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The River Shannon silver eel fisheries: variations in commercial and experimental catch levels

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Abstract

Management of the eel fisheries of the River Shannon, Ireland's largest river system, has involved various stock enhancement measures since 1959. Declining natural recruitment levels have limited the effectiveness of stocking programmes for nearly two decades. Observations on declining yellow eel stocks in several major lakes have been supported by the results of studies undertaken annually on the seaward migrating silver eel populations from 1992 to '99. A decline in the combined silver eel yield from a series of commercial and experimental fishing sites has occurred, despite increases in fishing effort. Changes in silver eel length-frequency distributions and sex ratios appear to be linked to declining stock levels. Silver eel migration patterns vary within the catchment and in upper Shannon catchment sites a lunar periodicity is normally evident in the autumn/winter silver eel movements. Silver eel migration in the lower reaches of the river system is strongly influenced by variations in discharge due to river regulation for hydroelectricity generation. Despite the decline in stock levels, the results of observations at experimental sites and on commercial eel weir operations suggest that improvements in silver eel fishing methods could result in significantly greater catch levels.

Keywords: eel, *Anguilla*, fisheries, Ireland, migration.

Introduction

The downstream migration of silver eels, *en route* to their spawning grounds, provide opportunities for many commercial eel fishing operations, throughout the range of the European eel *Anguilla anguilla* L. These extensive eel movements are typically seasonal, and in northern Europe they usually occur in autumn and early winter. In addition, they are generally characterised by diel and lunar periodicity, with most movements taking place at night and during the last lunar quarter of the monthly lunar cycle. Various hydrological and meteorological factors can, according to location, time of year and eel physiological condition, alter the intrinsic rhythmicity of the migratory phenomena. Environmental factors such as stormy weather and depression-generated microseisms, together with increased river discharge can dramatically increase the intensity of silver migrations. Extensions of the riverine migratory phase can be associated with delays resulting from man-made obstacles along a river course or more frequently the presence of lakes, which may delay the downstream movement of eels, as can also environmental factors such as decreasing water temperatures (Lowe 1952, Deelder 1970, Tesch 1977, Vøllestad *et al.* 1986).

In Ireland the broad pattern of silver eel movements, well known to commercial fishermen, has been documented scientifically in the case of a number of river systems for which good catch statistics are available, including the important Lough Neagh/ River Bann fishery (Frost 1950, Parsons *et al.* 1977, Kennedy & Vickers 1993), the

small western River Burrishoole system (Poole & Reynolds 1990 & 1998) and the River Shannon (Moriarty 1990, Cullen & McCarthy, in press).

In this paper some results of observations made on silver eel catches at commercial fishing weirs and experimental fishing sites in the River Shannon system for 1992/93 to 1998/99 inclusive are presented. The implications for future management of the fishery and eel stock conservation are also reviewed.

Study area

The River Shannon system (Figure 1) is Ireland's longest river system, draining a catchment area (upstream of Limerick) of approximately 11 700 km^2 and including an estimated 41 000 ha of surface waters. The extensive lacustrine habitats, typically mesotrophic to eutrophic in character due to their low-lying distribution and the underlying calcareous bedrock, are becoming increasingly enriched (Bowman, 1998). The three largest lakes in the system, Lough Derg (11 635 ha), Lough Ree (10 500 ha) and Lough Allen (3500 ha), are distributed along the low-gradient main River Shannon

