THE EUROPEAN SMELT *OSMERUS EPERLANUS* L. IN IRELAND: GENERAL BIOLOGY, ECOLOGY, DISTRIBUTION AND STATUS WITH CONSERVATION RECOMMENDATIONS

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ABSTRACT

The European smelt *Osmerus eperlanus* L. is listed in the Irish Red Data Book as vulnerable. Known from only a few locations around Ireland, its distribution appears to be disjunct and all populations confined to estuarine habitats. The current paper gives an overview of the species' ecology, biology, status and known distribution in Ireland today, with emphasis on the resident population on the River Shannon from which they were first described in Ireland.

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INTRODUCTION

The European smelt is a small- to medium-sized, slender, silvery, shoaling fish with a characteristic cucumber smell. It is normally found in coastal waters and estuaries from southern Norway, around the western coast of Europe (including the Baltic Sea), to north-western Spain. The species is tolerant of a wide salinity range, and several non-migratory, purely freshwater populations occur (Hutchinson and Mills 1987).

Smelt have large cycloid scales and eyes, and a large mouth with a projecting lower jaw. The jaw, tongue and vomer bones are armed with large teeth and, in common with salmonids and coregonids, the smelt has a fleshy adipose fin. The normal size range in Europe is 10–20cm, with occasional specimens reaching 30cm (Maitland and Campbell 1992).

Although the existence of smelt in Ireland was not authenticated until the 1940s (Kennedy 1948), the species had been caught regularly by netsmen in the Shannon Estuary (M. Kennedy, pers. comm.). Here they are referred to as 'stinkers', due to the strong smell that lingers in a boat or on fishing nets if smelt are left dead in them for a day or more.

In certain parts of Europe, smelt are harvested for human consumption and animal feed (Cihar 1981; Lyle and Maitland 1997). In Ireland, they were formerly taken from the River Shannon in Limerick for both local consumption and for export (R. Cusack, pers. comm.). While exploitation of smelt from the River Shannon still continues on a relatively small scale, the primary purpose is not for food, but as an angling bait for pike *Esox lucius* L.

Apart from some basic artificial rearing experiments carried out by the former Inland Fisheries Trust during the early 1970s (Inland Fisheries Trust 1971; 1972), as well as some data on age determinations (Bracken and Kennedy 1967), very little has been published on the biology of smelt in Irish waters so far.

METHODS

The authors examined published and unpublished literature that dealt with aspects of smelt in Ireland. Additional unpublished material is also presented, including anecdotal records and information from fishermen. Data were gathered during investigations by the Shannon Regional Fisheries Board into the species in the Shannon Estuary. Adult smelt specimens were collected from anglers fishing for smelt during their annual spawning run through the Shannon at Limerick city.

Juvenile specimens were captured as a bycatch in conical nets set for glass eels in tidal tributaries of the lower Shannon (Igoe *et al.*, this volume). Smelt spawning beds were identified through visual inspection, and egg counts were taken during the spawning seasons from 2001 to 2003. The Shannon is Ireland's largest river system, draining a catchment area of 11,700km^2 upstream of Limerick city. The river is regulated in its lower reaches by Parteen weir near Parteen village in County Clare. This weir supplies water to Ardnacrusha hydroelectric station, which is

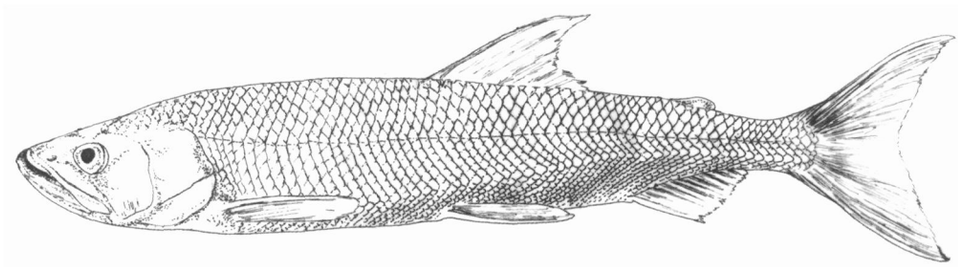

Fig. 1 — The European Smelt *Osmerus eperlanus* L. Drawing by Mr Billy Clark of a specimen taken in Limerick city during the 2001 spawning run.

located at the tidal head, approximately 2km upstream of Limerick city. As the Shannon Estuary is Ireland's largest estuary, the smelt population in the Shannon is probably the largest in Ireland.

DISTRIBUTION OF SMELT

Smelt is regarded as an indigenous species in Irish waters (Quigley 1996b; 1996c; Quigley and Flannery 1996). However, its distribution in Irish waters still appears to be very localised (Went and Kennedy 1976). Fig. 2 shows the known distribution of smelt in Irish waters today. The occurrence of smelt in Irish waters was only confirmed in 1948, when it was described from the River Shannon (Kennedy 1948). However Kennedy acknowledged that the species was known in the area for some time. Since then, smelt (adult and/or juvenile) have been recorded from nearly all of the rivers entering the Shannon Estuary, including the Fergus (Bracken and Kennedy 1967; Inland Fisheries Trust 1970), the Maigue and Feale (O'Connor 2002), and smaller tributaries such as the Rine, Owenogarney and the Landstown Rivers.

The species has also been found in the Foyle Estuary (Vickers 1974; Vickers and Watson 1974; Minchin and Molloy 1978) and River Suir (Quigley 1996a) and from inshore waters at Larne, Co. Antrim, and Belfast Lough, Co. Down (Moorehead and Service 1992).

