of eel using warm water recirculation technology. They have produced literature explaining topics such as the management of juvenile eel stocks for fishery enhancement and eel farming. BIM are concerned that a continuing supply of elvers can be found to supply eel farms as well as for development of existing fisheries.

The *Electricity Supply Board* operates the largest eel fishery in the State on the Shannon catchment and have been undertaking research on eel stocks in recent years aimed at maximising the eel harvest on a sustainable basis. They share the view of the CFB in relation to stock management on a catchment basis and are preparing their own document on eel management. Although no specific submission was made to the CFB in relation to the preparation of this paper, the ESB has indicated that they would be keen to discuss the strategy outlined in this paper with a view to reaching an agreed policy on eel exploitation.

## Recommendations on future management

### Legislative changes required

*Authorisation for eel fishing*

It was intended in Section 19 of the Fisheries (Amendment) Act of 1994 to allow Regional Fisheries Boards to control all forms of eel fishing. Requests for authorisations are made to the Department of Marine & Natural Resources who refer to the relevant Regional Board for advice on the suitability of the applicant. On receipt of an authorisation, which specifies a list of conditions (including type of gear and place where it may be used) an annual licence is purchased in the relevant Fishery Region. However, since the recent judgement in a case in the North Western Regional Fisheries Board, where it was established that a long-line was not deemed to be a fixed engine, an authorisation is not required for the use of a long-line. An applicant can therefore purchase a licence without any conditions attached.

Notwithstanding the 1998 by-law capping the number of long-lines available, legislation is needed to require an authorisation for the use of a long-line for eel fishing. Long-line eel fishing is an extremely effective method of harvesting eel and stocks in certain catchments cannot sustain the current levels of exploitation. If eel are to be managed on a sustainable basis it is imperative that all forms of eel harvesting be subject to adequate regulation and control.

*Number of licences*

The number and type of eel fishing licences issued in a Fishery District should be determined by Regional Fisheries Boards following completion of stock surveys and the establishment of *total allowable catch* in each catchment. Priority should be given to traditional fishermen. Authorisations should specify in which catchment eel fishing is being permitted as this will be necessary to control catches under the proposed TAC system. The cost of eel fishing licences needs to be reviewed.

*Fishing methods*

It is anticipated that in many catchments eel stocks will only be exploitable on a sustainable basis using fyke-nets. These nets have the advantage of being able to release small eel unharmed by having escape rings fitted. All fyke-nets should have rings capable of allowing eel of less than 120 g to escape. Licensing fyke-net fishermen to an agreed number of nets per catchment will lead to a greater number of participants in the fishery than would be possible using long-lines. Fyke-nets have little or no effect on other fish species.

With the exception of well established long-line fisheries where it can be shown that such fishing is sustainable, the fishing method for yellow eel should be restricted to fyke-nets. Only the traditional 2 ft × 12 mm nets should be permitted.

*Close seasons*

If the eel fishery could be developed on the basis of a sustainable harvest using TACs on a catchment basis, then when the annual target harvest has been reached the season should close. This system would mean that a specific close season for eel would not be necessary. However, such a

system may take many years to introduce and enforce and it is the view of the Central and Regional Fisheries Boards that a close season for eel fishing should be introduced as a conservation measure, at least until the system described above is operational.

As a close season for eel fishing already exists on the Erne system in Northern Ireland, close liason would be required before the introduction of close seasons on the Erne south of the border.

*Size limit*
The introduction of a 30 cm minimum size limit for eel for sale, consumption or processing is required as a conservation measure. This regulation should not apply to eel being captured for enhancement.

*Eel dealers*
A national eel dealer licence is required. The eel dealer should, as part of the licence condition, be obliged to record all purchases at the place of purchase so as to enable catches from individual catchments to be logged.

*Conger eel*
Traditionally conger eel have only been fished for sport and there has been no market for conger for consumption. In recent years, however a demand has grown in Europe, most notably in France. BIM gave advice and technical assistance and at least one commercial vessel concentrated on long-lining conger from Ballycotton. This experimental fishing faded out due to poor financial results and BIM are no longer involved in developing the fishery.