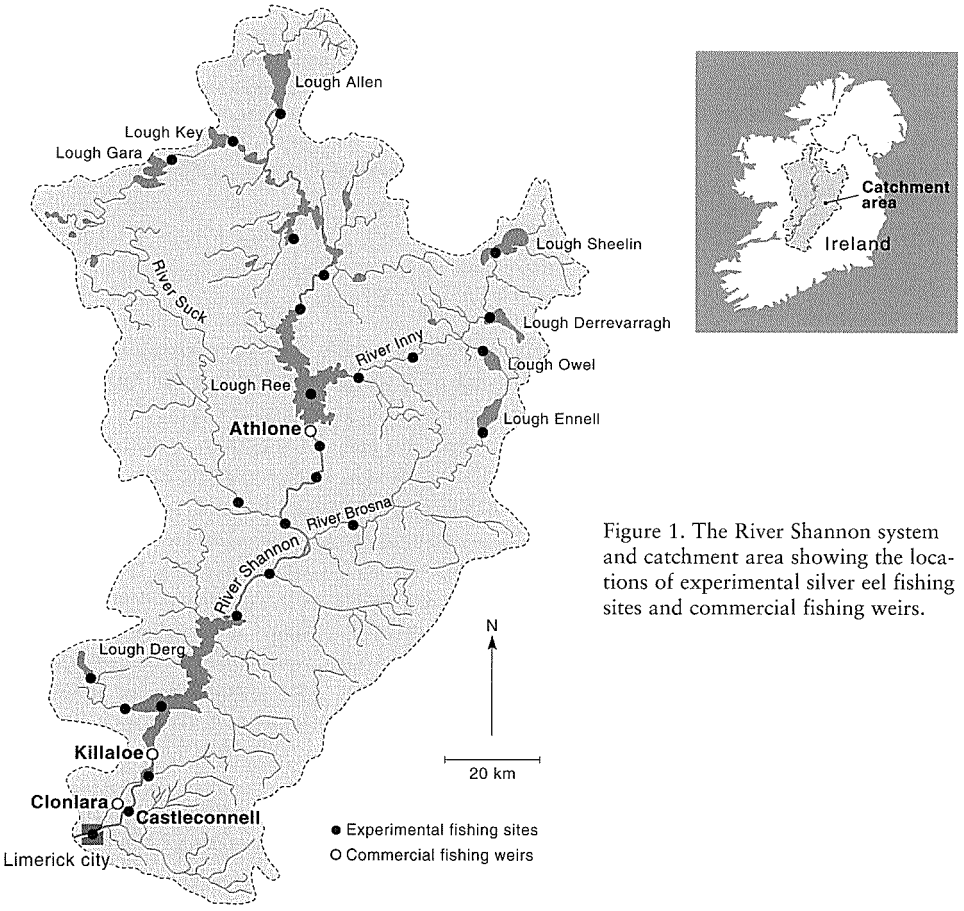

Figure 1. The River Shannon system and catchment area showing the locations of experimental silver eel fishing sites and commercial fishing weirs.

channel which falls only 18 m in 200 km southwards from Lough Allen to below Killaloe (Figure 1). 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 $m^3 \cdot s^{-1}$. A minimum 10 $m^3 \cdot s^{-1}$ 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 $m^3 \cdot s^{-1}$ to a winter average of 274 $m^3 \cdot s^{-1}$.

Materials and methods

Commercial fishing for silver eels on the River Shannon occurs at three major eel weir sites (Athlone, Killaloe and Clonlara) and extensive reliable long-term data are available for these operations. Technical descriptions of these weirs have been provided by O'Leary (1971), McGrath *et al.* (1976), McCarthy *et al.* (1994). An account of the commercial fishery was given by Quigley & O'Brien (1996). In addition a series of experimental fishing sites have been established since 1993 at which fishing activities of authorised two-man crews have been monitored (Figure 1).

Between 1992 and 1999 yearly observations were made on the activities of silver eel fishing crews, both commercial and experimental. In addition to records of daily fishing activities and catches recorded by fishing crews in log books, student observers were employed to monitor selected fishing crews and the commercial eel-processing operations. These students also obtained samples of eels for laboratory analyses. The methodology employed during these surveys has previously been described by McCarthy *et al.* (1994 & 1998).

Results

The effective silver eel fishing season on the River Shannon varies from year to year and between sites, though authorisations to fish generally are granted for the September to March period. Evidence of some eel migration outside of this official fishing season has been provided by observations of silver eels in the catches of fishermen using summer fyke nets to capture yellow eels and by test netting at major eel weirs. However, the bulk of the sea-ward eel migration normally occurs in the late autumn/winter months and catch statistics from commercial weirs and experimental fishing sites illustrate this (Figure 2). In the upper catchment, and especially at lake outlet sites, clear evidence of the underlying lunar periodicity in silver eel migration is regularly observed, as illustrated for Loughs Allen and Ennel (Figure 2) where catches normally peak during the last quarter of the lunar month. In the main River Shannon channel, and especially in the lower catchments, where the catches made are combinations of various migrating sub-populations, the underlying lunar periodicity is regularly masked by the effects of regulated discharge and other environmental factors. The results presented in Figure 2 for the Killaloe eel weir (1994/95) illustrate this phenomenon where the bulk of the catch occurred in December/January and the peak in daily catches was clearly associated with a sudden increase in river discharge volume.