More recently smelt have been confirmed from the Rivers Barrow (S. Berridge, pers. comm.) and Suir (Quigley 1996a). The River Nore is a sister river to these major rivers, and it is probable that smelt also occur there, as samples have been collected in Waterford Estuary, into which all three rivers drain (Doherty 1999). Specimens are now regularly encountered by snap-net fishermen from the Waterford Estuary up to Carrick-on-Suir (A. Cullagh, SRFB, pers. comm.). In the autumn of 1999, anglers in the nearby River Blackwater (Co. Cork) also captured two specimens (W. Roche, CFB, pers. comm.).

HISTORICAL REFERENCES TO SMELT IN THE LITERATURE

Quigley (1996a) reviewed the distribution of European smelt *O. eperlanus* in Irish waters. He noted that there were several references to the occurrence of smelt or smelt-like fish in Irish waters dating back to the late seventeenth century (Rutty 1772; Smith 1750; Browne 1774; Dubourdieu 1802; O'Flaherty 1846). However, for many years it was generally accepted that these anecdotal accounts probably referred to the atherine or sand smelt *Atherina presbyter* Valenciennes, an unrelated species (Thompson 1856; Day 1880–4; Farran 1946; Kennedy 1948; Bracken and Kennedy 1967). Thompson (1856) was of the opinion that the *O. eperlanus* did not occur in Irish waters, and this view seems to have persisted until the mid 1940s, when Farran (1946) remarked that *O. eperlanus* was still a 'very doubtful native to Ireland.'

Templeton (1837) appears to have been the only author who specifically referred to the occurrence of *O. eperlanus* in Irish waters prior to its definitive identification by Kennedy (1948). Although he gave no specific details regarding location, Templeton remarked that 'it is sometimes taken on our coasts in considerable abundance; but, often, several years intervene during which they are rarely met with.'

There is circumstantial evidence that smelt may have frequented the River Corrib Estuary during the seventeenth century. In 1684, O'Flaherty (1846) stated:

> 'Here (in Lough Corrib) is another kind of fish which hath recourse to the sea as the salmon (*Salmo salar* L.) yearly to and fro, they are called Chops, and in Gaelic Trascain, very like herrings (*Clupea harengus* L.) only that herrings come not into freshwater.'

Although Farran (1946) suggested that the fish in question was almost certainly a species of shad *Alosa* sp., he acknowledged that it might also have been a type of 'smelt'. He noted that a phonetically similar Gaelic name (*Trosgan*) was used in various

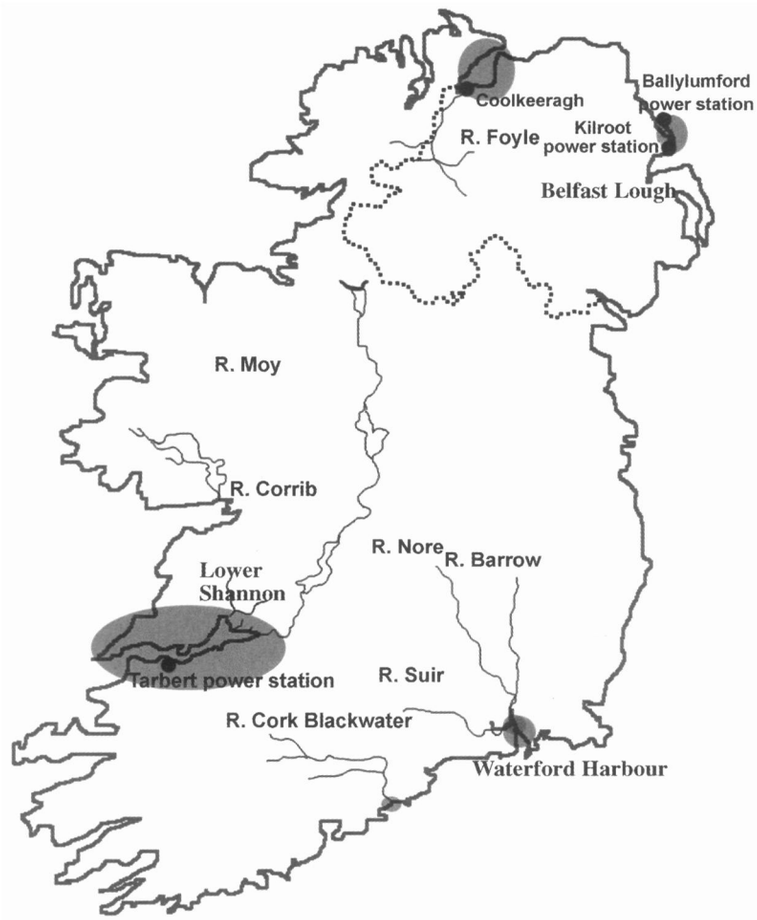

Fig. 2 — Known distribution of smelt in Ireland.

parts of Ireland to describe 'smelt', and that the name *Trascain* was specifically used in County Kerry to describe *A. presbyter*. While *A. presbyter* is known to occur in Galway Bay (O'Connell *et al*. 1992) and is commonly found in estuarine areas, it is not known to penetrate into freshwater like *O. eperlanus*. Although *O. eperlanus* has never been positively identified from Galway Bay, or indeed the Corrib, it is possible that the species may have frequented the Corrib prior to the construction of the present flood control weir in Galway city.

