A Survey of Juvenile Lamprey Populations in the Moy Catchment






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A Survey of Juvenile Lamprey Populations in the Moy Catchment

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EXECUTIVE SUMMARY

- Three indigenous species of lamprey occur in Ireland; the non-parasitic resident brook lamprey *Lampetra planeri*, and the parasitic anadromous river lamprey *Lampetra fluviatilis* and sea lamprey *Petromyzon marinus*. All three species are listed under Annex II of the European Union Habitats Directive (92/43/EEC). This Directive requires the Irish Government to designate Special Areas of Conservation (SACs) and to maintain the favourable conservation status of these species.

- As part of ongoing assessments of Annex II species in Ireland, the National Parks and Wildlife Service (NPWS) commissioned a survey of juvenile lamprey populations in the Moy catchment. This survey was undertaken by Ecofact Environmental Consultants Ltd. during July/August 2004.

- A total of 75 sites were sampled using electrical fishing methods, while an additional 26 sites were visited but not assessed due to the absence of suitable habitat. Physical habitat measurements were also recorded at each survey site.

- The presence of at least two species of lamprey in the Moy catchment was confirmed during the current survey; sea lamprey and brook/river lamprey. The distribution and size characteristics of the *Lampetra* sp. juveniles recorded strongly suggest that brook lamprey is the main species present. It was not possible to ascertain whether river lamprey is present due to difficulties in distinguishing between brook and river juveniles. It is recommended that adult lampreys in the river be examined during the spring to confirm the presence/absence of river lamprey.

- The Moy catchment was subjected to a major arterial drainage scheme during the 1960s and the impact of this scheme on lamprey production in the catchment was probably highly significant. Many areas of the catchment can no longer support lamprey populations due to the absence of suitable habitat. However, despite the drainage works the Moy catchment remains a significant habitat for lampreys. Existing lamprey habitat in the catchment is under threat from drainage maintenance, physical impacts of farm animals, and pollution.

- Lampreys were present at 47 out of the 75 sites investigated, with *Lampetra* sp. accounting for 84.9% of the lampreys encountered by number. *P. marinus* larvae were generally confined to the Lower River Moy, but were also present in some of the tributaries, notably the River Deel.

Nominal numbers of larvae of this species were also recorded in the Upper Moy catchment. *Lampetra* sp. larvae were well distributed in the catchment but were absent from areas above natural impassable barriers, areas which have been badly damaged by arterial drainage, and polluted habitats.

- Mean minimum densities of larvae recorded was 0.10 ± 0.09 *P. marinus* m^{-2} and 0.69 ± 0.32 *Lampetra* sp. m^{-2}. These minimum densities were significantly lower that those recorded recently in other NPWS surveys of Irish rivers (i.e. Slaney and Munster Blackwater). This may reflect the poor and fragmented supporting habitats which occur in many areas of the Moy catchment – mainly as a result of the 1960' arterial drainage programme.

- Population structure varied significantly between different sub-catchments. Some areas displayed a strong presence of young-of-the-year (YOY) larvae, hatched in spring 2004, while this age group was absent in other areas. Areas with a prominent YOY year class generally also had other cohorts present. Standard length of *P. marinus* and *Lampetra* sp. larvae encountered ranged from 2.5 cm to 17.6 cm and 1.8 cm to 18.2 cm respectively.

- The relationship between lamprey abundance and environmental conditions was explored using Principle Components Analyses (PCA). Mean depth, wetted width, bank height, pool/riffle presence, shade/canopy cover and fine substrate presence were all found to be important macro-habitat predictors for juvenile lampreys. The most important micro-habitat predictor was found to be silt (%).

- During the survey, information on the distribution of other aquatic species was also recorded. A total of 15.3 Kg of other fish comprising 10 species was intercepted during the electrical fishing activities. Two previously unknown populations of the endangered Annex II listed pearl mussel *Margaritifera margaritifera* were also recorded.

- The main lamprey populations in the River Moy are currently protected within the existing SAC boundary area and no recommendations are made to extend the boundary area.

1 INTRODUCTION

Three species of lamprey (Pisces:Agnatha:Pteraspidomorphi:Petromyzontiformes) occur in Ireland. These are the brook lamprey *Lampetra planeri*, the river lamprey or lampern *Lampetra fluviatilis* and the sea lamprey *Petromyzon marinus*. All three Irish lamprey species are listed under Annex II of the European Union Habitats Directive (92/43/EEC). This directive legally protects each of these species in designated Special Areas of Conservation (SACs) and requires the monitoring and protection of lamprey species coupled with the conservation and maintenance of their preferred habitat. Prior to the Habitats Directive, protecting native lamprey populations was not a fisheries management priority in Ireland. Most of the fisheries programmes undertaken in Ireland have focused exclusively on salmonids and other species of recreational or commercial importance. As a result, there is a paucity of published scientific information on lampreys in Ireland which makes management of these species difficult in rivers such as the River Moy.

It is now appreciated that lampreys are an important element in river ecosystems. The key importance of lampreys is the fact that, together with the hagfishes, they are the sole survivors of the agnathan (jawless) stage in vertebrate evolution. Recent work on fossils in China indicates that lampreys arose over 500 million years ago. Lampreys are of high ecological value and can play an important role in processing nutrients, nutrient storage, and nutrient cycling in streams. Moreover, they also constitute a food source for other animals and can act as a buffer for salmon from predators in areas where they are abundant. It is now understood that they are susceptible to the same threats facing other native freshwater fish (i.e. pollution, barriers to migration, habitat destruction, etc.) and will require careful management and consideration in the future. The status of the three lamprey species in Ireland as a whole has been recorded as indeterminate (Whilde, 1993), largely due to the very limited records in the scientific literature. However, recent studies have greatly added to our knowledge of lampreys in Ireland. Kurz and Costello (1999) undertook a desk study which gathered information on locations where lamprey species were recorded in Ireland during the period 1960-1995, Kelly and King (2001) reviewed aspects of lamprey ecology and conservation relevant to Ireland, while King & Linnane (2004) reported the results of a survey of lamprey species in the Slaney and Munster Blackwater catchments. The current investigation is similar to the one undertaken by King & Linnane (2004) and concerns the Moy catchment, part of which is a designated SAC (River Moy cSAC, site code 002298).

Very little is known about lampreys in the Moy catchment. Kurz & Costello (1999) reported that *P. marinus* and unidentified juveniles had been recorded from the catchment. However, previous fisheries studies in the Moy catchment have had an emphasis on species of angling importance (i.e.

salmonids) and this is thought to have resulted in the under-surveying of lamprey habitats and the under-recording of lampreys. The current investigation involved electrical fishing investigations at 75 sites in the catchment and focused exclusively on juvenile lampreys. Only habitats which were physically suitable for juvenile lampreys were investigated during the current study.

The aims of the current investigation were to:-

- Establish which species of lamprey are present in the Moy catchment, and
- Assess the distribution of these species with the catchment.

This study was undertaken during the period July to September 2004 by Ecofact Environmental Consultants Ltd (ECOFACT) on behalf of the National Parks and Wildlife Service of the Department of Environment, Heritage and Local Government.

1.1 Lampreys

A full description of the three lamprey species which occur in Ireland is given in Maitland & Campbell (1992), Maitland (1980), Holcik (1986), and more recently Kelly & King (2001).

1.1.1 The Atlantic Sea Lamprey

The Atlantic sea lamprey is the largest of the anadromous parasitic lampreys and reaches lengths of up to 1.2 m and weights up to 2.3 kg. In adult form, it can easily be distinguished from the other lampreys by both it size and its sharply mottled coloration. It is widely distributed on both sides of the north Atlantic and a smaller form is landlocked in the Great lakes basin of North America. Sea lampreys have been known to undertake extensive spawning migrations, historically penetrating up to 850 km upstream on large rivers such as the Rhine and Elbe. However, there has been a marked decline over the past century in the numbers of sea lamprey entering European rivers. The decline is generally attributed to loss of habitat from both pollution and river engineering.

Sea lampreys generally spawn in areas of flowing shallow water among sand, gravel and pebbles of varying sizes (1-5 cm diameter). Spawning has also been observed at depths of 40-60 cm in currents speeds of 1-2 m^3 sec^{-1}. The nests are usually found in unshaded sites where they receive direct sunlight, often at the top of riffles or rapids where the water flow becomes calmer. In many places, the spawning sites are located below obstructions such as weirs. The nests can measure up to 1 m along their longest diameter, which is in the direction of the current and nests are often found in close

vicinity to each other. Sea lampreys are often seen spawning in areas also used for spawning by salmon, trout and other lampreys.

Spawning activity normally occurs during the months of June and July in Irish rivers. Sea lampreys are thought to be monogamous and males defend the nests from rivals. Both sexes die after spawning. An adult female sea lamprey can produce 200,000 ova, which are deposited in gravel nests excavated in suitable areas. Ova to larvae survival rates may be as low as 1% due to poor retention in the nests, low fertilization rates and predation. Sea lamprey ova will hatch in approximately 11 days at 15 ^{o} C, but the larvae do not leave the nest for 3-4 weeks after fertilization of ova. They then emerge from the nests and are carried downstream in the current.

The larvae are called 'ammocoetes' and settle in silt, gravel or clay beds in shaded areas downstream of the spawning areas. The particle size in areas that they settle is in the range of 200-400 microns, and they are normally found where stream gradients are in the range of 1.6-5.7 m/km. Within the stretches of suitable gradient, adequate sites are usually found in conditions of slowing current, where deposition of sand and silt occurs (e.g. Eddies and backwaters). The larval part of the lifecycle lasts for at least five years. Larvae live in burrows feeding on detritus, algae and diatoms. Following this period, the larvae metamorphose or transform into a sexually mature non-feeding stage known as the macrophthalmia. The timing of the downstream migration of macrophthalmia to the sea varies from autumn - spring and is dependent on the occurrence of suitable environmental stimuli.