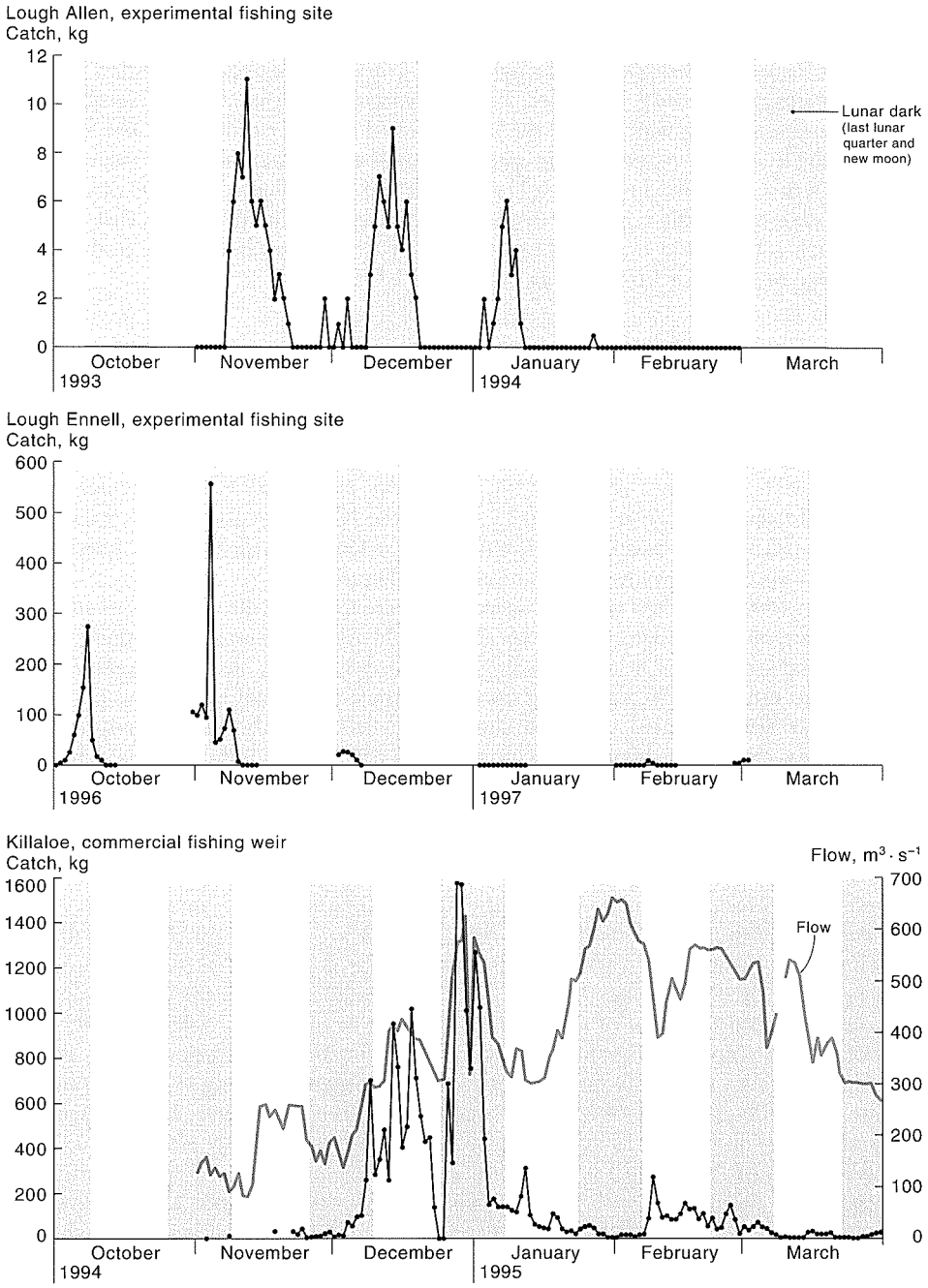

Figure 2. Daily catch records from the experimental fishing sites at the Lough Allen and Lough Ennell outlets during the 1993/94 and 1996/1997 fishing seasons, respectively, and the commercial eel weir at Killaloe during the 1994/95 fishing season. The lunar dark is highlighted and for Killaloe flow records are also presented.