BIOLOGY AND ECOLOGY

Smelt has been variably described as a coastal water, estuarine (Maitland and Lyle 1990) and sea inhabitant (Cihar 1981; Pecl *et al*. 1995). It is tolerant of a wide range of salinities, and exclusively freshwater populations occur in some lakes in southern Norway, Finland and Sweden (Hutchinson and Mills 1987). Although a single smelt specimen was recorded in the stomach of a cormorant on the Little Saltee Island in County Wexford (West *et al*. 1975), there are few, if any, strictly marine records, and this specimen could have been swallowed in a nearby estuary. Maitland and Campbell (1992) considered smelt populations in Great Britain to be relatively local and probably confined to their estuaries. It is likely that Irish populations of smelt are similarly confined. These populations are anadromous: the majority of their life is spent living and feeding in the estuary, returning only for a brief period to spawn in freshwater. Commercial salmon netsmen carry out draft netting in the Cashen (estuarine River Feale) or drift their nets along most of the Shannon Estuary from the confluence of the River Feale upstream to Coonagh (3km downstream of Limerick city) and throughout the Fergus Estuary. During these netting exercises, smelt often get caught by their own teeth in the salmon nets, sometimes in considerable numbers. In 2001 the Shannon Regional Fisheries Board circulated questionnaires to commercial salmon netsmen, requesting information on the distribution of

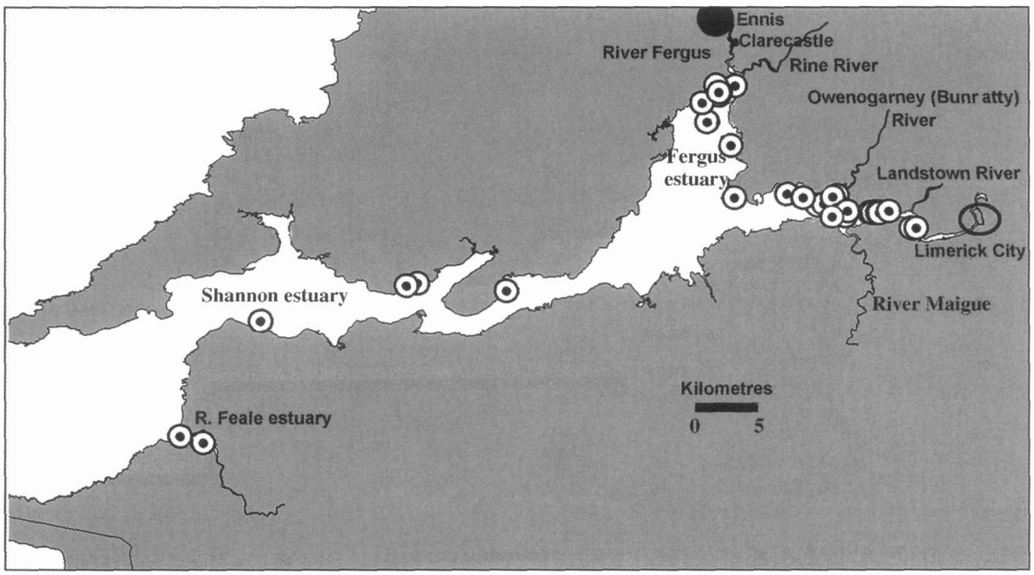

Fig. 3 — The lower Shannon at Limerick city. Spawning locations are highlighted in black.

smelt in the Shannon Estuary. Over 60% of the fishermen participated in the survey. Fig. 2 shows the distribution of smelt captured in the salmon nets, and it is evident that the greatest concentrations occurred in the upper Shannon and Fergus estuaries. These areas correspond to relatively shallow waters underlain by extensive mud flats. No smelt were recorded over deeper water or in the outer estuary.

Some information on juvenile smelt distribution can be deduced from studies of the bycatch of a pilot glass eel *Anguilla anguilla* fishery in the Shannon Estuary. O'Connor (2002) studied the bycatch from this fishery from 1997 to 1999 and found that juvenile smelt were an important component of the fish community in upper areas of the estuary. Smelt were the second most abundant fish (out of a total of 16 fish species) after three-spined stickleback *Gasterosteus aculeatus* L., accounting for 8.4% of all bycatch ($n = 79{,}000$). Mean weight of smelt ($n = 760$) recorded at one site (Bunratty or Owengarney Estuary) was 2.78g ($\pm$ 0.12g, $\alpha = 0.05$, range 0.28–11.54g).

GROWTH AND LIFESPAN

Fig. 4 shows a length frequency distribution for smelt from the River Shannon at the same time of year, combining the bycatch of conical nets set for glass eel and spawning smelt taken in dip nets by anglers fishing for bait. In 2002, the largest Shannon smelt examined was 20cm ($n = 19$) and in 2001 ($n = 73$) the largest was only 17.8cm. Smelt captured using conical nets, set from bridges over tidal sections of tributaries of the River Shannon on the flooding tide, were predominantly age 0+ fish, with the occasional 1+ smelt taken. These fish were associated with lamprey (both ammoecoetes and transforming river lamprey), three-spined stickleback, pipe fish, sprat and glass eels. Therefore the graph shows the length distributions for three age classes of smelt (0+ = 1, 1+ = 2 and 2+ = 3 years old) from the Shannon Estuary. The maximum age recorded for smelt from the River Shannon is 3+ (four years old) (Geraghty 1996). Doherty (1996), however, recorded smelt up to 26cm in length and up to 5+ years old in the Waterford Estuary. In Scotland, Hutchinson and Mills (1987) recorded smelt up to 28cm in length on the River Cree.