In early 1997 these was a dramatic upturn in the use of long-lines for conger, particularly on the angling grounds of the Ling Rocks west to the Fastnet Reef. Angling charter skippers believe there is a direct link between the recent decline in conger catches and the increase in commercial fishing. Conger has traditionally been one of the prime angling attractions in the Ballycotton, Cork Harbour and Kinsale areas and any decline in conger numbers would have serious implications for tourist angling.

The biology of conger eel in Irish waters is very poorly understood. It is imperative that commercial exploitation of conger eel be examined with a view to maximising their availability for sea angling. BIM and the Marine Institute could be requested to carry out this examination in consultation with the industry.

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# COSTS AND BENEFITS OF A NATIONAL EEL PROGRAMME

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**Abstract**

A management project, incorporating techniques known to be successful in Northern Ireland and elsewhere, will increase the national yield of wild-caught eel by a factor of four, from 250 to 1,000 t per annum. A parallel development of intensive culture could yield a further 1,000 t so that an annual yield in the order of 3,000 t for the whole of Ireland can be achieved. A supply of this magnitude will provide the basis for a processing industry and bring about substantial cost reduction in handling and marketing, thereby maximising profits. The ultimate target is an annual value of £60 million for the whole of Ireland. The goal for the capture fishery may best be attained by the operation of an ideal plan comprising 3 years of intensive study plus 7 years stocking and at a cost of £7,820,000. Thereafter the management operation will cost £630,000 per year. The value of the annual yield when the ten-year development project has been completed will be £5 million, with a probability of £15 million value added through processing. An alternative project, with an annual outlay in the order of £565,000, could attain similar results but would leave significant gaps in the knowledge required to operate with maximum efficiency. The essential principle in the operation is that the enhancement of the capture fishery leads to a four-fold increase in product simply by the more effective exploitation of an existing habitat.

## Introduction

Lough Neagh has long been known as one of the world's greatest producers of eel. In 1959 the Fisheries Division of the Department of Lands initiated a study to discover why eel yield elsewhere in Ireland was very much smaller. In 1963, an improved management regime was established in Lough Neagh. By 1982 it was evident that an annual yield in the order of 700 t, or 20 kg per hectare, had been achieved and sustained. Over the following 16 years, this sustainability was clearly demonstrated.

The Fisheries Division's initiative led to a study programme comprising extensive survey work by fyke-netting together with silver eel monitoring. It included observations made in two seasons in Lough Neagh and drew the following conclusions (Moriarty, 1982, 1987; Moriarty and Reynolds, 1997):

- Growth rates of eel from many Irish waters are similar to those of Lough Neagh.
- Greater population densities have been observed elsewhere in Ireland.
- Greater yields than Lough Neagh's are known in Europe.
- A substantial area of Lough Neagh does not produce good eel stocks, suggesting that 20 kg per hectare may be an underestimate of attainable yield.
- Many other species of fish thrive in Lough Neagh; therefore the dense eel population appears to offer no competition.
- Bycatch in the fyke-nets is so small that they pose no threat to other fish species.

The studies therefore have yielded overwhelming evidence that other lakes can produce equal or greater quantities than Lough Neagh without impinging on other fish species. In round figures, an area of 500 km$^2$ of suitable lakes is available, from which a sustainable yield of 1,000 t per year could be established. Employment in the capture fishery alone would be for 500 persons from May to September.

The price paid to the fisher is £5 per kg, making an initial value of £5 million for the Republic. The total achievable yield of the capture fishery for Ireland north and south approaches 2,000 t to which 1,000 t of cultured eel might be added. A supply of this magnitude would be sufficient to establish

a processing industry with added value in the order of three times that of the wet weight. The goal for a managed Irish eel industry should therefore be taken to be £60 million.

Market performance at present may not be encouraging but there are a number of reasons for the expectation that a major improvement is likely in the course of the next ten years. Above all, the eel is a luxury product with a limited supply base. The increasingly high standards of living are bound to lead to increased demands for top quality food and there is no reason to believe that the eel can fail to hold its place amongst the most highly priced species of fish. It must be remembered that the current high prices are paid for the species in the virtual absence of any marketing effort.