Analyses of commercial records of the quantities of eels, assigned daily to four size classes during grading at the eel-processing station, show that at the lower River Shannon eel weirs (Killaloe and Clonlara) irregular variations in the size structure of the migrating eel populations occur throughout the season (Figure 3). However, no evidence of early migration by the very small category of eels, which comprise the male component of the population, has been recorded.

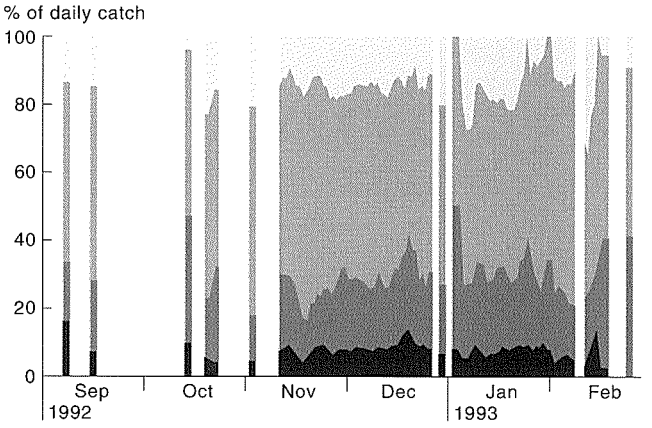

Figure 3. Seasonal variations in the relative abundances of different size categories of silver eels (by results of commercial size grading) of the Killaloe eel weir catches during the 1992/93 fishing season.

Investigations on length-frequency distributions of silver eels captured at different sites in the Shannon indicated considerable variability, reflecting differences in sex ratios in the various sub-populations of migrating eels. Results presented in Figure 4 illustrate this phenomenon, in that samples of silver eels captured in the Castleconnell area (Figure 1) of the lower River Shannon were predominantly small, male individuals, whereas those captured at the upper catchment Lough Sheelin lake outlet site were exclusively larger, female eels. However, the typical Shannon silver eel catches are similar to those obtained at Killaloe, where, though the bulk of the eels captured were female, a proportion of males also typically occured (Figures 3 & 4). The proportion of the Killaloe catch comprised of the very small commercial category, i.e. males, has declined from 7.7 to 4.6% in the 1992/93-1998/99 period, with a minimum of 2.9% recorded during the 1996/97 fishing season.

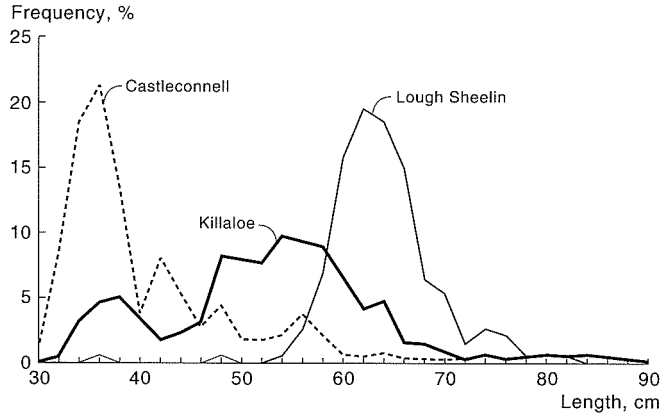

Figure 4. Length-frequency distribution of silver eels sampled from catches made at the outlet of Lough Sheelin, the Killaloe eel weir and Castleconnell during the 1993/94 fishing season.