Growth data for River Shannon smelt are presented in Fig. 5. These results are similar to those recorded by Bracken and Kennedy (1967) for River Shannon smelt, and they illustrate that smelt grow quickly in the Shannon Estuary. Doherty (1999) calculated the growth of smelt from the Waterford Estuary, and although he recorded more age classes from the Waterford population, the growth of the first three compares favourably with the River Shannon.

SPAWNING POPULATION CHARACTERISTICS

Fig. 4 also shows the age–class composition of the sample of spawning smelt recorded from the River Shannon at Limerick city in 2002. All fish were mature, and the sample only comprised of two age

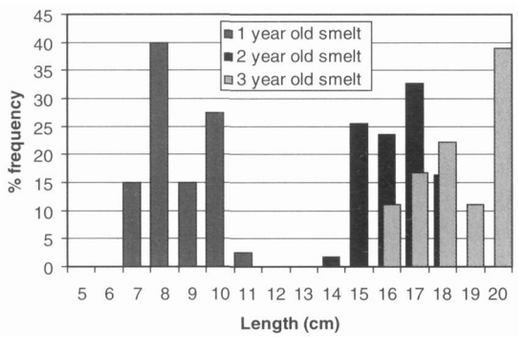

Fig. 4 — Length frequency data of smelt from the Lower Shannon/estuary. 0+ = 1 year old smelt taken in conical nets in the River Rine, Co. Clare on 4/2/02 ($n = 12$), 17/2/03 ($n = 1$), 4/3/03 ($n = 13$). 1+ = 2 year old ($n = 55$) and 2+ = 3 year old ($n = 18$) smelt taken on 17/02/02 by dip net on the River Shannon at Limerick City.

classes (75% were 1+, and the remainder were 2+ fish). Of these fish, 81% were male (82% of 1+ were male and 78% of 2+ were male). Hutchinson and Mills (1987) noted that at the early stages of the spawning run on the River Cree the ratio was close to unity, but as the run progressed males became more dominant. This shift has also been noted in other studies cited by Hutchinson and Mills (1987) and is attributed to females dropping out of the river after spawning, while the males continue to spawn with other females. It is likely therefore that the 2002 River Shannon sample was taken at the latter end of the spawning run, as Bailey (1964) showed that spawning activity of rainbow smelt *Osmerus mordax* (Mitchill) reached a peak when sex ratios approached unity. The average fork length of the spawning smelt taken in 2002 was 15.7cm and ranged from 13.5cm to 20cm. These lengths are similar to those reported by Bracken and Kennedy (1967) for a small sample of smelt taken from the same area. A sample of smelt that perished during a fish kill in 2001 was also measured. These fish (69% 1+, 31% 2+, $n = 13$) had a mean length of 16.4cm (range 12.8–17.4cm).

A hydroacoustic survey was undertaken in a large pool downstream of Curragour Falls, on the River Shannon in Limerick city, in the middle of the 2002 spawning run. A length–frequency distribution based on the targets encountered was calculated and is presented in Fig. 6. This frequency distribution is similar to that calculated from actual fish lengths measured in 2002, showing that the majority of smelt in the river section at that time had lengths corresponding to the 1+ and 2+ age groups. A few larger fish were noted, however, which could either have been large smelt or brown trout. Geraghty (1996) noted the presence of (3+) four-year-olds in a sample of River Shannon smelt taken on 23 March 1995, and Kennedy (1948) commented that 6oz (171g) fish were not uncommon. It is likely therefore that there are larger smelt in the Shannon Estuary, as recorded by Doherty (1999) for the Waterford Estuary.

SPAWNING RUN AND SPAWNING GROUND CHARACTERISTICS

In Scotland, the adult smelt migrate upstream from the estuaries and into the lower reaches of large clean rivers between January and April (Lyle and Maitland 1997). Spawning in the River Shannon takes place between the end of February and early April. Hutchinson and Mills (1987) and Lyle and Maitland (1997) suggest that temperature and moonlight are probably the main factors that influence the timing of smelt spawning runs. The actual spawning timing is most likely the consequence of the cumulative effect of a number of environmental triggers (Rupp 1959). Various researchers have found that the spawning initiating temperature for *Osmerus* spp ranges from 4°C–7°C (McKenzie 1958), 8°C–9°C (Scott and Crossman 1973), <4.4°C–5.5°C (Bigelow and Schroeder 1953), 4°C–6°C (Kuznetsov 1976), and >4°C (Rembiszewski 1970). Hutchinson and Mills (1987) noted that smelt began their ascent from the estuary at >5°C. Temperatures in the range of 4.5°C–5°C were recorded in the lower Shannon at the time of arrival of smelt into Limerick city and subsequent spawning in 2001 (Fig. 7). Inland Fisheries Trust (1972) found eggs at early stages of development on moss in the lower Shannon on 4 March 1971, when the water temperature was 6.4°C.

In Scotland, spawning can last anywhere from a few days up to two weeks, depending on prevailing environmental conditions. The fish usually congregate in the lower reaches of these rivers for a number of days prior to moving upstream to spawn. Females are highly fecund and can carry as many as 106,000 eggs, although the average is about 50,000 eggs (Hutchinson and Mills 1987). These eggs are adhesive and are deposited on a range of substrates around the limit of the tidal influence.