Sea lamprey is listed in Appendix II of the Habitats Directive and Appendix III of the Bern Convention. Sea lampreys and unspecified lamprey ammocoetes have been recorded from the Moy catchment (Kurz & Costello, 1999). In addition to other areas of the Moy catchment, sea lampreys have been recorded from Loughs Conn and Lough Cullin and unspecified lamprey ammocetes have been recorded from the Manulla River.

1.1.2 The River Lamprey

The river lamprey occurs in both anadromous and landlocked forms and is normally up to 30 cm long and 60g in weight. It can easily be distinguished in adult form from *P. marinus* by its size and darker coloration. It is widely distributed in Northern Europe and historically penetrated deep into central Europe along larger river systems. As with the sea lamprey, it has shown a marked decline over the past century.

In the British Isles, lamperns generally spawn during May-June in flowing water areas among silt and gravel substrates. The particle sizes used may be smaller than those used by *P. marinus*, but similar to those used by *Lampetra planeri*. Lamperns spawn in deeper water than L. planeri, and have been recorded spawning at depths of 20-150 cm in currents speeds of 1-2 m^3 sec^{-1}. Lamperns spawn in groups and each female produces at least 7,500 ova. Incubation rates have been recorded to be 13-15 days at 13-14 ^{o} C. The 4mm larva leaves the nest and drifts downstream within 5 days of hatching and settles in silt, gravel or clay beds in shaded areas downstream of the spawning areas. After a larval period of approximately 5 years, the larvae transform into macrophthalmia and migrate downstream.

River lamprey is listed in Annexes II and IV of the Habitats Directive and Appendix III of the Bern Convention. This species has not been recorded to date from the Moy catchment.

1.1.3 The Brook Lamprey

The Brook lamprey *Lampetra planeri* is a non-parasitic freshwater lamprey that undertakes only localised migrations. This lamprey does not feed as an adult. It is the smallest of the three species occurring in Ireland and is normally up to 15 cm long. Although the ammocoetes of lamperns and brook lampreys are difficult to identify apart, the adults can easily be distinguished by size and the absence of developed teeth in L. planeri. The brook lamprey is the most abundant and widespread of the lampreys of the British Isles, and still present in many areas throughout Northern Europe where other lamprey species have gone extinct.

Brook lampreys spawn at temperatures over 10-11 degrees C. They spawn in shallow flowing waters (3-30 cm) with shallow gravels. Brook lampreys sometimes favour shaded spawning sites such as under bridges, and their nests are oval depressions 20 x15 cm in width and 5-10 cm deep. Flows at spawning sites have been measured to be 0.2-3 m^3 sec^{-1}. Brook lampreys are also communal spawners nesting in groups of up to 30, and each female produces at least 2,500 ova. Spawning activity may last over one week. Adults die within one month of spawning. Larval life is thought to be 6 years in British rivers.

Brook lamprey is listed in Annex II of the Habitats Directive and Appendix III of the Bern Convention. During the 1993-1994 survey of the Moy catchment by the Central Fisheries Board, juvenile lampreys were noted at a small number of sites only (King, J., pers. comm.). However, this may have been due to under-recording by the survey teams, the emphasis being on salmon and trout.

It is also likely that many sites investigated at this time were more suited to salmonids than juvenile lampreys. Prior to the current survey, brook lampreys were recorded from some upper Moy tributaries (Sonnagh and Mullaghanoe Catchments) during the preparation of an Environmental Impact Statement for a proposed realignment of the N17 (King, J., pers. comm.).

2 STUDY AREA

2.1 The Moy catchment

The Moy catchment (figure 1) is located in the northwest of Ireland and encompasses an area of 2,100 km^2. The River Moy is the most important river in the catchment, with a main channel length of 90 km (McGarrigle *et al*, 1998). The Moy rises in the Ox Mountains at approximately 500m above sea level and flows from the north-east corner of the catchment south-west for approximately 65 km before turning north and flowing for a further 25 km towards the Atlantic Ocean at Killala Bay. The main River Moy network drains the eastern section of the catchment with 460 km of main channel tributaries draining into the main stem. The western part of the catchment is dominated by Lough Conn (48 km^2) and Lough Cullin (10 km^2) and their tributaries. The Rivers Deel, Castlebar, Clydagh, Manulla, and others drain 890 km^2 to the west and south of Lough Conn. This western section has approximately 225 km of main stem channel length. There are approximately 278 lakes in the catchment as a whole, the majority of which are less than 10ha in area. Overall, there are approximately 45 rivers in the Moy catchment (McGarrigle *et al*, 1998). Most of the Moy catchment lies within the 1,200 and 1,400 mm rainfall isohyets, and precipitation ranges from 1,080 to 1,820mm with some high altitude regions receiving as much as 2,000mm locally (McGarrigle *et al*, 1998). Mean annual runoff is in the range of 42-50 m^3 sec^{-1} at Ballina. The Moy catchment lies primarily on carboniferous limestone bedrock but there is a strip of harder sedimentary and metamorphic rocks with a small amount of granite running from the south-west to the north-east along the line of the Ox Mountains (McGarrigle *et al*, 1998).

As in most of Ireland, the dominant land use in the Moy catchment is grassland based agriculture (McGarrigle *et al*, 1998). Most of the remainder of the catchment comprises large areas of natural or semi-natural vegetation with low intensity grazing or peat harvesting being the predominant uses in these areas. The proportion of the catchment that is not actively farmed is one of the highest in Ireland, at 50%. McGarrigle *et al* (1998) considered that this is an important factor accounting for the generally high water quality of rivers and lakes in the catchment. Extensive areas of coniferous forestry (mainly Sitka spruce and lodgepole pine) have been planted in the catchment since 1954 with accelerated planting during the past 10-15 years. Agricultural activities are most intensive in the more fertile northern and southern sections of the catchment, with beef and dairy farming predominating. Currently, there are few intensive pig and poultry rearing units in the catchment, but these are increasing in number. There are two main population centres in the catchment, namely Castlebar and Ballina. The urban area of Castlebar has a population of over 7,500 with an additional

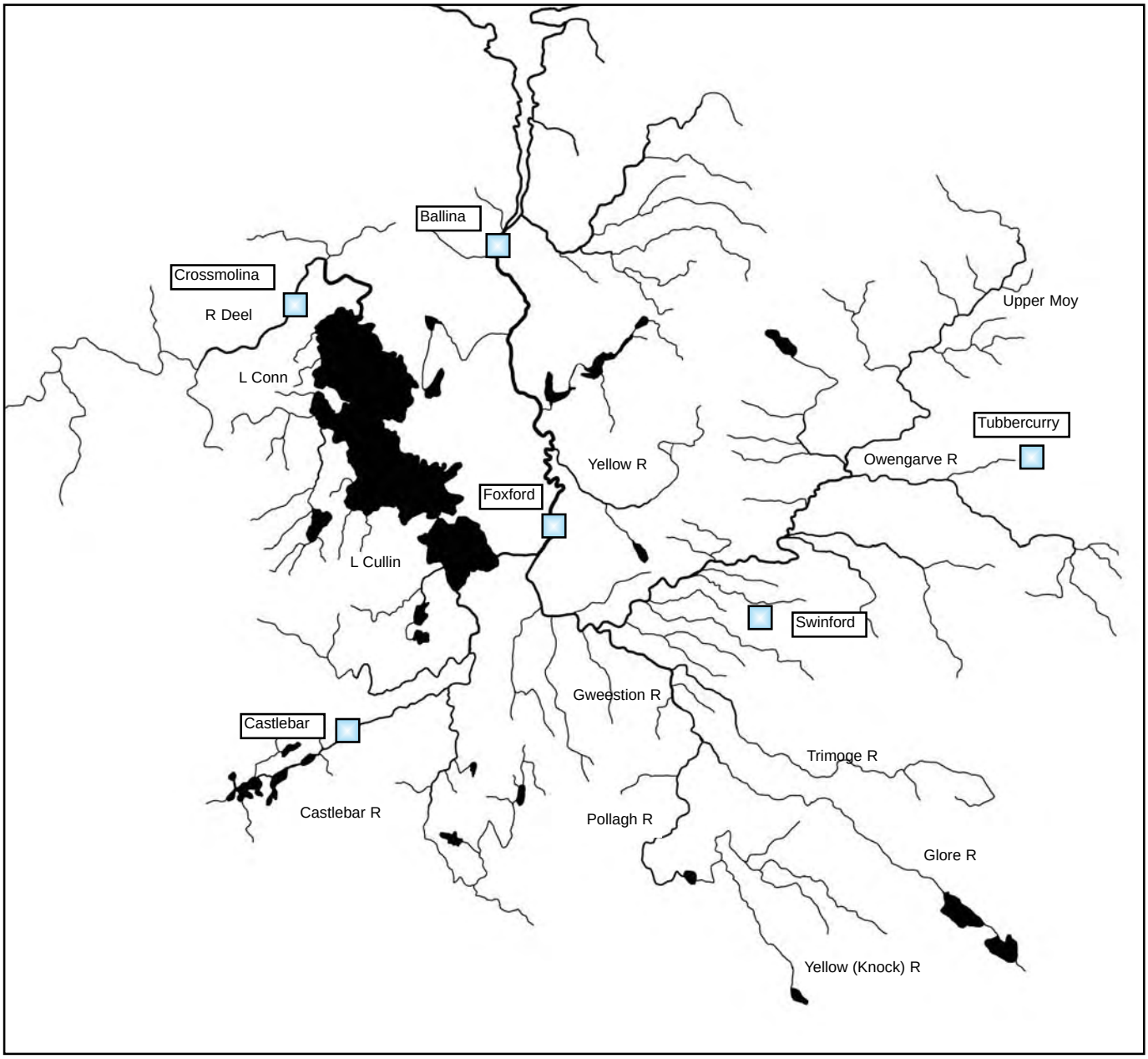


Figure 1 Map of the Moy catchment showing the approximate location of the six major towns in the area.