The basis of the management programme is the capture and distribution of glass eel at a rate of 0.1 kg per hectare per year. This requires an annual capture and distribution of 5 t to which 5 t would need to be added to yield 1,000 t of cultured eel. Captures in the order of 5 t per from Ardnacrusha and Ballyshannon combined have been made from time to time in recent years and were regularly obtained in the 1960s and 1970s when glass eel were very much more plentiful. There are theoretical reasons to suppose that intensified and improved fishing could easily yield 10 t of glass eel per year (McCarthy *et al.* 1994).

This paper presents, for the first time, an estimate of the cost of developing and executing such a programme and the benefit to be derived. The proposal is to operate on a nation-wide basis with maximum input from the start. This would be the most cost effective and rapid means of achieving the goal. In response to doubts expressed at the Workshop as to the pragmatism of proposing a scheme with relatively high initial cost and additional manpower, a second, phased proposal is included. The costing is based:

on research and development by the Marine Institute or Central Fisheries Board in collaboration with the Regional Fisheries Boards

on purchase of glass eel from contract fishers at £50 per kg.

## National and regional strategy

Development of the fishery requires in the first place a major research programme, co-ordinated by a central authority. The Marine Institute would be appropriate as it currently employs an eel specialist but the Central Fisheries Board could be an equally acceptable headquarters in view of its position with regard to the Regional Fisheries Boards.

*Personnel*

All personnel would be fulltime appointments since the initial steps outlined in this paper will, in addition to solving the most immediate problems, constantly bring forward new ideas which will need to be scientifically tested. Moreover, as the fishery develops and fishing pressure on the stocks rises, increasingly sophisticated monitoring techniques will need to be applied to ensure that the fishery is managed to attain maximum efficiency and yield.

The central authority team would comprise one scientist as project leader, with appropriate clerical support, to co-ordinate national effort. After an initial three-year phase he would require a full-time technician.

Six regional teams would engage in research, development and management work, each to comprise a scientist as project leader, a technician and two fishery officers. The latter would not work full time on eel since the capture fishery for market eel will operate mainly from May to October and the elver transportation project will take place from late February to late April. This part of the project will require intensive work only for a few days every two weeks since elver movement is strongly influenced by tides.

*Glass eel and elver development*

All the teams would concentrate in early spring on elver capture and transportation. While the capture of elvers ascending into fresh water is well established on the Erne and Shannon, extremely little is known about the behaviour and catchability of estuarine glass eel. This problem is extremely complex and will require a serious research effort over many years. It has not been adequately approached anywhere in the world.

Apart from the fact that all Irish river systems are significantly different from each other, conditions in other European waters are different from those in Ireland. Therefore, extrapolation from the few scientific studies that exist already cannot provide the detail required for a management plan in Ireland. Furthermore, only a very small number of studies have been conducted over a sufficiently long time scale to explain variations caused by temperature, water levels and flood conditions which change from year to year.

*Yellow eel fishery*

The scope for development varies greatly between Regions. The most important eel habitats are listed in Table 1. Five Regions contain a number of substantial lakes and estuaries but the Southern has no lakes big enough for eel development while the lakes of the Southwestern are in general too acid to support a profitable fishery. Many of its estuaries, however, appear to present very promising glass-eel habitats. It is therefore suggested that the Southern and Southwestern Region be merged for eel development.

**Table 1. Major productive eel habitats in Fisheries Regions.**

| | |
|---|---|
| Eastern | Ramor, Monaghan lakes, Wexford Harbour |
| Southern / Southwestern | Waterford Harbour, Barrow |
| Shannon | Shannon lakes, Clare lakes, Shannon estuary |
| Western | Corrib catchment lakes, Loughrea |
| Northwestern | Conn, Gill, Arrow and smaller lakes |
| Northern | Cavan lakes in Erne catchment |

*Silver eel fishery*

A number of profitable fisheries for silver eel exist. While measures to increase the efficiency of any of these may be justified on economic grounds, the need to introduce new operations is open to question. Because normal migration of the silver eel takes place in flood conditions, the capital cost of effective barriers is extremely high. This probably explains the fact that very few have been erected in the course of the 20th century and many have been abandoned.