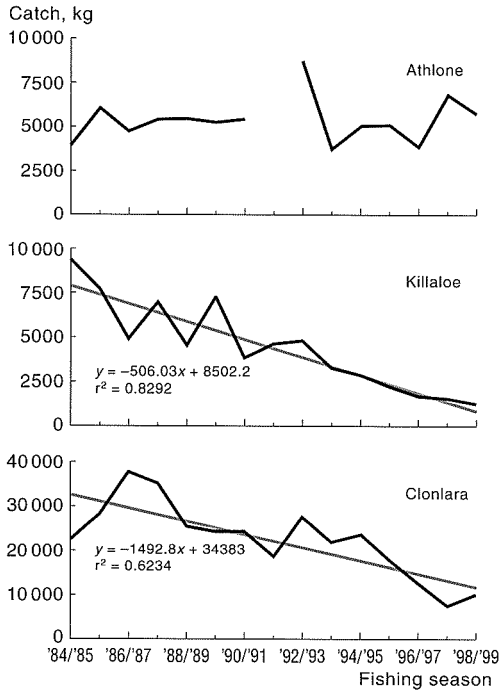

Figure 5. Total yearly catches of silver eel recorded from the commercial fishing weirs at Athlone, Killaloe and Clonlara for the fishing seasons of 1984/85-1998/99 inclusive.

In the period 1984/85-1998/99 a progressive decline in the catches recorded at both the Killaloe and Clonlara eel weirs has been recorded (Figure 5). This trend has not been recorded at the Athlone eel weir. In Table 1 a summary of the catches of silver eels for the combined upper and lower (Lough Derg and downstream) Shannon sites, respectively, are presented. The increased captures in the upper Shannon in 1997/98 and 1998/99 reflect increased fishing effort during those fishing seasons. In 1992/93 there was only one major weir operating in the upper Shannon catchment area, whereas in subsequent years numerous minor experimental fishing sites were exploited using a variety of netting techniques. Spearman Rank correlation analysis (rS) indicated that the annual silver eel captures in the lower River Shannon (Table 1) for 1992/93 to 1998/99 were significantly inversely correlated with those recorded in the upper catchment sites ($rS = -0.8571$, $p < 0.05$).

Table 1. Annual catches of silver eels recorded from the upper Shannon catchment (all sites upstream of Lough Derg) and the lower Shannon catchment (Lough Derg and downstream) areas for the fishing seasons of 1992/93 to 1998/99 inclusive.

	No. of fishing locations		Catch, tonnes	
	Upper	Lower	Upper	Lower
1992/93	1	2	8.70	32.39
1993/94	6	3	6.42	25.53
1994/95	10	3	12.27	26.90
1995/96	13	7	13.07	22.84
1996/97	9	5	12.74	14.21
1997/98	25	4	22.41	8.92
1998/99	25	3	19.83	11.64

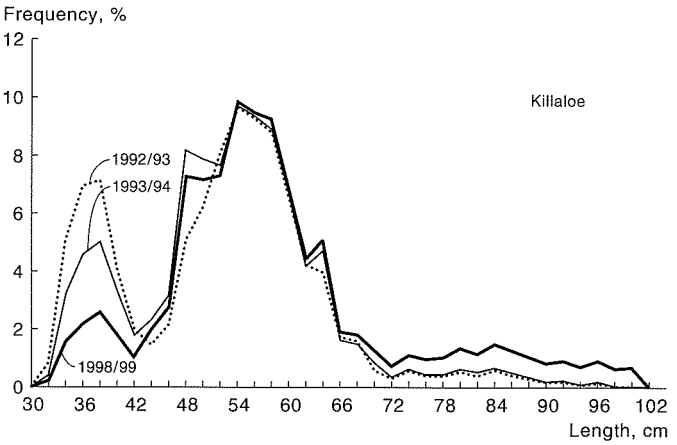

Figure 6. Length-frequency distributions of silver eels captured at the Killarloe eel weir during the fishing seasons of 1992/93, 1993/94 and 1998/99.

The decline of silver eel catches in the lower Shannon (Figure 5) has been associated with a progressive decrease in the proportion of male eels captured and this is illustrated by differences in the length-frequency distributions of silver eels captured at Killaloe in 1992/93, 1993/94 and 1998/99 (Figure 6). Observations on length frequencies at upper catchment experimental sites, such as those recorded from the outlet of Loughs Allen, Sheelin and Ennel, indicated that the sizes of eels being captured were greater in recent years than those observed in the initial 1992-94 study period (Figure 7).