13,000 people living within a 10-mile radius of the town, while Ballina has a population of approximately 6,850 in the urban area and 25,800 living in a 10-mile radius of the town. (Source: Dept. of Community, Rural and Gaeltacht Affairs). Ballina is located on the tidal section of the River Moy whereas Castlebar is located approximately 35 km upstream on the Castlebar River. In both cases modern wastewater treatment works are in place and Castlebar has recently installed a tertiary treatment stage to its treatment works in order to control eutrophication in the Castlebar River and Lough Cullin. Smaller towns in the catchment are Crossmolina, Foxford, Charlestown, Swinford, Tubbercurry, and Kiltimagh.

The Environmental Protection Agency (EPA), and its predecessors (An Fóras Forbatha, Environmental Research Unit), has assessed water quality (Chemical and Biological) in the Moy catchment since the mid-1970s as part of the National Water Quality Monitoring Programme (McGarrigle, 2002). A summary of the overall results for the Moy catchment (hydrometric area 34) during the period 1998-2000 are presented in Table 1. Overall, water quality in the Moy catchment is of a very high quality. Indeed, the Moy catchment has one of the highest proportions of unpolluted River channels in Ireland (McGarrigle *et al*, 1998). Virtually all rivers have mean BOD values less than 2mg/l and most have unfiltered molybdate reactive phosphate (MRP) values of less than 0.020mg P/l (McGarrigle *et al*, 1998). Pollution problems have been noted on some lakes within the catchment, particularly Loughs Conn and Cullin. Lough Cullin has suffered in the past from phosphorous inputs from the Castlebar River. However, water quality in Lough Conn was satisfactory during the period 1995-1997 (McCarthy *et al*, 1999).

Table 1 Summary of water quality results from EPA hydrometric area 34 showing overall results for the Moy catchment and results from the Castlebar River. Data is from EPA biological surveys during the period 1998-2000 (adapted from McGarrigle, 2002).

Catchment	**Class A**	**Class B**	**Class C**	**Class D**	**Total (km)**
Moy (km)	521.5	45.0	24.5	0.0	591.0
Moy (%)	88.0	8.0	4.0	0.0	

2.1.1 Fish and fisheries of the River Moy

The fish fauna of Ireland is not as diverse as other European countries due to the impact of glaciation. Most of the fish species present in Irish river catchments, such as the River Moy, have colonized from the sea or have been artificially introduced. Native fish species in the Moy catchment, in addition to lampreys, include the Atlantic salmon *Salmo salar* (O'Grady, 1994), and the red data book listed glacial relic, Artic charr *Salvelinus alpinus* (McGarrigle *et al*, 1998). The European eel

Anguilla anguilla and brown trout *Salmo trutta* are other common native species present in the Moy catchment, while introduced fish species in the catchment include northern pike *Esox lucius*, stone loach *Barbatula barbatula*, and minnow *Phoxinus phoxinus* (McGarrigle *et al*, 1998). The Moy River is one of Ireland's premier salmon fisheries and is widely recognized as being the most prolific river for salmon angling in Ireland (O'Reilly, 2004). Indeed, the Central Fisheries Board regards it to be the best salmon angling water in Western Europe. A fisheries survey of the catchment was carried out in 1993 by the Central Fisheries Board (O'Grady, 1994). This survey showed that fish stocks in the Moy catchment at this time were dominated by salmon. One of the conclusions of this report was that the Moy was of national significance in terms salmon production and was more productive overall than larger Irish salmonid catchments such as the Suir, Nore and Boyne.

2.1.2 Moy arterial drainage scheme

Despite its fisheries and ecological importance, the Moy catchment, with the exception of the Deel River upstream of Crossmolina, was subjected to a major arterial drainage scheme during the 1960s (McGarrigle *et al*, 1998). The purpose of this scheme was to improve agricultural production in the catchment. This scheme had a major impact on the hydrology, ecology and fisheries of the catchment and resulted in the loss of a number of lakes in the southern part of the catchment and the reduction in size of others, such as Lough Conn (McGarrigle *et al*, 1998). The impact of the scheme remains apparent today, and most of the main rivers have high, modified banks and trapezoidal shaped channels. However, salmon stocks have recovered well in most of the tributaries and now extensively use blasted rock deposits (rubble) in the main channel for spawning and nursery. The recovery of salmon populations in the Moy after the drainage scheme may also be a result of the high rainfall levels in the catchment which maintains good flows in even small first and second order streams. Moreover, the fact that dredging works in many of the tributaries exposed glacial gravels that were previously covered by peat has mitigated many of the impacts of the scheme on salmon. McGarrigle *et al* (1998) reported that widening of the natural channel width was not a feature of the drainage programme and the number of natural meanders on the main river channel removed during the course of the works was insignificant. However, while the production of juvenile salmon stocks may have recovered in the catchment, it is accepted that there has been significant loss of ecological diversity, adult trout habitat, and salmon resting areas in the catchment. Despite the scheme, the portion of the catchment that is not actively farmed continues to be one of the highest in Ireland, while the fisheries on the river have come to be appreciated as being among the most valuable in Europe. Recently, a physical rehabilitation programme has been undertaken in some areas of the catchment using funding from the EU Tourism Angling Measure (TAM).

Plates 1-4 The lower River Moy. (1) Ballina - The Ridge Pool, (2) Mount Falcon - The Wall Pool, (3) Gannon's Fishery, (4) recently developed salmonid angling water at Foxford.

Plates 5-6 The upper River Moy. (5) Stirabout Bridge, (6) Cloongullaun Bridge stretch near Swinford.

Plates 7-12 Moy tributaries - (7) The Yellow (Foxford) River, (8) The Castlebar River, (9) Gweestion, (10) Owengarve, (11) Deel at Crossmolina, and (12) the lower Mullaghanoe.

The impact of the drainage scheme on lampreys is difficult to ascertain due to the absence of any information of on lampreys in the river prior to the works. However, it is likely that it was highly significant. Drainage on the main Moy extended continuously from its estuary well into upland areas and almost every section of its tributaries and associated streams were affected. Many of the tributaries and some areas of the upper Moy were also severely channelised. Dredging of the river was likely to have resulted in the physical removal of a significant proportion of lamprey larvae present and the almost complete destruction of existing lamprey spawning and nursery habitats. Although the excavated channel beds are now used by lampreys, these areas were initially likely to be unstable for some time after the works. Moreover, ongoing drainage works would have resulted in significantly elevated suspended solids levels in the river which would have caused prolonged impacts on lamprey populations in some areas. Recovery in the dredged channels is likely to have been slow and even today these channels clearly have a much reduced lateral heterogeneity and a lower availability of flow refugia and backwater habitats than undrained rivers. Ongoing maintenance works further threaten lamprey populations.

3 METHODOLOGY

3.1 Selection of sites

Sections of river channel near existing EPA water quality sampling stations were assessed for the presence of juvenile lamprey habitat during an initial walkover survey. Juvenile lamprey habitat was identified from the descriptions given in Maitland (2003). Such sections generally had fine-grained bed material and have a water depth suitable for wading. When available, an area of up to 30 m^2 was selected for surveying in the vicinity of each EPA water quality station. In many areas it was difficult to locate suitable larval lamprey habitat. In some cases fragments of habitats spread over more than 300m were assessed as a single site. In addition to the 75 sites surveyed, an additional 26 areas were visited but not surveyed due to the absence of suitable habitat.

3.2 Electrical fishing assessment

Sites were investigated using electrical fishing[1]. This is a well-established technique for sampling fish populations in freshwater (Lagler, 1978; Reynolds, 1983; Bohlin *et al*, 1990). When an electric current is passed through water, a fish within the electrical field will turn and swim towards the anode (known as the anodic effect). This mechanism is referred to as electrotaxis and fish may be stunned (electronarcotisation) as it reaches the anode. A dip net is then used to retrieve the fish from the water. Electrical fishing has become increasingly popular with the advent of small, lightweight, and safe backpack units.

Electric fishing activities were undertaken during suitable environmental conditions (normal flows, dry weather). The methodology used in the current survey is based on the portable gear methods used for sampling *P. marinus* larvae in North America described by Weisser & Klar (1990) and for *L. tridentata* larvae by Moser & Close (2003). A *Marine Electrics Safari Researcher 660D* portable electrical fishing unit was employed during this survey. This unit is powered by two 12v batteries and delivers a 100Hz pulsed DC current at 200V. The anode handle consists of fibreglass and is equipped with a steel ring shaped electrode (diameter 300mm) and a button which is used to deliver a charge. The steel ring electrode was fitted with a fine mesh net (1mm) to facilitate juvenile lamprey collection. The cathode, consisting of three wires, was allowed to trail behind the operator. The operators (2-3 persons) wore insulated chest waders. The machine was secured on the back of one operator who also held the anode. An assistant held an insulated dip net (mesh size 1mm; 40 cm x 40

[1] Authorised under Section 14 of the Fisheries (Consolidation) Act, 1959, by the Dept. of Communications, Marine and Natural Resources.

cm frame, handle length 182 cm) for collecting lampreys that failed to be captured by the operator. The sampling approach permitted the recording of presence/absence as well as facilitating collection of population structure and minimum density data.

Electrical fishing for larval lampreys is unique because the larvae, unlike most other fish, normally burrow into the substrate. Sampling areas at each site were fished in a zigzag manner. The area fished varied depending on the extent of fine-grained bed material and suitable water depth available at any site. Each one m^2 section of the surveyed area was fished for 1-2 minutes or until lampreys stopped emerging from their burrows. A fishing operation started with the gear constantly 'on' followed by a regular on/off sequence. This intermittent operation of the electrode is used to irritate larvae out of the substrate. While the gear was operated, the anode was slowly pulled backwards in the water to cause lampreys to emerge from burrows as a result of electro-taxis. This procedure was repeated throughout the operation. When lampreys emerged the electrode was held in the 'on' position to stun (or electro-narcotise) the larvae for capture. By keeping the anode 1-15 cm above the sediment and pulling the anode backwards, the number of lampreys stunned within the substrate was thought to be reduced. Captured lampreys (and other fish) were removed quickly using the anode net or dip net and placed into a container of river water. Surveys were completed after 30 minutes continuous fishing (or earlier if large quantities of lampreys were encountered or if there was a paucity of suitable and accessible habitat at the site). After each survey was completed, all captured fish were anaesthetised using a 0.05% solution of tricaine methanesulphonate (MS-222). Bycatch species were counted and weighed. Lampreys were measured to the nearest millimetre (Standard Length), weighed to the nearest 0.1g and identified using the keys given in Gardiner (2003).