Silver eel represent potential spawning stock and have traditionally been protected, usually by the requirement for a 'free gap' in catching engines. The enhancement measures proposed in this paper will lead to increases in silver eel escapement and could justify development of the fishery, especially since the product is more valuable than the yellow eel. The approach should be to take no active steps to encourage silver eel fishing developments. Sampling of silver eel, where possible, is an important factor in stock assessment and should be a regular feature of all scientific studies.

## Major studies

Major studies have been made recently of the eel in the Shannon catchment and are in progress on the Erne. The Southern RFB has begun studies in Waterford Harbour and the Northwestern RFB is to begin a survey of its most productive eel waters. To carry such studies out with existing staff is a very significant step forward and will yield important results. It must, however, be stressed that the problem is too large and complex to be satisfactorily approached on a part-time basis. Serious progress in eel development demands a long-term commitment to full-time work.

The extensive study conducted on the Shannon (McCarthy *et al.* 1994, Reynolds *et al.* 1994) and that in progress on the Erne (p. 21) provide or will provide essential base-line data. These will need to be updated by monitoring teams. In addition, both Shannon and Northern Regions have other lakes, such as those on the Fergus and Drowes, which need attention by the proposed teams.

### Development and maintenance programme

The programme envisages an initial three-year phase during which research and development on a regional basis will be undertaken by six teams in parallel with co-ordination where necessary by the central team. The work programme for the regional scientific teams is summarised in Table 2 and for the fishery officers in Table 3. When the three-year programme has been completed, it is proposed that the main scientific input be from the central team with back-up from the regional fishery officers.

**Table 2. Work outline for regional scientific teams.**

| | |
|---|---|
| February–May | 1. Exploratory glass-eel fishing<br>2. Glass-eel sampling |
| May–September | 1. Exploratory fishing<br>2. Catch sampling<br>3. Silver-eel sampling |
| October–December | Silver-eel sampling |
| January–February | Data analysis |

**Table 3. Work outline for regional fishery officers.**

| | |
|---|---|
| March–May | Operate/patrol glass-eel fishery<br>10 nights per month |
| May–September | Patrol yellow-eel fishing<br>3 - 7 days per week |
| October–December | Patrol silver-eel fishery<br>6 nights per month |

### Costs

The cost of such an operation is set out in Table 4. It includes seven vehicles to allow one for each team. The glass-eel are costed at £50 per kg. This would give a very reasonable return to contract fishers. This approach can be taken because glass-eel fishing throughout Ireland has traditionally been prohibited by law and is permitted only for stock enhancement or aquaculture.

### Benefits

A simple analysis of the costs and potential benefits (Table 5) gives the interesting result that the total development cost over the initial 10-year period is not very much greater than the wet-weight value of the eel to be caught in year 11 and, moreover, is less than half the value to the country if the eel were to be processed. By far the greater part of cost and benefit is accounted for by employment within the country with only a small proportion involving imported goods or services.

It must be noted in particular that the greater part of the annual development and maintenance cost, some £250,000 for elvers, is actually payment to the people involved in catching them. At least 100 persons should be involved for 3 nights every fortnight from February to April inclusive.

The fishing industry throughout Ireland has been heavily subsidised and fishers, by and large, have never been expected to pay the costs of national research and development. A rough estimate may be made that a fisher or fish processor might spend 10% of his earnings in VAT alone. This means that, even assuming zero return from income tax, the Exchequer stands to gain £2 million from the fully developed fishing and processing industry. This is more than four times the annual cost of maintenance of the fishery.

### Eel culture

The eel cannot be spawned artificially and therefore all the seed for eel culture must be wild-caught. At present, the shortage of glass eel presents a serious problem for the aquaculture in-

A glass eel-based enhancement project in Ireland requires a lead-in time of ten years on account of the slow growth rate of the species. The first results of increased yield become apparent ten years after the first stocking season and the yield will continue to rise for the following five years after which it will stabilise if properly managed. The development scheme will take place in two phases: (i) three years basic research with contract scientists and technicians, (ii) annual stocking, management and scientific monitoring operation.