A study of the spawning areas of smelt in the lower Shannon found that the maximum spawning effort appeared to take place immediately downstream of the Ardnacrusha hydroelectric power station, in the lower reaches of the river (Fig. 8). This area also corresponds with the maximum tidal influence on the river. High densities of smelt ova were found in moss (*Fontinalus* sp.) attached to the concrete wall along the right bank immediately below the

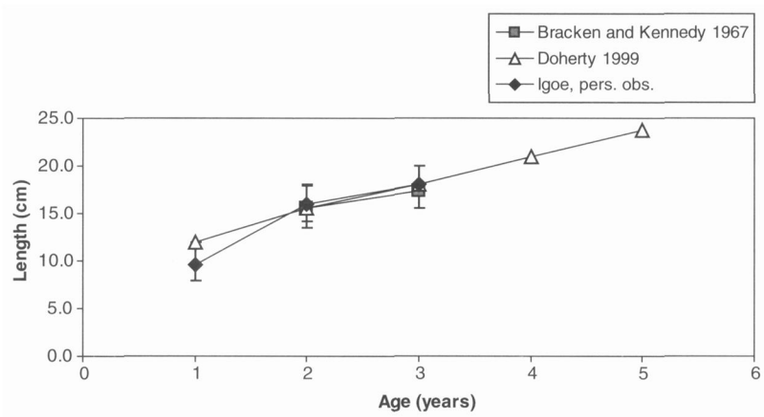

Fig. 5 — Growth rate of smelt from the River Shannon, based on smelt captured by conical nets and dip nets (February/March 2002) and historical Shannon data (Bracken and Kennedy 1967). Waterford estuary estimates from Doherty (1999).

dam (fronds up to 15cm long were found on a 60m-long section of wall). Average egg density along this wall in 2001 was approximately ($463{,}000 \pm 203{,}000$, $\alpha = 0.05$) eggs m^{-2}. The estimated total number of eggs in this location was (58 million $\pm$ 25 million, $\alpha = 0.05$), or equivalent to the egg deposition of approximately 1,200 females (Igoe, pers. obs.). Spawning also took place along the tail race of the hydroelectric station, in moss attached to alder (*Alnus alnus*), some of which is intermittently submerged along the banks of the channel, and on the moss covered blast rock banks. These egg densities were lower than those recorded at the dam, although an occasional dense cluster of non-viable eggs was observed (Igoe, pers. obs.).

Water levels in the tail race can fluctuate rapidly by as much as several meters, due to the influence of water regulation and tides. Eggs along the upper layers of the moss in the tail race are vulnerable to desiccation, and Lyle and Maitland (1997) point out that excessive exposure of smelt eggs will result in high mortalities. However, the moss at the tail race is relatively dense, and eggs laid in the underlayers of this moss were viable, even after a heavy frost (N. Roycroft, pers. comm.). The Inland Fisheries Trust (1970) concluded that very large numbers of eggs occur in the lower moss layers at this location and that these hatch successfully. Hatching normally occurs after 20–35 days depending on temperature. After hatching, the larvae passively drift downstream into the estuary, where they begin to feed on zooplankton. Tow netting in the tail race on 21 April captured large numbers of larvae, many with yolk sacs still in place (Inland Fisheries Board 1970). Efforts were made to locate eggs along the tidal limit of the old channel route of the River Shannon. This channel now has a reduced discharge as a result of the construction of the Ardnacrusha power station and the tail race. Inspections were made along an area known as the Lax Weir in 2001 or 2002 without any success. The channel offers ideal spawning substrates—cobble, gravel and boulders and some woody debris—all with an ample covering of aquatic mosses. This raises the question, where did the smelt spawn prior to the construction of Ardnacrusha Dam?

Spawning smelt have been observed on the River Fergus (Bracken and Kennedy 1967) in Ennis Town. This spawning population was confirmed for the River Fergus, when in 2002 smelt eggs were recorded on the Fergus near Clarecastle outside Ennis Town. These eggs had obviously drifted down from upstream. Subsequent investigations to pinpoint the spawning beds of the smelt on the Fergus were unsuccessful due to high water levels and turbidity.

The River Shannon in Limerick city (along the concrete walls on both Clancy's and O'Callaghan's strands) and along the Ardnacrusha tail race, and the River Fergus in Ennis Town are essentially heavily modified channels, and until recently were the only areas where smelt spawning grounds had been positively identified. In 2002 a smelt spawning ground was located along the lower Owenogarney River, near Six Mile Bridge in County Clare (Igoe, pers. obs.). Snorkelling at the site in 2003 confirmed it as an area extensively used by spawning smelt. Here the smelt spawn in a broad, braided channel with a gravel cobble substrate, and the nature of the site may reflect a natural or unmodified smelt spawning area for Ireland.

FEEDING

Smelts are voracious predators of both zooplankton and fish (Moyle and Cech 1999). Bracken and Kennedy (1967) noted that a small sample of smelt taken from the Fergus Estuary near Clarecastle were

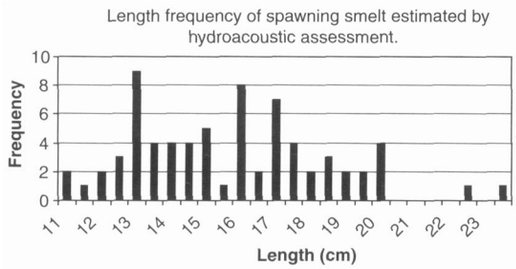

Fig. 6—Length frequency distribution data for smelt immediately downstream of Curragour falls, River Shannon, Limerick City. Transects run between 14.00 and 15.00 on 17/02/02, on flood tide, gale force 8 winds.