Subsequent to examination, all fish were allowed to recover in a container of river water. All fish were released alive and spread evenly over the sampling area. Results of the investigations are presented using two CPUE indices (lamprey number m^{-2}, and lamprey weight (biomass) m^{-2}.

3.2.1 Quantitative electrical fishing assessment

A total of three sites were selected for quantitative assessment. These sites were closed off using heavy duty fine mesh stop nets with bottom weights and floats. These sites were at least 4m in length and 1 m wide, depending on the characteristics of the site. Electrical fishing within the enclosures was the same as described above. Three passes were made in each enclosure, with a fifteen-minute rest period after each sampling effort. Fish from each pass were retained separately for identification, enumeration and measurement of length and weight. On completion of the electric fishing, a steel

framed net was used to scrape through the upper 50-100mm of sediment in each enclosure. This process served to ascertain the presence of further juveniles, including the very small young-of-the-year. Minimum densities were calculated using the Leslie-Davies Method. Results of the electrical fishing investigations are presented as a minimum density estimate (number and biomass/m^2).

3.3 Description of sites

Following completion of the fishing the dimensions and physical habitat characteristics of each site were recorded. The following general physical habitat characteristics of the stretch of river where the site was located were recorded: -

- Wetted width (m)
- Bank height (m)
- Mean depth (cm)
- Maximum depth (cm)
- Bank cover (%)
- Canopy cover (%)
- Bank slope (degrees)
- Riffle (%)
- Glide (%)
- Pool (%)
- Vegetation cover (%)
- Shade (%)
- Rock substrate (%)
- Cobble/Rubble substrate (%)
- Gravel substrate (%)
- Fine substrate (%)
- Flow (m sec^{-1})
- Bank slope (degrees)

Flow measurements were carried out using a Hydro-Bioskiel mechanical flow meter and wading rod. The following physical habitat characteristics were recorded for the area fished:-

- Mean depth (cm)
- Sand (%)
- Silt (%)
- Clay (%)
- Density (index)
- Shade (%)
- Rooted Vegetation Cover (%)
- Flow (m^3 sec^{-1})

Other general characteristics such as the presence of larger materials (cobbles etc.) and the presence of organic material were also recorded. Substrate density was assessed using a penetrometer. Site photographs (of river channel and actual area fished) were taken with a 4MP *Nikon* digital camera and site location was recorded with a handheld GPS unit (*Garmin Geko 301*). Altitude was estimated using an altimeter (*Kestrel 3000*) which was calibrated daily to known elevations. Conductivity and water temperature were measured on site using an *Oakton Acorn Con 5* handheld meter.

Plates 13-18 (13) Back-pack electrical fishing at Mount falcon on the Lower Moy, (14) closeup of electrical fishing unit control box (15) collection of habitat data, (16) equipment used to examine larval lampreys; headband magnifier, measuring board, handheld balance, calipers, tweesers, white board, and portable microscope, (17) catch of juvenile lampreys from the Lower Deel, and (18) surveying the Bunnifinglas River.

Plates 19-20 (19) Ideal substrate for lampreys from the R. Moy at Stirabout Bridge, (20) Sub-optimal substrate for juvenile lampreys from the River Glore at Glore Bridge.

Plates 21-22 (21) On the Sonnagh R. lampreys were present at a slipway and cattle drink (22) On the Moy, near Foxford, lampreys were present within the roots of *Schoenoplectus lacustris*.

Plates 23-24 Ideal habitat for lampreys - (23) Silty deposits on the R. Moy at Rinnaney, (24) On the R Deel near Ballycarroon House lampreys were present within the roots of *Sparganium erectum*.

3.4 Data analyses

3.4.1 Introduction

The main data analyses techniques used were correlation (Spearman's Rank) and Principle Components Analyses (PCA). These methods are described in Anderson (1984), Sokal & Rohlf (1995) and summarised below. A PCA was run on the environmental data using the computer program Minitab. This produced (a) coefficients which describe the relationships between the environmental factors, and (b) scores which describe the relationships between the individual sites based on their environmental characteristics. The relationship between the derived PCA coefficients and lamprey density was assessed using Spearman's rank correlation analyses.

3.4.2 Principal component analysis (PCA)

Principal component analysis (PCA) is an ordination technique which is used to help to understand underlying data structures. It breaks down or partitions a resemblance matrix into a set of orthogonal axes or PCA "components". The first few PCA components will explain the largest percentage of variation in the data set, and ordinations of sampling units on these axes provide information about the ecological relationships between them.

3.4.3 Spearman's rank correlation coefficient

The Spearman's rank correlation coefficient is a non-parametric measure of correlation – that is, it assesses how well an arbitrary monotonic function could describe the relationship between two variables, without making any assumptions about the frequency distribution of the variables. Unlike the Pearson product-moment correlation coefficient, it does not require the assumption that the relationship between the variables is linear, nor does it require the variables to be measured on interval scales; it can be used for variables measured at the ordinal level.

4 RESULTS

4.1 Electrical fishing sites

A total of 75 sites were investigated using electrical fishing during the July/August 2004. An additional 26 areas were visited but were not surveyed due to the absence of suitable lamprey habitat. The location of all areas investigated is presented in Figure 2 and a list of the areas surveyed is provided in Table 2. Photographs (JPEG format) of each survey site (area surveyed and adjoining river channel) are provided in the attached CD-ROM. These can be accessed using the hyperlinks given in the file MOY SURVEY 2004 (ECOFACT).XLS. Photographs of the adjoining river channels are also provided in Appendix 1.

A total of 17 sites were investigated on the main channel of the River Moy. A total of 14 sites were located in the Gweestion sub-catchment and 10 sites were located in the Clydagh (Castlebar) sub-catchment. A total of 16 sites were located on the upper Moy tributaries – the Owengarve, Mullaghanoe, and Sonnagh Rivers, while a total of five sites were located on the lower tributaries – the Yellow (Foxford), Strade and Bunfinglas Rivers. Five survey sites were located on the River Deel and one site was located at Pontoon - the connection between Lough Conn and Lough Cullin. Areas which were visited but not surveyed included a number of locations along the middle reaches of the Moy where no suitable habitat could be found, the Addergoole River and several areas in the Clydagh (Castlebar) sub-catchment. All survey work was undertaken during July and August 2004.

4.2 Site electrical fishing characteristics

The general characteristics of the electrical fishing sites are given in Table 3. Sites investigated were located throughout the catchments and were distributed at altitudes from near sea level to 75m a.s.l. The wetted width of channels investigated ranged from 2 to 50m while depths ranged from 2 cm to <200 cm. Water quality in most of the areas investigated has previously reported by to be satisfactory (McGarrigle *et al*, 2004). Areas investigated which were previously reported to have unsatisfactory water quality included the Mullaghanoe and Castlebar Rivers. The results of observations made during the current survey suggest that the water quality of rivers which was previously classified by McGarrigle *et al* (2004) as satisfactory may now be unsatisfactory (i.e. middle and upper reaches of the River Glore). Conductivity levels recorded during the current survey were within the range of values reported previously for the Moy catchment by McGarrigle *et al* (1998). Bank height of surveyed channels was generally high (0.7m to 6.0m) reflecting the drained nature of most of the rivers in the study area. Likewise, glide habitat – a predominant feature of drained river channels -

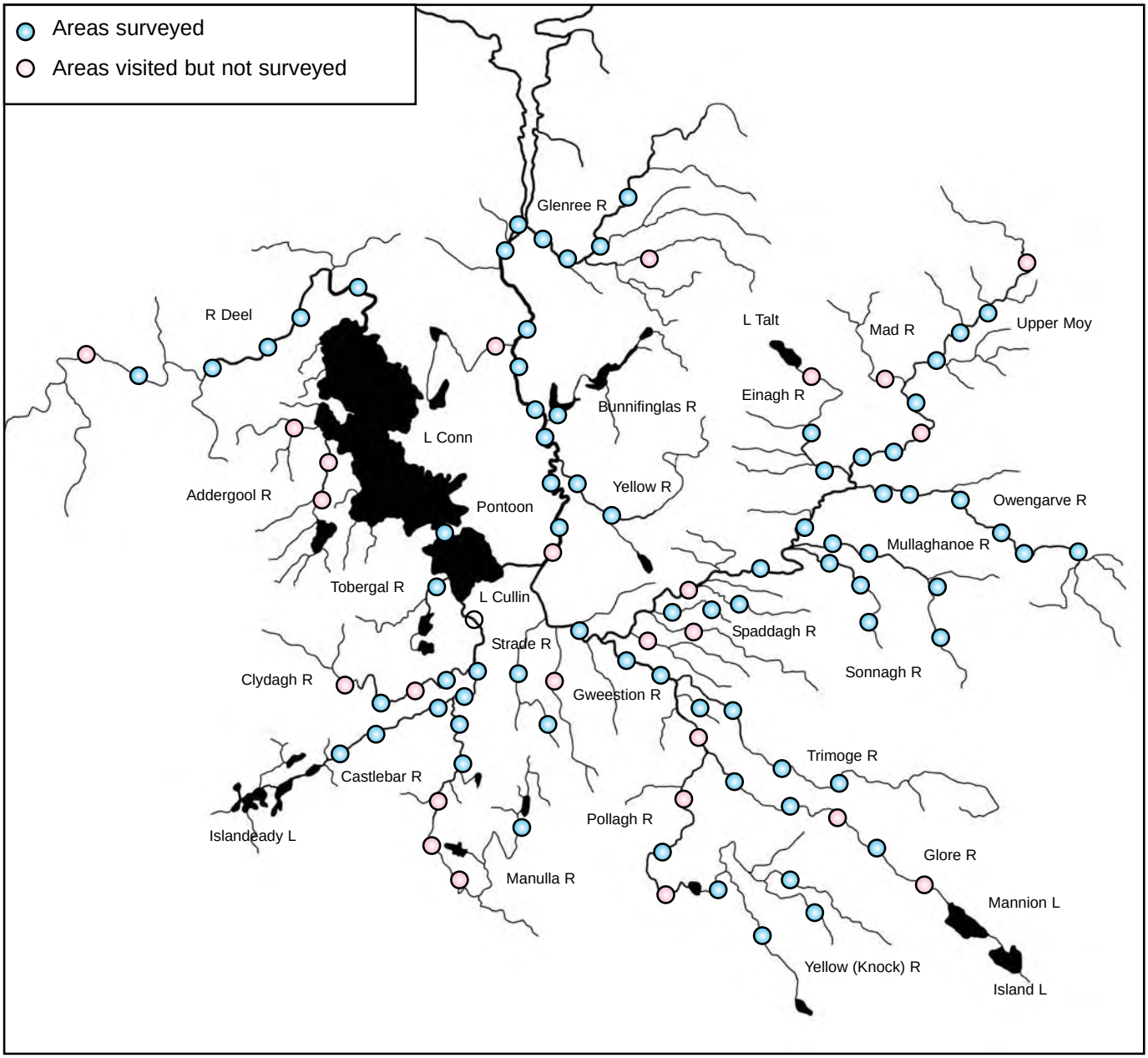


Figure 2 Map of the Moy catchment illustrating the location of the surveyed areas. Areas which were visted but not surveyed, due to the absence of suitable habitat, are also indicated.