**Table 4. Costs of ideal large-scale research and development plan.**

| | | | |
|---|---|---|---|
| **Phase 1: Three-year basic survey by research teams (£)** | | | |
| *Start-up capital* | | | |
| Vehicles | 140,000 | | |
| Lab equipment | 70,000 | | |
| Glass-eel storage | 120,000 | | |
| *Personnel costs* | | *salary* | *t & s* |
| 7 scientists @ £20,000 | | 140,000 | 70,000 |
| 6 technicians @ 15,000 | | 90,000 | 60,000 |
| 6 fishery officers @ 12,500 | | 75,000 | 60,000 |
| *Total costs* | *year 1* | *year 2* | *year 3* |
| Manpower | 495,000 | 495,000 | 495,000 |
| Equipment | 330,000 | 10,000 | 10,000 |
| Glass-eel @ £50 per kg | 250,000 | 250,000 | 250,000 |
| Total | 1,075,000 | 755,000 | 755,000 |
| **Grand Total for Phase 1** | | | **2,585,000** |
| **Phase 2. Annual operation** | | | |
| | *salary* | *t & s* | |
| 1 scientist | 20,000 | 10,000 | |
| 1 technician | 15,000 | 10,000 | |
| 6 fishery officers | 75,000 | 60,000 | |
| Equipment maintenance | 20,000 | | |
| Elver cost | 250,000 | | |
| Annual total | 460,000 | | |
| **Grand total for ten-year project** | | | **5,805,000** |

dustry. There is reason to believe that adequate glass eel enter Irish coastal waters. Therefore, although the thrust of this paper has been directed towards the development of the capture fishery, it indicates that the proposed exploratory and experimental fishing for glass eel should yield adequate supplies to develop the culture industry. Eel culture in effect depends on the existence of a glass-eel fishery and cannot develop without a major input in this field.

Eel culture has been used to contribute to stock enhancement (Rossi *et al.*, 1988) and experiments in this direction are in progress in Ireland. The pro-

**Table 5. Costs and benefits of 11-year plan**

| | £ |
|---|---|
| Total development cost (years 1–10) | 5,805,000 |
| Value of catch in year 11 | 5,000,000 |
| Value added | 15,000,000 |
| Annual development/maintenance cost | 630,000 |
| Annual earning of elver fisher for 18 nights' effort | 5,000 |
| Annual earning of fisher in 5 months season | 10,000 |

duction of 'bootlace' eel for ranching could reduce the lead-in time for the development of the capture fishery from ten years to five.

A further benefit of eel culture is that any increase in eel production in Ireland gives Irish producers a stronger hold over the market and reduces many of the overheads – such as the cost of transport of the finished product. The culture industry, although different in many ways from the capture fishery, should therefore be promoted concurrently.

## Reduced development programme

Although the paper clearly shows that the 'ideal' plan outlined above will be cost-effective, it has to be accepted that funding to the extent required may not be universally approved. A greatly simplified proposal is therefore outlined below.

It envisages that research and co-ordination be confined to the central team, with the Regional Boards carrying out the development work. In such a case, the first priority would be to find additional sources of glass eel and to stock waters at the rate proposed above. On the assumption that Regional Fisheries Boards could make vehicles and staff available, the costs of such a minimal approach are summarised in Table 6.

**Table 6. Cost of minimal research and development scheme**

| *Start-up capital (year 1)* | £ |
|---|---|
| Lab equipment | 10,000 |
| Glass-eel storage (£ 10,000 per Region) | 60,000 |
| *Annual costs* | |
| 1 scientist (salary + t & s) | 30,000 |
| 1 technician (salary + t & s) | 25,000 |
| Equipment maintenance | 10,000 |
| Elver cost | 250,000 |
| *Total annual* | 315,000 |

This gives a capital cost of £70,000 and an annual outlay of £315,000. Such an approach would achieve much, but would lose in failing to prepare the base-line study on which the best possible management programme must be based. A compromise might be achieved by centralising one research team rather than the six regional teams proposed. Such a team would, over a period of eighteen years, be able to achieve much the same results as the ideal six teams would in three years.