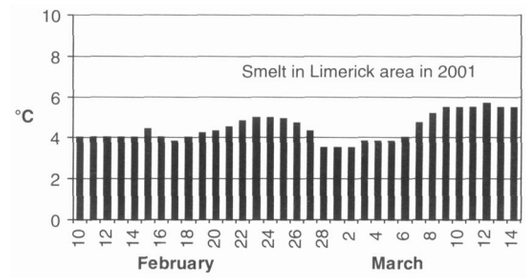

Fig. 7—Duration of smelt run in River Shannon at Limerick City in 2001, based on observations (S. Quinlivan, pers. comm.), and corresponding temperatures from Parteen Hatchery, Lower Shannon.

predominantly feeding on *Crangon* sp. In Waterford Estuary, smelt were found to be feeding almost exclusively on *Praunus neglectus* (Doherty 1999). Other macroinvertebrates such as *Hyperia galba* and *Crangon crangon* were also noted. Larger smelt tended towards piscivory, and *Merlangus merlangus*, *Sprattus sprattus* and smelt were noted, particularly during summer months. Cannibalism can be high among smelt populations, reflecting high density, dependent interactions for the species (Sepulveda *et al.* 1993).

OTHER WILDLIFE

It is likely that smelt are important as a prey fish to other estuarine wildlife, at least at certain times of the year. Inland Fisheries Board (1970) noted that smelt were probably abundant in the Shannon Estuary and concluded that these shoals could be an attraction to slob brown trout *Salmo trutta* L. and sea bass *Diecentrachus labrax* L. The occurrence of smelt in Limerick city coincides with increased numbers of cormorants and herons *Ardea cinera* in the area. Local anglers believe that smelt may be important for reconditioning spent slob trout within the city and downstream prior to the elver run as trout have been caught with stomachs full of smelt (S. Quinlivan, pers. comm.). Doherty (1998) found that the diet of allis shad *Alosa alosa* L. in the Waterford Estuary included smelt. In other European countries smelt form an important food base for commercially exploitable fishes (Thiel *et al.* 1996).

STATUS

The Irish Red Data Book (Whilde 1993) describes the status of smelt as 'vulnerable'. Although new populations have been discovered within the last ten years (Quigley 1996a; this paper), data to date suggest that smelt have a limited distribution in Ireland. Information is not yet available to accurately assess the status of smelt in Ireland, although negative experiences in other countries (Maitland and Lyle 1997) suggest that the 'vulnerable' description (Whilde 1993) appears to be warranted. Spawning sites have only been recorded for sites associated with the Shannon/Fergus Estuary. Clearly, there is a need to investigate the distribution of smelt in Ireland in a systematic manner and determine the status of the species nationally with more accuracy.

THREATS AND PROPOSED CONSERVATION MEASURES

Overexploitation, erection of barriers and water quality deterioration threaten many European smelt populations, and local populations are easily driven to extinction (Hutchinson and Mills 1987; Maitland and Lyle 1990). Similar threats probably pertain to Irish populations. In 2001 over 10,000 smelt that had migrated up the River Shannon to spawn perished in a fish kill; the cause of which was never identified. Analysis of tissue from the affected fish showed elevated levels of aluminium. Subsequent to this event, a number of diesel and oil spillages occurred in the general area, possibly further stressing survivors and reducing egg survival. In 2003 the Limerick city annual smelt spawning run only lasted one night, and egg densities were very low compared to 2001. This short spawning run and subsequent low egg deposition rate in 2003 are probably a direct result of the 2001 fish kill. Approximately 70% of the spawning populations in the Shannon is made up of 1+ fish (this paper; M. Kennedy, pers. comm.), and in 2003 these fish would correspond to the 2001 age class. This is a clear indication of the vulnerability of Irish smelt to perturbations in the estuary.

Sepulveda *et al.* (1993) conclude that further river regulation on the Elbe could adversely affect the smelt in that region, particularly if spawning beds are affected. Concerns about the impact

Fig. 8—Spring/summer distribution of smelt in the Shannon estuary deduced from a questionnaire sent out to commercial netsmen. Most of these fish are adult smelt entangled by their teeth. Tributaries where juvenile smelt have been recorded are also shown.

that dredging may have on smelt and other fish species in the Shannon led to the formation of environmental windows for two major projects in the estuary (Igoe 2002; Igoe and Fitzsimons 2002). In 2002 smelt were monitored at their spawning sites in Limerick city to ensure that sufficient adults had successfully migrated to the spawning grounds, before dredging across the Shannon Estuary to lay the gas pipeline to the west took place. Similar but more detailed studies have been carried out in other countries, where dredging may affect smelt populations. For example, concerns about the possible effects of proposed dredging of the Lower Columbia River, USA, on the eualachon smelt *Thaleichthys pacificus* has led to extensive studies in the United States (e.g. Howell and Uusitalo 2001).

It is likely that the erection of weirs on some Irish rivers could have adversely affected smelt populations, but there is a lack of historical data. Overfishing of smelt has never been formally identified in Ireland, and again there is not much in the way of historical data. The authors know of no Irish fishery for smelt for food. However, smelt have been taken in large numbers in Limerick city in certain years for use as pike angling bait. Again no accurate census of numbers taken has been compiled, and the impact that this may have, if any, on the population is unknown.