Table 2 List of sites investigated for juvenile lampreys during the 2004 survey of the Moy catchment.

									Lampreys Recorded	
Site	EPA Site Code*	Q-Value*	River	Tributary	Sub-tributary	Location	Grid Ref	Date Surveyed	*P.marinus*	*Lampetra sp.*
M 1	34/M/O2 - 1200	4	Moy			Ballina, Bunree	G 25384 19584	10/08/2004	●	
M 2	34/M/O2 - 1200	4	Moy			Ballina	G 25006 19184	10/08/2004	●	
M 3	34/M/O2 - 0960	4	Moy			Mount Falcon Lower (LHB)	G 24853 13658	10/08/2004	●	●
M 4	34/M/O2 - 0900	4	Moy			Mount Falcon Fishery (RHB)	G 25521 14612	10/08/2004	●	●
M 5	34/M/O2 - 0770	4	Moy			Rinnany Fishery (RHB)	G 26808 08692	11/08/2004	●	●
M 6	34/M/O2 - 0850	4-5	Moy			Knockmore Salmon Anglers (LHB)	G 26244 10528	10/08/2004	●	●
M 7	34/M/O2 - 0850	4-5	Moy			Scott-Knox-Gore Fishery (RHB)	G 26310 10475	11/08/2004	●	●
M 8	34/M/O2 - 0770	4	Moy			Foxford Fishery (Lower) (RHB)	G 26693 05483	10/08/2004	●	●
M 9	34/M/O2 - 0700	4	Moy			Ballylahan Br. (LHB)	M 27715 99389	05/08/2004	●	●
M 10	34/M/O2 - 0500	4-5	Moy			U/s Cloonacanna Br. (RHB)	G 39085 02341	27/07/2004		●
M 11	34/M/O2 - 0470	4	Moy			U/s Bellanacurra Br. (LHB)	G 40353 04722	28/07/2004		
M 12	34/M/O2 - 0420	4	Moy			Cooleen Br.	G 43533 08952	30/07/2004		●
M 13	34/M/O2 - 0400	4-5	Moy			Foot Br. at Curraghboy	G 45206 09442	30/07/2004		
M 14	34/M/O2 - 0300	4-5	Moy			Annagh Br.	G 46656 12351	02/08/2004	●	●
M 15	34/M/O2 - 0200	4-5	Moy			Metal Br.	G 47277 14842	03/08/2004		●
M 16	34/M/O2 - 0100	5	Moy			U/s Cloonacool Br.	G 50142 17259	29/07/2004		●
M 17	34/M/O2 - 0050	4-5	Moy			U/s Stirabout Br.	G 51078 18282	29/07/2004		●
M 18	34/Y/01 - 0400	4-5	Yellow (Foxford)			100m u/s of Moy confluence	G 27037 08681	11/08/2004		
M 19	34/Y/01 - 0200	4-5	Yellow (Foxford)			Rinnany	G 28313 06717	11/08/2004	●	●
M 20	34/S/04 - 0800	4-5	Strade			N58 Br.	M 25778 97464	05/08/2004		●
M 21	34/L/02 - 0300	4-5	Strade	Little		D/s N5 Br.	M 26930 94716	05/08/2004		●
M 23	34/G/03 - 0200	4	Gweestion			Scarrownageeragh Br.	M 30332 97532	25/07/2004	●	●
M 24	34/G/03 - 0100	4	Gweestion			Ballymiles Br.	M 32897 96083	23/07/2004		●
M 25	34/P/01 - 0300	4	Gweestion	Pollagh		D/s Cloondoolough Br.	M 32984 90747	21/07/2004		●
M 26	34/Y/02 - 0400	4	Gweestion	Pollagh	Yellow (knock)	U/s Cuiltybo L.	M 33754 85973	24/07/2004		●
M 27	34/Y/02 - 0275	4	Gweestion	Pollagh	Yellow (knock)	R323 Br.	M 37647 86432	21/07/2004		
M 28	34/C/10 - 0100	4	Gweestion	Pollagh	Cloonlavis	Bridge west of Knockbaun	M 37910 81351	24/07/2004		
M 29	34/Y/02 - 250	3-4	Gweestion	Pollagh	Derrykin Lough Fork	N17 Br.	M 40330 84396	23/07/2004		
M 30	34/G/02 - 0200	4	Gweestion	Glore		Glore Br.	M 35015 91799	21/07/2004		
M 31	34/G/02 - 0100	4	Gweestion	Glore		NW of Cloonfallagh	M 40760 88824	21/07/2004		
M 32	34/G/02 - 0050	4	Gweestion	Glore		N17 Br.	M 42472 86926	22/07/2004		
M 33	34/T/01 - 0400	4	Gweestion	Trimoge		Ballinlag	M 34457 95417	22/07/2004		
M 34	34/T/01 - 0300	4	Gweestion	Trimoge		Bridge SW of Rinn Lough	M 39221 90941	22/07/2004		●
M 35	34/T/01 - 0200	4	Gweestion	Trimoge		Killkelly	M 43808 91457	22/07/2004		●
M 36	Not assessed		Gweestion	Ballymiles		Gortnasillagh	M 33270 95466	23/07/2004		
M 37	34/S/03 - 0200	5	Spaddagh			Ardhoom Br.	M 32775 99063	25/07/2004		●
M 38	34/S/03 - 0100	3-4	Spaddagh			NW of Carrowreagh	M 33722 99149	24/07/2004		●
M 39	34/S/05 - 0200	3	Swinford			U/s N26 crossing at Lagcurragh	G 36560 00500	25/07/2004		●
M 40	34/S/02 - 0200	3-4	Sonnagh			Gorteen Br. (Near Cloonfinish)	G 41485 04012	26/07/2004		
M 41	34/S/02 - 0090	4	Sonnagh			U/s disused railway line	G 44824 01308	26/07/2004		●
M 42	34/S/02 - 0075	4	Sonnagh			Bridge at Trouthill	G 44365 00611	26/07/2004		●
M 43	34/M/03 - 0300	4	Mullaghanoe			Cornageeha Br.	G 41136 04874	03/08/2004		
M 44	34/M/03 - 0250	3-4	Mullaghanoe			West of Cully Cross Roads	G 43670 04472	26/07/2004	●	●
M 45	34/M/03 - 0250	3-4	Mullaghanoe			Charlestown	G 47696 01930	27/07/2004		●
M 46	34/M/03 - 0070	3-4	Mullaghanoe	Bracklagh Fork		N17 Br.	M 48010 99890	27/07/2004		●
M 47	34/O/03 - 0200	2-3	Owengarve			Dawros Br.	G 45319 06433	30/07/2004		●
M 48	34/O/03 - 0150	3-4	Owengarve			Curraghbonaun	G 45500 07339	03/08/2004		●
M 49	34/O/03 - 0150	5	Owengarve			Carrowreagh	G 47215 06911	30/07/2004		●
M 50	34/O/03 - 0100	5	Owengarve			N17 Br., Curry	G 49360 06133	28/07/2004		●
M 51	34/O/03 - 0080	5	Owengarve	Coarse River		Botinny Br.	G 51716 04567	28/07/2004		
M 52	34/O/04 - 0200	5	Owengarve	Owenlobnaglaur		Tonnagh Br.	G 53749 04076	28/07/2004		●
M 53	34/E/01 - 0300	5	Einagh			Clonogoonagh Br.	G 43121 08106	12/08/2004		●
M 54	34/E/01 - 0200	4	Einagh			Aclare	G 41032 10040	12/08/2004		●
M 55	34/G/01 - 0200	4-5	Brusna			Ballina	G 25416 19583	09/08/2004		●
M 22	34/C/07 - 0600	4	Bunfinglas			100m u/s of Moy confluence	G 26310 10475	11/08/2004	●	●
M 56	34/G/01 - 0060	4-5	Brusna			D/s Black R. confluence	G 28144 17991	09/08/2004		
M 57	34/G/01 - 0050	4-5	Brusna			Corimla Br.	M 28610 19123	09/08/2004		
M 58	34/B/07 - 0400	4-5	Brusna	Glenree		SW of Cloonta	G 30035 19798	09/08/2004		
M 59	34/C/05 - 0150	4	Clydagh			Ballyguin Br.	G 20921 95135	05/08/2004		
M 60	34/C/05 - 0100	4	Clydagh			Clydagh Br.	M 17208 94541	07/08/2004		
M 61	34/M/01 - 0400	4	Clydagh	Toormoore		N5 Bridge	M 23349 94496	04/08/2004	●	
M 62	34/M/01 - 0400	4-5	Clydagh	Toormoore		Minor Br. South of N5	M 23408 94250	05/08/2004		●
M 63	34/C/01 - 0300	3	Clydagh	Castlebar		D/s Turlough	M 20720 93659	04/08/2004		
M 64	34/C/01 - 0200	3	Clydagh	Castlebar		Ballyneggin	M 18153 92286	04/08/2004		
M 65	34/C/01 - 0180	3-4	Clydagh	Castlebar		Castlebar	M 14919 90577	04/08/2004		
M 66	34/M/01 - 0500	4-5	Clydagh	Castlebar	Manulla	Ist br. u/s Toormore confluence	M 21938 93350	04/08/2004		
M 67	34/M/01 - 0300	4	Clydagh	Castlebar	Manulla	N60 Br. (Manulla Br.)	M 21285 88593	04/08/2004		
M 68	34/M/01 - 0100	4	Clydagh	Castlebar	Manulla	Needhams Lough inflow	M 23741 84771	04/08/2004		●
M 69	34/C/11 - 0300	4	Tobergal			Bunduvowen	G 21397 01622	07/08/2004	●	●
M 70	Not assessed		Pontoon			West of carpark at L. Cullin inflow	G 21466 04415	07/08/2004		
M 71	34/D/01 - 0400	4-5	Deel			Deelcastle	G 17796 18969	06/08/2004		●
M 72	34/D/01 - 0300	4	Deel			N59 Br.	G 15740 19212	06/08/2004	●	●
M 73	34/D/01 - 0100	4-5	Deel			Ford east of Ballycarroon House	G 12130 16094	06/08/2004	●	●
M 74	34/D/01 - 0050	3-4	Deel			Ballymulty Br.	G 08967 15095	09/08/2004		
M 75	34/D/01 - 0025	3-4	Deel			Cominch Br.	G 06725 14265	09/08/2004		