## Conclusions

The project is based on techniques known to be successful in Northern Ireland and elsewhere. It will increase the national yield of wild-caught eel by a factor of four, from 250 to 1,000 t per annum. A parallel development of intensive culture could yield a further 1,000 t so that an annual yield in the order of 3,000 t for the whole of Ireland can be achieved. A supply of this magnitude will provide the basis for a processing industry and bring about substantial cost reduction in handling and marketing, thereby maximising profits. The value of the processed product will be in the order of £60 million per year.

The goal for the capture fishery may best be attained by the operation of an ideal plan comprising 3 years of intensive study plus 7 years stocking and costing £5,805,000. Thereafter the management operation will cost £315,000 per year. The value of the annual yield when the ten-year development project has been completed will be £5 million, with a probability of £15 million value added through processing. An alternative project, with an annual outlay in the order of £240,000, could attain similar results but would leave significant gaps in the knowledge required to operate with maximum efficiency.

The essential principle in the operation is that the enhancement of the capture fishery leads to a four-fold increase in product by the more effective exploitation of an existing habitat. The cost lies in capture and transport of the seed and there is no expenditure in food. Furthermore, the fishery is labour-intensive and operates with a low capital outlay and high environmental acceptability.

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# EEL MANAGEMENT WORKSHOP CLOSING REMARKS

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I won't comment on the presentations of the last two speakers, because the details are still fresh in your minds. Instead, I will refer briefly to what struck me as the main points of the earlier papers, and relate all of them to what appear to me to be the central issues concerning the future management of Ireland's eel resources.

In their account of eel RTD in Ireland, Richard Donnelly and Kieran McCarthy presented some extremely interesting data. Richard gave us estimates of glass eel natural mortality as up to 95%; such high levels are comparable to the mortality rates experienced by the early life stages of marine fish, however. Kieran showed that there has been a steady decline in catch-per-unit-effort (cpue) in the Lough Derg eel fishery during the period 1992–1997. If effort is standardised, as it appears to have been in these data, then it can be used as an index of abundance; the Lough Derg eel stock, therefore, would seem to have undergone a serious decline in recent years. I presume that the management policy which is under development in the experimental situation in Lough Derg will reflect this. As Kieran McCarthy's paper pointed out, "realistic objectives must be linked to product development, market demands, and commitment at regional and national levels".

Management objectives are also being developed in the Erne system. Milton Matthews listed them:

- to maximise the recruitment of glass eel,
- to assess the current state of eel stocks throughout the Erne system,
- to co-ordinate the cross-border management of the Erne system's eel.

In a riveting presentation, Fr Oliver Kennedy described eel fishery management in Lough Neagh. With an annual turnover of £5 million and 180–190 licensed boat owners in the fishery, the Lough Neagh Co-operative has developed a tight management regime:

- daily boat quotas which are closely linked to market conditions (which themselves are frequently associated with such variable considerations as whether the weather is warm or cool);
- a minimum landing size of 40 cm (compared with the less conservative limit of 30 cm set by the Department of Agriculture for Northern Ireland);
- the firm policy that Lough Neagh cannot sustain more and more licences each year (so the number of annual licences is fixed at something between 180 and 190).

It struck me that Christopher Moriarty has for years been preaching the gospel that the eel of the Republic's waterways could yield a significant contribution to the fishing sector of the economy, if only the resource were to be developed – but until now his advice has been ignored. Meanwhile, up at Toomebridge, Fr Kennedy and his Co-op just went ahead and did it; their success is there for all to see.