DISCUSSION

To date spawning populations of smelt have been recorded in only three Irish locations (Foyle, lower Shannon, and Suir, J. King, pers. comm.), although it is likely that spawning populations occur within other estuarine systems, particularly along the south coast. Experience elsewhere, particularly in Britain, shows that smelt are vulnerable to a number of threats. A recent fish kill in the lower Shannon illustrates similar vulnerability for Irish populations. Therefore it is prudent to be concerned about the long-term status of the few known Irish populations.

To determine the status and conservation requirements of any species, an understanding of its biology, distribution and abundance, and a means of monitoring changing trends in populations are needed (Swaby and Potts 1991). It is clear that very little is known about the current status of smelt in Irish waters, and this lack of basic information is of particular concern. The presence and status of smelt in all river and estuarine systems containing the species should be established as a priority. Where smelt are known to occur, action plans should be developed even in the absence of robust data sets from the relevant localities. Supplementary information from other countries could be used for this exercise in the short term. The importance of smelt for fish stocks and other estuarine wildlife requires investigation.

Smelt are not listed as a species requiring Special Areas of Conservation (SAC) under Annex II of the European Habitats Directive and, therefore, are not afforded specific protection under this legislation. However, sites where smelt do occur but do not necessarily spawn (e.g. the lower Shannon) will get SAC status and, therefore, will be afforded some protection. Although listed in the Irish Red Data Book (Whilde 1993) as a vulnerable species, smelt will not be afforded protection under the Wildlife Act 2001. Existing fisheries legislation in Ireland is aimed more at the conservation of fish as an exploitable resource rather than recognising their heritage value and protecting them as an element of our native fauna. Clearly a shift in emphasis in fisheries legislation to include the conservation of threatened fish species is required to improve their protection. Limited protection could be given to threatened fish species such as smelt by the enactment of specific by-laws under the Fisheries Consolidation Act 1959, prohibiting fishing in specified waters, imposing close seasons for angling and commercial fishing, specifying size and catch limits and designating protected spawning and nursery areas. This act was recently used in order to provide specific protection for sea trout, eel and sea bass. If this cannot be achieved, then the inclusion of protection measures for smelt under the Wildlife Act should be considered.

REFERENCES

Bailey, M.N. 1964 Age, growth, maturity and sex composition of the American smelt, *Osmerus mordax* (Mitchill), of western Lake Superior. *Transactions of American Fisheries Society* **93,** 382–95.

Bigelow, H.B. and Schroeder, W.C. 1953 Fishes of the Gulf of Maine. *Fisheries Bulletin of the US Fish and Wildlife Service* **74**, 133–9.

Bracken J. and Kennedy, M. 1967 Notes on some Irish estuarine and inshore fishes. *Irish Fisheries Investigations* Series **B** (3), 1–28.

Browne, P. 1774 Monthly chronologer for Ireland: catalogue of fishes observed on our coasts, and in our lakes and rivers, classed and disposed according to Linnaeus. *Exshaws's Magazine* August, 515–16.

Cihar, J. 1981 *A guide in colour to freshwater fish*. Blitx editions. Leicester. Bookmark.

Day, F. 1880–4 *The fishes of Great Britain and Ireland*. London and Edinburgh. Williams and Norgate.

Doherty, D. 1999 Studies on the parasite assemblages and general biology of some rare and endangered Irish fishes. Unpublished PhD thesis, National University of Ireland, Galway.

Dubourdieu, J. 1802 *Statistical survey of the county of Down* (Royal Dublin Society Statistical Survey). Dublin. Graisberry and Campbell.

Farran, G.P. 1946 Local names of Irish fishes. *Irish Naturalists' Journal* **13**, 370–6.

Geraghty, F. 1996 Studies on smelt, *Osmerus eperlanus* (L.), and pollan, *Coregonus autumnalis pollan* (P.), from the River Shannon, with particular reference to their parasite assemblages. Unpublished BSc thesis, National University of Ireland, Galway.

Howell, M.D. and Uusitalo, N. 2001 Eulachon (*Thaleichthys pacificus*) studies related to lower Columbia river channel deepening operations. Annual Report by the Oregon Department of Fish and Wildlife to the U.S. Army Corps of Engineers, Portland, Oregon.

Hutchinson, P. and Mills, D.H. 1987 Characteristics of spawning-run smelt, *Osmerus eperlanus* (L.) from a Scottish river, with recommendations for their conservation and management. *Aquaculture and Fisheries Management* **18**, 249–58.

Igoe, F. and Fitzsimons, M. 2002 Impact of the proposed gas pipeline to the west on fish stocks, with particular reference to migratory fish; River Shannon, River Fergus, and Ballycorick. Report prepared for M.C. O'Sullivan & Co. Ltd.

Igoe, F. 2002 The fish fauna of the Upper Shannon Estuary in the vicinity of the Limerick Southern Ring Road II Crossing at Coonagh, with particular reference to migratory fish species. Report prepared for M.C. O'Sullivan & Co. Ltd.

Inland Fisheries Trust 1970 *Annual report of the Inland Fisheries Trust, 1969–1970.*

Inland Fisheries Trust 1971 *Annual report of the Inland Fisheries Trust, 1970–1971.*

Inland Fisheries Trust 1972 *Annual report of the Inland Fisheries Trust, 1971–1972.*

Kennedy, M. 1948 Smelt in the Shannon. *Irish Naturalists' Journal* **9**, 151–2.

Kuznetsov, V.A. 1976 The reproduction, distribution and growth of juveniles of non-commercial fish species in Siyaga Bay, Kuybyshev reservoir. *Journal of Ichthyology* **16**, 746–56.