**EPA site codes refers to the codes used by the EPA during their roll over water quality surveys of Irish rivers (McGarrigle et al, 2002).*

The site numbers given refer to the closest EPA site to the areas surveyd for lampreys.

The Q-Values given refer to those reported for the 1998-2000 survey (McGarrigle et al, 2002).

dominated most of the channels investigated. Canopy cover ranged from 0.0% to 70.0% in the surveyed rivers. Canopy cover was very low along the lower Moy due mainly to the large size of the river. Other areas, such as the Mullaghanoe and Gweestion Rivers, had excessive canopy cover in places. Bank erosion was apparent in several areas as a result of unstable channels resulting from the drainage history (i.e. Lower Moy, Owengarve). Other areas were affected by overgrazing by farm animals (i.e. Lower Moy). Excessive trampling by salmon anglers has also caused damage to the banks in some areas. The mean proportion of fine substrate in the channels adjoining surveyed areas was 21.0%. The lower River Moy and channels such as the Owengarve, Sonagh and Strade had a high proportion of fine material in their substrates. The lowering of the river channels during the 1960s arterial drainage programme exposed bedrock and glacial gravels in many areas and this may have reduced the quantities of fine substrate material in the river. However, expansive silt bars have developed on meanders on the lower River Moy. Recent instream development works for salmonids on the main Moy in areas such as Ballintemple and Banada may have contributed to the loss of lamprey nursery habitat from these areas.

Selected micro-habitat characteristics of the sites investigated are provided in Table 4. The mean depth of the areas surveyed for juvenile lampreys was 25.9 ± 2.0 cm. Mean flow in the areas surveyed was 0.05 ± 0.01 $m^3 sec^{-1}$ and ranged from 0.00 to 0.24 $m^3 sec^{-1}$. Some of the areas surveyed were backwaters (n=8) and had flows in the opposite direction of the main river, two areas were intertidal, and a total of 21 sites had no measurable flow. The overall composition of fine material surveyed at the 75 sites was 53.4% sand, 37.8% silt and 8.8% clay. A large proportion of the sites surveyed were shaded, or partially shaded and rooted vegetation cover ranged from 0.0% to 85.0%. In figure 3 the frequency distribution of the areas fished at individual electrical fishing sites is provided. The average area fished was 13.3 m^2 (Minimum 3 m^2, Maximum 30 m^2, Standard Deviation 7.7). Areas were fished for a minimum of 1 minute per m^2 and up to four minutes per m^2 when significant numbers of lampreys were present.

4.3 Lamprey catch

Three lamprey species occur in Ireland, and at least two of these are present in the Moy catchment. It was not possible to determine which species of *Lampetra* sp. was present as no fully developed transformers were captured. The bulk of the *Lampetra* sp. lampreys present were likely to have been Brook lamprey *Lampetra planeri*. A total of n=108 (155.9g) *P. marinus* larvae and n=611 (1,170.9g) *Lampetra* sp. larvae were recorded during the investigation of 1,001 m^2 at 75 sites. The cumulative catch of *P. marinus* larvae and *Lampetra sp*. larvae and the cumulative area investigated is also

Table 3 General characteristics of the areas where juvenile lamprey sampling was conducted during the 2004 survey of the Moy catchment. Range in ( ).

River	Elevation (m)	Wetted Width (m)	Water Quality (Q-Value)	Water Conductivity (ms cm^{-1})	Water Temperature (^{o}C)	River Depth (cm)	Bank Height (m)	Canopy Cover (%)	Fine Substrate (%)	Gravel Substrate (%)	Riffle Habitat (%)	Glide Habitat (%)	Bank slope (degrees)
Moy	22 (1 to 58)	21 (7 to 50)	Q3 to Q5	352 (127 to 631)	16.8 (14.8 to 20.0)	>200 (35.0 to >200)	3.1 (1.0 to 6.0)	6.7 (0.0 to 50.0)	30.5 (2.0 to 100)	35.5 (0.0 to 90.0)	4.6 (0.0 to 30.0)	70.7 (50.0 to 100.0)	70.6 (45.0 to 85.0)
Gweestion/Glore/ Pollagh/Trimoge	54 (30 to 72)	5 (3 to 12)	Q3 to Q4-5	570 (433 to 636)	15.7 (13.4 to 18.1)	48.1 (30.0 to 70.0)	1.85 (0.7 to 4.0)	7.6 (0.0 to 70.0)	20.4 (5.0 to 60.0)	19.3 (0.0 to 40.0)	20.7 (0.0 to 60.0)	51.4 (10.0 to 100.0)	72.3 (30.0 to 90.0)
Clydagh/Castlebar /Manulla	26 (12 to 45)	7 (4 to 13)	Q3 to Q5	476 (173 to 615)	17.0 (16.0 to 18.1)	43.7 (2.0 to 100.0)	2.7 (1.0 to 5.0)	9.0 (0.0 to 30.0)	15.3 (1.0 to 90.0)	6.8 (0.0 to 25.0)	32.0 (0.0 to 80.0)	56.0 (10.0 to 100.0)	67.5 (45.0 to 80.0)
Owengarve	52 (37 to 70)	8 (6 to 12)	Q3-4 to Q5	406 (330 to 476)	15.8 (13.9 to 18.5)	40.8 (35.0 to 50.0)	3.17 (2.0 to 5.0)	11.7 (0.0 to 30.0)	10.0 (0.0 to 35.0)	30.8 (0.0 to 80.0)	23.3 (0.0 to 50.0)	43.3 (0.0 to 100.0)	72.5 (70.0 to 80.0)
Deel	22 (10 to 40)	17 (10 to 22)	Q3-4 to Q4-5	397 (243 to 583)	18.0 (17.1 to 19.1)	39.0 (20.0 to 60.0)	1.8 (0.0 to 4.0)	3.0 (0.0 to 5.0)	14.0 (5.0 to 25.0)	17.0 (0.0 to 35.0)	13.0 (0.0 to 40.0)	48.0 (0.0 to 10.0)	66.0 (40 to 90.0)
Brusna/Glenree	21 (3 to 36)	8 (5 to 12)	Q4 to Q5	556 (401 to 658)	16.2 (14.7 to 17.4)	33.7 (25.0 to 40.0)	1.67 (1.0 to 3.0)	5.0 (0.0 to 10.0)	11.2 (5.0 to 30.0)	17.5 (5.0 to 55.0)	45.0 (0.0 to 90.0)	50.0 (10.0 to 90.0)	85.0 (80.0 to 90.0)
Mullaghanoe	47 (35 to 70)	5 (3 to 6)	Q2-3 to Q4	422 (314 to 484)	15.6 (13.9 to 16.6)	41.2 (35.0 to 50.0)	2.8 (1.7 to 5.0)	15.0 (0.0 to 30.0)	43.7 (5.0 to 100.0	10.0 (0.0 to 20.0)	12.5 (0.0 to 50.0)	35.0 (0.0 to 90.0)	77.5 (60.0 to 90.0)
Sonnagh	66 (56 to 75)	3 (3 to 4)	Q3-4 to Q4	509 (498 to 521)	14.5 (14.2 to 14.7)	46.7 (30.0 to 60.0)	1.73 (0.7 to 3.5)	1.7 (0.0 to 5.0)	11.6 (10.0 to 15.0)	31.7 (25.0 to 40.0)	31.7 (5.0 to 50.0)	55.0 (30.0 to 85.0)	86.7 (80.0 to 90.0)
Einagh	41 (36 to 45)	7 (7 to 8)	Q4 to Q4-5	359 (327 to 391)	15.8 (15.8 to 15.9)	37.5 (35.0 to 40.0)	3.5 (1.0 to 6.0)	15.0 (10.0 to 20.0)	10	35.0 (10.0 to 60.0)	70.0	55.0 (10.0 to 100.0)	42.5 (35.0 to 50.0)
Spaddagh	30 (23 to 37)	3 (2 to 4)	Q3 to Q4	564 (558 to 570)	15.9 (15 to 16.9)	17.0 (4.0 to 30.0)	2.0 (1.5 to 2.5)	15.0 (10.0 to 20.0)	5	12.5 (0.0 to 25.0)	22.5 (10.0 to 35.0)	52.5 (35.0 to 70.0)	80
Strade/Little	22 (19 to 25)	3 (2 to 5)	Q4-5	537 (510 to 564)	17.3 (17.0 to 17.5)	45.0 (40.0 to 50.0)	3.00	3.0 (1.0 to 5.0)	25.0 (10.0 to 40.0)	37.5 (15.0 to 60.0)	0.0	95.0 (90.0 to 100.0)	75.0 (60.0 to 90.0)
Yellow (Foxford)	7 (4 to 10)	7 (5 to 10)	Q4-5 to Q5	395 (369 to 421)	18.2 (17.9 to 18.6)	>200 (35.0 to >200)	3.5 (1.0 to 6.0)	5.0 (0.0 to 10.0)	57.5 (15.0 to 100.0)	5.0 (0.0 to 10.0)	40.0 (0.0 to 80.0)	50.0 (0.0 to 100.0)	55.0 (40.0 to 70.0)
Bunfinglas	5	4	Q4 to Q4-5	290	18.2	20	4.00	30	10	50.0	70.0	10	80
Swinford	61	2.5	Q3-4	675	14	35	3.00	0	15	0.0	0.0	90	70
Tobergal (Crumlin)	13	4.5	Q4	254	16.7	35	1	40	40	30	100.0	0	90

Table 4 Selected micro-habitat characteristics on the sites investigated during the 2004 survey of the Moy catchment. Range in ( ).