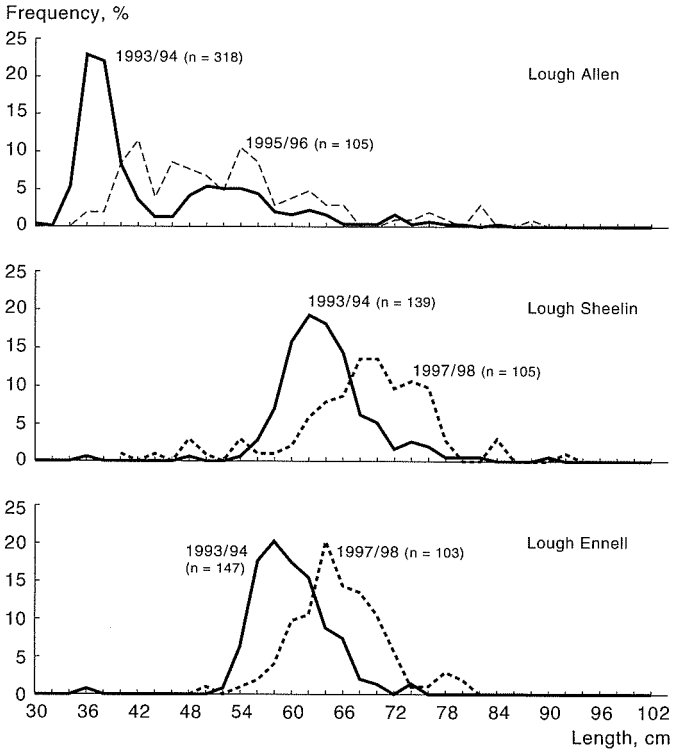

Figure 7. Length-frequency distributions of eels captured at Lough Allen during the fishing seasons of 1993/94 and 1995/96 and at Loughs Ennell and Sheelin during the fishing seasons of 1993/94 and 1997/98.

Discussion

Though some downstream movement of eels may occur in the River Shannon throughout the annual cycle (Moriarty 1990), silver eel migrations normally occur during the autumn/winter months. This seasonality is typical of many larger western European river systems, especially those in which lakes or man-made obstacles may delay seaward migration rates. Elsewhere in the range of the species the migrations of silver eels may occur at other times of the year. For example, in North Norway migrations may occur in July-September (Bergersen & Klemetsen 1988), whereas in Byelorussian lakes the season extends from April to October, but with peak movements occurring in May and September. Regional and longitudinal variations such as these reflect differences in water temperatures, day length and other environmental factors.

Between-year variations in the temporal patterns of silver eel migration in the Shannon, as indicated by daily catches at the Killaloe eel weir, are associated with differences in environmental conditions. Hydrological (Figure 2) and meteorological factors generally obscure the underlying lunar periodicity of the silver eel migrations at Killaloe. However, in smaller tributary systems and at lake outlet fishing sites in the upper catchment area (Figure 2) clear evidence of the lunar periodicity, that is a feature of silver eel migration throughout Europe (Tesch 1977), can be observed. Furthermore, monitoring of daily fyke net catches of yellow eels in the largest of the Shannon lakes, Lough Derg, has indicated increased movements of maturing silver eels in July and August, though no significant emigration from the lake has been evident in those months.

Sex differentiation in eels is strongly influenced by environmental factors and males typically predominate in high-density populations and social factors appear to be involved (Colombo & Grandi 1996). Changes in sex ratios observed in silver eel populations in two Irish rivers, River Burrishoole and River Bann, have been shown to be associated with variations in eel population densities (Parsons *et al.* 1977, Poole & Reynolds 1989). The predominance of female silver eels in the catches at Killaloe (Figures 4 & 6), probably reflects low stock recruitment to the Shannon fisheries in recent decades (McCarthy & Cullen 2000). Likewise, the decreasing percentage of males being captured in recent years (Figure 6) is associated with the progressive decline in Killaloe silver eel catches (Figure 5). The yellow eel populations in Lough Derg also appear to be declining progressively, as indicated by fyke net capture rates (McCarthy *et al.* 1999).

However, relatively good stocks still exist in many other parts of the system, as evidenced by the fact that silver eel catches have not been declining at Athlone (Figure 5). Results also indicate that with increased fishing effort, improvements in the yield from the upper catchment silver eel fishery have been obtained in recent years (Table 1). The significant inverse relationship between annual silver eel catches in the upper and lower sections of the river system (Table 1) may be indicative of the effects of increased upper catchment fishing pressure on numbers of eels accumulating in Lough Derg during early autumn months. However, a decline in the overall stock seem to be the principal factor associated with the reduction in annual catches observed at Killaloe (Figures 5 & 6).