Lyle, A.A. and Maitland, P.S. 1997 The spawning migration and conservation of smelt *Osmerus eperlanus* in the River Cree, southwest Scotland. *Biological Conservation* **80**, 303–11.

Maitland, P.S. and Campbell, R.N. 1992 *Freshwater fishes*. London. Harper/Collins.

Maitland, P.S. and Lyle, A.A. 1990 Conservation of sparling and other fish in Scotland. *Journal of the Edinburgh Natural History Society* **1990**, 1–2.

Maitland, P. and Lyle, A. 1997 The smelt *Osmerus eperlanus* in Scotland. *Freshwater Forum* **6**, 57–68.

McKenzie, R.A. 1958 Age and growth of the smelt *Osmerus mordax* (Mitchill) of the Miramichi river, New Brunswick. *Journal of the Fisheries Research Board of Canada* **15**, 1313–27.

Minchin, D. and Molloy, J. 1978 Notes on some fishes taken in Irish waters in 1977. *Irish Naturalists' Journal* **19**, 265–8.

Moorhead, P.W. and Service, M. 1992 Capture of fish on screens of power stations in Northern Ireland. *Irish Naturalists' Journal* **24**, 3–8.

Moyle, P.B. and Cech, J.J. 1999 *Fishes: an introduction to ichthyology*. 5th edn. New Jersey. Prentice-Hall Engineering/Science/Mathematics.

O'Connell, M., Fives, J.M. and O'Ceidigh, P. 1992 Littoral fishes on Inishmore, Aran Islands, Co. Galway. *Proceedings of the Royal Irish Academy* **92**B, 109–31.

O'Connor, W. 2002 Non-target fish species recorded during the operation of a pilot scale glass eel fishery in the Shannon Estuary (poster). Royal Irish Academy, National Commission for Hydrobiology Annual Conference, Roscrea.

O'Flaherty, R. 1846 *West or Iar Connaught*, 1684. J. Hardiman (ed.), Irish Archaeology Society no. 27.

Pecl, K., Hisek. K. and Maly, J. 1995 *Fishes of lakes and rivers*. Leicester. Magna Books.

Quigley, D.T.G. 1996a First record of smelt *Osmerus eperlanus* L. from the River Suir, together with a review of Irish records. *Bulletin of the Irish Biogeographical Society* **19**, 189–94.

Quigley, D.T.G. 1996b Status and conservation of euryhaline fish in Irish waters. *Aquatic Conservation: Marine and Freshwater Ecosystems* **6**, 313–18.

Quigley, D.T.G. 1996c Conservation status of uncommon Irish inshore marine fishes. In B.F. Keegan and R. O'Connor (eds), *Irish Marine Science 1995*. Galway University Press Ltd.

Quigley, D.T.G. and Flannery 1996 Endangered freshwater fish in Ireland. In A. Kirchhofer and D. Hefti (eds), *Conservation of endangered freshwater fish in Europe*. Basel. Birkhauser Varlag.

Rembiszewski, J.M. 1970 Population variation of smelt, *Osmerus eperlanus* (Linneaus) in Poland. *Annals of Zoology* **22**, 263–84.

Rupp, R.S. 1959 Variation in the life history of the American smelt in inland waters of Maine. *Transactions of the American Fisheries Society* **88**, 241–52.

Rutty, J. 1772 *An essay toward a natural history of the County of Dublin*. Dublin. Sleator.

Sepulveda, A., Thiel, R., and Nellen, W. 1993 *Distribution patterns and production of early life stages of European smelt, Osmerus eperlanus L. from the River Elbe*. ICES.

Scott, W.B. and Crossman, E.J. 1973 Freshwater fishes of Canada. *Bulletin of the Fisheries Research Board of Canada* no. 184.

Smith, C. 1750 *The ancient and present state of the county and city of Cork*. Dublin. Royal Irish Academy.

Swaby, S.E. and Potts, G.W. 1991 Rare British marine fishes—identification and conservation. *Journal of Fish Biology* **37** (suppl. A), 133–43.

Templeton, R. 1837 Irish vertebrate animals: Pisces. *Magazine of Natural History* **1**, 409–13.

Thiel, R., Sepulveda, R., Kafemann, R. and Nellen, W. 1996 Environmental factors as forces structuring the fish community of the Elbe Estuary. *Journal of Fish Biology* **46**, 47–69.

Thompson, W. 1856 *The natural history of Ireland*. Vol. 4. Bohn, London.

Vickers, K.U. 1974 Occurrence of smelt *Osmerus eperlanus* (L.) in the estuary of the Foyle. *Irish Naturalists' Journal* **18**, 24.

Vickers, K.U. and Watson, P.S. 1974 Observations on the fishes recovered from the intake screens of Coolkeeragh Power Station, River Foyle, in 1973. *Foyle Fisheries Commission 22nd Annual Report*, App. 3.

Went, A.E.J. and Kennedy, M. 1976 *List of Irish fishes*, 3rd edn. Dublin. Stationery Office.

West, B., Cabot, D. and Greer Walker, M. 1975 The food of the cormorant *Phalacrocorax carbo* at some breeding colonies in Ireland. *Proceedings of the Royal Irish Academy* **75**B, 285–304.

Whilde, A. 1993 *Threatened mammals, birds, amphibians and fish in Ireland. Irish Red Data Book 2: Vertebrates*. Belfast. HMSO.