What we can learn from all the foregoing is that management, if intelligently and firmly applied, can be highly effective without necessarily having to wait for *precise* details of where the biological limits are. It is very unwise not to take account of the possibility of over-exploitation, and the Toomebridge Co-operative clearly and deliberately builds these considerations into its management policy. Fr Kennedy pointed out that they seem to have hit on the appropriate level of exploitation for their eel stock, as indicated by the fact that the proportion of brown eel and silver eel in the catch has remained fairly constant over the years, despite a policy of fishing the brown eel to the maximum sustainable yield (which as yet remains unassessed). Given the relatively slow growth and long life-span of some of Ireland's eel populations, it could take 10 years or so to rebuild in the event of a population being driven to collapse by over-fishing. The aim of enhancement (by transporting glass eel and elver upstream) is thus a very rational start to developing the resource.

Declan Duggan showed how an eel cultivation operation can be successfully established with, as he said, a supply of water and electricity supply as the only essentials. He pointed out that he has to import 85% of his supply because of the poor infrastructure in glass eel capture in Ireland at present (surely a pointer to future development requirements here?), and that he must operate with an overall mortality of 15–20% among these juveniles. This percentage seems comparable to the smolt mortality levels experienced by salmon farmers. Declan also stressed that the market is tight and that quality is therefore paramount (echoing one of Fr Kennedy's points). He pointed out that one must keep a strict business perspective at all times and not rely exclusively on one's husbandry skills. As the session chairman pointed out, though, it struck me that Declan was originally a plumber by profession, and it seems to me that prospective eel farmers would be well advised to acquire the plumber's skills of handling fluids in pipes (whether the fluid is a liquid, or a gas such as oxygen), or else to get access to these skills in addition to those of husbandry and marketing.

In analysing eel culture trends in Europe, Per Bovbjerg showed that in order to remain competitive, farmers will have to find ways to reduce the variable costs of their operation and increase production, the latter by raising stock density rather than boosting the growth rate, which has proved difficult. I feel that an innovative RTD programme could make a fruitful contribution in these areas.

Barbara Byrne and Peter Koch-Bodes explained how the German market (identified by Per Bovbjerg as one deserving greater interest in view of the dwindling Dutch market) relied on live eel to the extent of 51% of its eel imports. The German smoking industry prefers to take in the raw product and process it in accordance with its own regional procedures and tastes, confirming a point made earlier by Fr Kennedy with respect to exports from Toomebridge to the Netherlands.

Paddy Gargan outlined the forthcoming National Strategy for Eel document which is being drafted by the Central Fisheries Board. The potential to be realised has already been clearly indicated by the proceedings of this Workshop, and I look forward to seeing the Strategy document in its final form. I note that it envisages the Total Allowable Catch (TAC) as one core element of a national eel management and development strategy, and I view this as a pragmatic and necessary step. As a management tool, the TAC has had "bad press" on account of the difficulties which have been experienced with the EU Common Fisheries Policy, but if we can learn from that experience, and from the positive experience of the Toomebridge Co-operative, then a TAC-centred strategy should be more successful than it has been for our sea fisheries. Good biological data for calculating realistic TACs should be (or become) available from the ESB "experiment" on Lough Derg and from the work on the Erne system, and from then on the process should be straightforward. TACs should not be regarded in a purely negative way; they are an essential tool in any rational fisheries management policy, which means one that includes sustainability of the resource and of the fisheries based on it. A boom-and-bust approach (such as has been accepted, with some justification, in fisheries for queen scallop and sprat) with a long-lived, relatively slow-growing species like the eel would lead to a very long-term bust indeed.

During the discussion period, two speakers raised the question of whether a national policy should favour the development of eel farming or eel fishing. In my opinion, it should be left up to the people of the regions to choose whether the local economy would be better served by cash for farmed eel, or the development of a fishing community, or a judicious mixture of both. To this end, I would encourage the Central Fisheries Board to give the nod, in their strategy document, to the carrying out of regional socio-economic studies to evaluate these options.

Finally, I refer you to the Minister's words in his opening address to the Workshop, when he stressed how it will be essential for people to do the necessary homework if even the best strategic plan is not to stay on the shelf. A lot of those homework tasks will, in all likelihood, fall on people like me and my colleagues in the Marine Institute, BIM and the CFB - *and entrepreneurs; we can't do it without industry involvement.* That means establishing and maintaining a dialogue between science, technology and people in the industry. Today's workshop has been a splendid start to that theme. Let's keep up the momentum.