The poor eel fishery yields from the Shannon lakes compared with those of the well-managed Lough Neagh system in Northern Ireland (McCarthy *et al.* 1997) has long been a matter of concern to the eel fishery management. The increased rate of silver eel capture in recent years in the upper catchment, despite the problems of poor eel re-

cruitment and declining stocks generally, suggests that through intensification of silver eel fishing and development of better fishing techniques, the commercial prospects of the fishery may be improved. Upper catchment lake outlet sites appear to have considerable potential in this regard and the predictability of the timing of eel migration patterns at these sites would reduce labour costs and facilitate scientific monitoring of fishing activities.

Efficiencies of silver eel capture at the commercial eel weirs on the Shannon has been shown to be generally low (McCarthy *et al.* 1994). Furthermore, because of the presently declining stock levels in the Shannon, recent difficulties in marketing eels in Europe and the high costs associated with construction of these structures, it is unlikely that new weirs will be constructed in the foreseeable future. However, opportunities for improved catches of silver eels in the main River Shannon channel may prove possible through use of alternative techniques such as the stow net fishing techniques employed in the Rhine (Tesch 1977). Likewise, use of light screens (Hadderingh *et al.* 1992) and other methods of redirecting migrating silver eels could, in addition to deflecting eels from hazards, be effective in increasing catches at existing fishing sites.

Unlike the Lough Neagh/River Bann fishery in Northern Ireland, for which both reliable recruitment and eel fishery yield data are available (McCarthy *et al.* 1997), modelling of the Shannon fishery is complicated by: the poor quality of data on juvenile eels stocked to the system from 1959 to 1992; extensive and unrecorded illegal fishing in the 1980s; and major alterations to the lower Shannon commercial silver eel weirs which improved their efficiency from 1982/83 onwards. Attempts to develop a model (Reynolds *et al.* 1994; Donnelly & Reynolds 1996) were criticised on statistical grounds (McCarthy *et al.* 1994). It is clear from the information now available concerning changes in the silver eel populations, that predictions made concerning the decline of the fishery in the upper versus lower catchments areas (Donnelly & Reynolds 1996) have not been substantiated. However, improved monitoring of recruitment, including annual observations on natural movements of juvenile eels and full documentation of stock enhancement measures (Reynolds *et al.* 1994, McCarthy & Cullen 2000), and better knowledge of spawning eel escapement from the system (McCarthy *et al.* 1994) means that in future it may be possible to develop a predictive model that would facilitate better management and conservation of the eel stocks of the Shannon.

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References

Bergersen, R. & A. Klemetsen, 1988. Freshwater eel *Anguilla anguilla* (L.) from north Norway, with emphasis on occurrence, food, age and downstream migration. – Nordic Journal of Freshwater Research. *64*: 54-66

Bowman J.J., 1998. The Shannon. – *In* C. Moriarty (ed.): Studies of Irish Rivers and Lakes, pp. 169-189. Marine Institute, Dublin.

Colombo, G. & G. Grandi, 1996. Histological studies of the development and sex differentiation of the gonad in the European eel. – Journal of Fish Biology *48*: 493-512.

Cullen, P. & T.K. McCarthy, in press. The effects of artificial lights on the distribution of catches of silver eels (*Anguilla anguilla*, L.) across the Killaloe eel weir, in the lower River Shannon. – Biology and Environment.

Deelder, C.L., 1970. Synopsis of biological data on the eel *Anguilla anguilla* Linnaeus, 1758. – FAO. Fisheries synopsis. 80 pp.

Donnelly, R.E., J.D. Reynolds & T. Walsh 1996. The management of glass eels in the Shannon estuary, Ireland. – Archives of Polish Fisheries *4*(2a): 211-221.

Frost, W.E., 1950. The eel fisheries of the River Bann, Northern Ireland and observations on the age of silver eels. – Journal du Conseil, Conseil International pour l'Exploration de la Mer *16*: 358-383.