River	Mean Depth (cm)	Flow (m3 sec-1)	Sand Substrate (%)	Silt Substrate (%)	Clay Substrate (%)	Substrate Density (index)	Shade (%)	Rooted Vegetation Cover (%)
Moy	26.5 (10.0 to 40.0)	0.04 (0.00 to 0.24)	64.2 (40.0 to 100.0)	44.7 (5.0 to 90.0)	9.7 (0.0 to 35.0)	3 (0 to 4)	25.8 (0.0 to 90.0)	30.1 (0.0 to 85.0)
Gweestion/Glore/ Pollagh/Trimoge	32.2 (20.0 to 50.0)	0.08 (0.00 to 0.22)	66.0 (50.0 to 80.0)	36.4 (0.0 to 80.0)	8.9 (0.0 to 50.0)	3 (2 to 4)	22.8 (0.0 to 50.0)	28.9 (0.0 to 50.0)
Clydagh/Castlebar /Manulla	25.5 (10.0 to 45.0)	0.03 (0.00 to 0.13)	56.3 (20.0 to 85.0)	30.5 (5.0 to 60.0)	20.0 (0.0 to 50.0)	3 (1 to 5)	38.5 (0.0 to 100.0)	12.0 (0.0 to 30.0)
Owengarve	26.7 (20.0 to 35.0)	0.01 (0.00 to 0.04)	43.7 (10.0 to 70.0)	31.6 (0.0 to 55.0)	4.2 (0.0 to 20.0)	4 (2 to 4)	40.0 (0.0 to 80.0)	20.8 (5.0 to 30.0)
Deel	26.0 (15.0 to 35.0)	0.02 (0.00 to 0.07)	56.7 (20.0 to 90.0)	30.0 (20.0 to 50.0)	5.0 (0.0 to 10.0)	3-4 (2 to 4)	35.0 (20.0 to 60.0)	35.0 (10.0 to 50.0)
Brusna/Glenree	17.5 (10.0 to 25.0)	0.01 (0.00 to 0.04)	85.0 (75.0 to 95.0)	42.5 (10.0 to 80.0)	1.2 (0.0 to 5.0)	3-4 (2 to 4)	27.5 (10.0 to 50.0)	21.3 (5.0 to 50.0)
Mullaghanoe	30.0 (25.0 to 35.0)	0.06 (0.01 to 0.12)	57.5 (55.0 to 60.0)	50.0 (25.0 to 90.0)	6.2 (0.0 to 10.0)	2-3 (2 to 4)	37.5 (10.0 to 50.0)	17.5 (5.0 to 40.0)
Sonnagh	23.3 (20.0 to 30.0)	0.03 (0.02 to 0.04)	27.5 (5.0 to 50.0)	40.0 (10.0 to 80.0)	3.3 (0.0 to 10.0)	2-3 (2 to 3)	31.7 (0.0 to 55.0)	11.7 (5.0 to 20.0)
Einagh	20	0.03 (0.02 to 0.03)	45.0 (5.0 to 85.0)	3.5 (2.0 to 5.0)	1	4	5.0 (0.0 to 10.0)	15.0 (10.0 to 20.0)
Spaddagh	15.0 (10.0 to 20.0)	0.04 (0.02 to 0.05)	46.7 (0.0 to 95.0)	40	2.5 (0.0 to 5.0)	3	25.0 (0.0 to 50.0)	15.0 (10.0 to 20.0)
Strade/Little	32.5 (30.0 to 35.0)	0.03 (0.00 to 0.05)	53.9 (5.0 to 100.0)	42.5 (35.0 to 50.0)	30.0 (0.0 to 60.0)	3	40.0 (30.0 to 50.0)	20.0 (10.0 to 30.0)
Yellow (Foxford)	20	0.00	48.5 (0.0 to 95.0)	55.0 (15.0 to 95.0)	0	4	20.0 (10.0 to 30.0)	27.5 (5.0 to 50.0)
Bunfinglas	15	0.00	60	40	0	3	20	5.0
Swinford	25	0.07	45	45	10	3	25	30.0
Tobergal (Crumlin)	10	0.03	60	35	5	3	60	10.0

Table 5 Mean densities and total lengths (cm) of sea lamprey *P. marinus* juveniles in each river where lampreys were collected during the 2004 survey of the Moy catchment. Range in ( ).

River	Number of sites	Area Sampled (m^2)	Sea Lamprey Density (Number m^{-2})	Sea Lamprey Length (cm)
Moy	17	274	0.28 (0.00 to 3.00)	7.0 (2.5 to 14.6)
Gweestion/Glore/Pollagh/Trimoge	14	202	0.00	-
Clydagh/Castlebar/Manulla	10	62	0.02 (0.00 to 0.20)	17.6
Owengarve	6	77	0.00	-
Deel	5	100	0.18 (0.00 to 0.80)	6.2 (2.8 to 14.3)
Brusna/Glenree	4	47	0.2 (0.00 to 0.80)	14 (10.9 to 15.7)
Mullaghanoe	4	65	0.01 (0.00 to 0.03)	14.6
Sonnagh	3	22	0.00	-
Einagh	2	15	0.00	-
Spaddagh	2	10	0.00	-
Strade/Little	2	22	0.00	-
Yellow (Foxford)	2	15	0.1 (0.00 to 0.20)	4.0 (3.8 to 4.2)
Bunfinglas	1	5	0.60	4.73 (4.2 to 5.0)
Pontoon	1	30	0.00	-
Swinford	1	30	0.00	-
Tobergal (Crumlin)	1	25	0.16	3.8 (3.2 to 4.6)

Table 6 Mean densities and total lengths (cm) of Brook/River lamprey *Lampetra sp*. juveniles in each river where lampreys were collected during the 2004 survey of the Moy catchment. Range in ( ).

River	Number of sites	Area Sampled (m^2)	Brook/River Lamprey Density (Number m^{-2})	Lampetra sp. Length (cm)
Moy	17	274	0.61 (0.00 to 2.69)	8.30 (1.80 to 14.70)
Gweestion/Glore/Pollagh/Trimoge	14	202	0.07 (0.00 to 0.32)	9.91 (6.50 to 12.10)
Clydagh/Castlebar/Manulla	10	62	0.13 (0.00 to 1.00)	12.01 (6.70 to 15.00)
Owengarve	6	77	1.20 (0.00 to 3.80)	8.57 (4.50 to 12.60)
Deel	5	100	1.19 (0.00 to 3.05)	10.77 (2.20 to 14.20)
Brusna/Glenree	4	47	0.02 (0.00 to 0.07)	14.10
Mullaghanoe	4	65	1.73 (0.13 to 4.00)	11.37 (4.30 to 18.20)
Sonnagh	3	22	0.27 (0.00 to 0.60)	10.60 (7.10 to 12.10)
Einagh	2	15	1.50 (1.00 to 2.00)	9.97 (5.60 to 13.60)
Spaddagh	2	10	0.9 (0.40 to 4.40)	9.96 (5.70 to 13.40)
Strade/Little	2	22	0.54 (0.29 to 0.80)	11.34 (6.60 to 15.70)
Yellow (Foxford)	2	15	0.40 (0.00 to 0.80)	6.80 (3.10 to 9.30)
Bunfinglas	1	5	9.60	9.64 (3.50 to 11.90)
Pontoon	1	30	0.00	-
Swinford	1	30	0.00	-
Tobergal (Crumlin)	1	25	1.96	6.75 (1.80 to 13.40)

Plates 25-26 (25) Sea lamprey ammocoete (top) and *lampetra* sp. ammocoete. (26) Young of the year (YOY) larvae and older cohorts - from the Tobergal R.

Plates 27-28 (27) Sea lamprey transformer (from the Moy at Ballina), (28) *Lampetra* sp. juveniles from the R. Deel.