Hadderingh, R.H., J.W. van der Stoep & J.M.P.M. Habraken, 1992. Deflecting eels from water inlets of power stations with light. – Irish Fisheries investigations Ser. A (Freshwater) *36*: 78-87.

Kennedy, C.R. & K.U. Vickers, 1993. The fish of Lough Neagh (part b). Investigations on salmon (*Salmo salar* L.) and eels (*Anguilla anguilla* L.) in the River Lower Bann. – *In* R.B. Wood & R.V. Smith (eds): Lough Neagh, the ecology of a multipurpose water resource. pp. 397-417. Kluwer Academic Publishers, Dordrecht.

Lowe, R.H., 1952. The influence of light and other factors on the seaward migration of the silver eel *Anguilla anguilla*, L. – Journal of Animal Ecology *21*: 275-309.

McCarthy, T. K., P. Cullen, K. Faherty & M.M. O'Farrell, 1994. River Shannon Silver Eels, Population biology, factors influencing downstream migration and commercial fishing. – A report presented to the Electricity Supply Board, Dublin, July 1994. 44 pp.

McCarthy T.K., M.M. O'Farrell, P. McGovern, P. Buckley & L. Copley, 1997. Eels part 1: Management of juvenile eels stocks for fishery enhancement. – Aquaculture Explained *19*: 56 pp. Bord Iascaigh Mhara, Irish Sea Fisheries Board, Dublin.

McCarthy T.K. & P. Cullen, 1998. The River Shannon Eel Fishery: Research, Commercial Development and Conservation. – A report presented to the Electricity Supply Board, Dublin, 1998. 21 pp.

McCarthy T.K. & P. Cullen, 2000. Eel fishing in the River Shannon: Eel population changes, fishery management options and fishery conservation issues. A synthesis report on the River Shannon eel Management Programme 1992-2000. – A report presented to the Electricity Supply Board, Dublin, March 2000. 21 pp.

McCarthy, T.K., P. Cullen & W. O'Connor, 1999. The biology and management of River Shannon eel populations. – Fisheries Bulletin (Dublin) *17*: 9-20.

McGrath C.J., D.P. O'Leary, P.J. Sharkey & D.F. Murphy, 1976. Experimental electrical guidance system for eels at the Killaloe eel weir on the River Shannon. Eel research and management, July 1979, – Rapports et Procès-Verbaux des Réunions, Conseil International pour l'Exploration de la Mer *174*: 22-31.

Moriarty, C., 1990. Short note on the silver eel catch of the lower River Shannon. – Internationale Revue der gesamten Hydrobiologie *75*(6): 817-818.

O'Leary, D.P., 1971. An account of some experiments in fishing eel nets in Ireland. – EIFAC Technical Paper *14*: 129-142.

Parsons, J., K.U. Vickers & Y. Warden, 1977. Relationship between elver recruitment and changes in the sex ratio of silver eels *Anguilla anguilla* L. migrating from Lough Neagh, Northern Ireland. – Journal of Fish Biology *10*: 211-229.

Poole, W.R. & J.D. Reynolds, 1990. Observations on the silver eel migration of the Burrishoole river system, Ireland, 1959-1988. – Internationale Revue der gesamten Hydrobiologie *75*: 807-815.

Poole, W.R. & J.D. Reynolds, 1998. Variability in growth rate in European eel *Anguilla anguilla* (L.) in a western Irish catchment. – Biology and the Environment *98*B(3): 141-145.

Quigley, D. & T. O'Brien, 1996. The River Shannon eel fishery – a management review. – Archives of Polish Fisheries *4*(2a): 249-266.

Reynolds J.D., R. Donnelly, S. Molloy & T. Walsh, 1994. Glass Eel, Elver and Juvenile Eel Programme: Final Report, July 1994. – A report presented to the Electricity Supply Board, Dublin, 1994. 118 pp.

Tesch, F.-W., 1977. The Eel, Biology and Management of Anguillid Eels. – Chapman and Hall, London. 433 pp.

Vøllestad, L.A., B. Jonsson, N.A. Hvidsten, T.F. Haesj, O. Haraldstad & J. Ruud-Hansen, 1986. Environmental factors regulating the seaward migration of European silver eels. – Canadian Journal of Fisheries and Aquatic Science *43*: 1909-1916.