Plates 29-30. (29) Sea lamprey ammocoete (top) and *lampetra* sp. ammocoetes from the upper Moy at Annagh Bridge. (30) *Lampetra* sp. lampreys burrowing following release (R. Mullaghanoe).

shown in figure 3. In figure 4 and 5, the minimum density (n m^{-2}) and minimum biomass (g m^{-2}) of *P. marinus* and *Lampetra* sp. larvae at the 75 electrical fishing sites is given. *Lampetra* sp. lampreys accounted for 84.9% of the lampreys encountered by number, and 88.2% by weight. Mean minimum density of larvae recorded was 0.10 ± 0.09 *P. marinus* m^{-2} and 0.69 ± 0.32 *Lampetra* sp. m^{-2}. The mean minimum densities of *P. marinus* and *Lampetra* sp. larvae from each river channel surveyed are given in Tables 5 and 6. Summary statistics for minimum density (number m^{-2} and weight m^{-2}) for each river channel surveyed are provided in Tables 7, 8, 9 and 10. These results are also shown in graphical form in Figures 6 and 7. The highest minimum densities of *P. marinus* larvae were recorded on the Lower Moy at Rinnany (3.00 larvae m^{-2}), on the Glenree River at its confluence with the Moy (0.80 larvae m^{-2}), and the River Deel at an undrained section near Ballycarroon House (0.80 larvae m^{-2}). Relatively high densities of the larvae of this species were also recorded on the Bunifinglas River immediately upstream of the Moy confluence (0.60 larvae m^{-2}), and at sites on the Moy at Mount Falcon (0.40 larvae m^{-2}) and at the Knockmore Salmon Fishery (0.40 larvae m^{-2}). During floods on the lower Moy the river backs up into the lower Bunnifinglas River so the *P. marinus* larvae found here may have originated in the main channel of the River Moy. Where present, the lowest densities of *P. marinus* larvae were recorded in the upper Moy at Annagh Bridge (one fish) and the lower Mullaghanoe River (also one fish only). The highest minimum densities of *Lampetra sp.* larvae were recorded on the Bunnifinglas River (9.60 larvae m^{-2}), on the Bracklagh Fork of the Mullaghanoe River (4.00 larvae m^{-2}), and on the middle reaches of the Owengarve River (3.80 larvae m^{-2}). Two sites on the River Deel (both upstream and downstream of Crossmolina) had relatively high densities of the larvae of this species (3.05 and 2.85 larvae m^{-2}).

4.3.1 Transformation rates

No fully transformed *Lampetra* sp. juveniles were recorded during the current survey, however many of the lampreys recorded were seen to be in the early stages of transformation. The overall observed transformation rate of *Lampetra* sp. juveniles over 10.0 cm was recorded as being 16.3%. The observed transformation rate for this size group on the R. Deel was 32.0%, while it was 17.5% on the R. Mullaghanoe. The overall observed transformation rate of *P. marinus* juveniles over 10.0 cm was 12.9%. It is possible, however, that the transformation rate was under-recorded due to the fact that the survey was undertaken during July/August and all examinations were made in the field rather under lab conditions.

4.4 Distribution and characteristics of lamprey populations

Lampreys were present at 47 out of the 75 sites investigated. Sea lamprey larvae were generally confined to the Lower River Moy, but were also present in some of the tributaries, notably the Deel and Glenree Rivers. Nominal numbers of larvae of this species were also recorded in the Upper Moy catchment – on the main Moy at Annagh Bridge, and in the lower Mulaghanoe River. It is possible that sea lamprey larvae were present at other sites at low densities and were not detected by the survey methods used. *Lampetra* sp. larvae were well distributed in the catchment but were absent from areas above natural impassable barriers (i.e Upper Deel, Glenree and Clydagh Rivers) and areas which have been badly damaged by arterial drainage (i.e. Glore and Manulla Rivers). In Figure 8 a map of the Moy catchment is given which illustrates the distribution of juvenile lampreys at the 75 sites investigated. In Figure 9, the location of known barriers, or potential obstacles, for lampreys in the Moy catchment is indicated.

Population structure varied significantly between different sub-catchments. Some areas displayed a strong presence of young-of-the-year (YOY) larvae, hatched in spring 2004 (i.e. Moy main channel, Deel), while this age group was absent in other areas (i.e. Mullaghanoe, Owengarve). Areas with a prominent YOY year class generally also had other cohorts present. Standard length of *P. marinus* and *Lampetra* sp. larvae encountered ranged from 2.5 cm to 17.6 cm and 1.8 cm to 18.2 cm respectively. Descriptive statistics for juvenile sea lampreys from each river system are given, in Tables 11 (lengths) and 12 (weights). Tables 13 and 14 respectively provide descriptive statistics for length (cm) and weight (g) for juvenile *Lampetra* sp. from each river system. Tables 15-22 provide detailed summaries of the size characteristics of lampreys (*P. marinus* and *Lampetra* sp.) captured at each site during the 2004 survey. In Figures 11 and 12, the mean length (cm) and weight (g) for *P. marinus* and *lampetra* sp. juveniles (± 95% C.I.) is presented respectively for each river area. In Figure 13 sample variances for *Lampetra* sp. samples are illustrated.

In Figure 14, the length and weight percentage frequency distributions of juvenile *P. marinus* from the main channel of the River Moy, and its tributaries, are compared. The distributions indicate that a number of age groups of sea lamprey are present both on the main channel and tributaries, however the tributary populations are characterised by young and older cohorts only and no juveniles in the 5.5 to 10.5 cm length range. This suggests that recruitment of sea lampreys does not occur every year in the tributary areas; but has occurred to some extent in recent years. It is not clear whether tributary areas are affected by poor escapement in some years or variable local environmental conditions during spawning times. Both frequency distributions show a peak at 4.0 cm and this may reflect a

recent successful spawning year. The possibility that young-of-the-year larvae were not captured with the same efficiency as older cohorts is addressed in the discussion. In Figure 15, the length and weight percentage frequency distributions of juvenile *Lampetra sp.* from the main channel of the River Moy, and its tributaries, are compared. As with the distributions for sea lamprey, there is a marked difference between the distributions recorded for river and main channel populations of *Lampetra* sp. lamprey. The dominance of older cohorts in the tributaries is apparent, while several strong cohorts are indicated to be present at the main channel sites. Figures 16 and 17 present the percentage frequency distributions of juvenile *Lampetra* sp. from all the individual tributaries in which they were found. The variation in the size of lampreys captured is apparent and is summaried in the following sections for individual sub-catchments.

4.4.1 Main Moy

A total of 17 sites were investigated on the main channel of the river Moy. Sea lamprey larvae were recorded at 10 sites, while *Lampetra* sp. larvae were noted from 13 sites. Lamprey were absent from two sites investigated. Overall, a total of 244 juvenile lamprey were intercepted of which 27% were identified as *P. marinus.* Sea lamprey was the only species recorded at the two sites investigated on the lower Moy at Ballina, while this species dominated the larval population at the site investigated on the Rinnaney fishery (site M5, 70.6% of the 51 larvae captured). It is thought that this stretch of river is a very important nursery area for sea lamprey in the Moy catchment. Young of the year larvae and several other cohorts were found in this area. This area was deepened, but not widened and channelised, during the 1960s arterial drainage scheme and contains extensive silt deposits. However, no suitable spawning areas are present along this entire stretch. It is likely that larvae in this area are recruited from spawning activity which occurs at Foxford.

A single *P. marinus* larva was captured at Annagh Bridge on the upper Moy. Extensive surveying at three sites upstream of Annagh Bridge (resulting in the capture of n=80 *Lampetra* sp. juveniles) failed to capture any additional sea lamprey larvae. It can be therefore concluded that the upper limit of recent sea lamprey penetration in the catchment is near Annagh Bridge. No sea lamprey larvae were captured in the next four sites downstream of Annagh Bridge (sites M13, M12, M11, M10). It is possible that this species is present at very low densities in these areas but was not detected by the current survey. These areas do not contain important lamprey habitats and significant populations of *Lampetra* sp. lampreys were not detected in these areas of the river. The percentage of juvenile *P. marinus* and *Lampetra* sp. present at sites located longitudinally along the main Moy channel is presented in Figure 10.

4.4.2 Gweestion

A total of 14 sites were investigated in the Gweestion catchment which included the Glore, Pollagh, Knock Yellow and Trimoge Rivers. Lampreys were present at six sites; all *Lampetra* sp. Lamprey densities ranged from 0.00 to 0.32 individuals m^{-2}. No evidence of recent spawning of lampreys in the catchment was suggested by sizes of the captured lampreys; lengths ranged from 6.50 to 12.10 cm. Lampreys were absent from the Glore sub-catchment due apparently to the general absence of suitable nursery habitats. The middle and upper reaches of this river also appeared to be enriched during summer 2004 with excessive growth of filamentous algae. Some suitable habitats for lampreys (nursery and spawning) were present on the Knock Yellow River, but no lampreys were found. Lampreys were present at both sites investigated on the main Gweestion channel, mainly in fragmented secondary habitats such as cattle drinking areas.

4.4.3 Clydagh/Castlebar

A total of 10 sites were investigated in the Clydagh catchment which included the Castlebar, Manualla, and Toormore Rivers. Lampreys were present at three sites. Two sites contained *Lampetra* sp. individuals while a single sea lamprey transformer was recorded on the lower Toormore/Clydagh River. The maximum densities of *Lampetra* sp. lampreys recorded was 1.00 individuals m^{-2} at the three sites. Lampreys were absent from the Castlebar sub-catchment. Lampreys may have historically been prevented from accessing this sub-catchment due to the presence of natural falls in the lower reaches of this river. However, there is a paucity of lamprey nursery habitat in the catchment and water quality has been unsatisfactory here in the past. Lampreys are also absent from the Clydagh River upstream of its confluence with the Toormore/Castlebar River. There is also an impassable natural falls on this river and lamprey nursery habitat is very scarce. The Manulla River was subjected to particularly severe channelisation works during the 1960s arterial drainage scheme and lamprey nursery habitat was absent from three out of the five areas examined during the 2004 survey. Although some development works for salmonids have been undertaken in recent years, this work has not provided any new nursery habitats for lampreys. Lampreys (*Lampetra* sp.) were present at one site only in the upper reaches of the catchment. No evidence of recent spawning of lampreys was detected at any of the sites examined in the Clydagh/Castlebar catchment. This was suggested by the sizes of the lampreys examined; *Lampetra* sp. lengths ranged from 6.70 to 15.00 cm, while the only sea lamprey encountered was a 17.6 cm long transformer. Water quality in the Castlebar River was assessed as being unsatisfactory by McGarrigle *et al* (2004).

4.4.4 Owengarve

A total of six sites were investigated in the Owengarve sub-catchment. Only *Lampetra* sp. lampreys were present. The river was severely damaged during the 1960s scheme and was channelised in some areas. However, extensive areas containing lamprey nursery habitats occur and there is an abundance of suitable spawning sites in the catchment. Lampreys were present at five out of the six sites investigated. No YOY size group lampreys were detected which suggests that spawning may not have taken place in this sub-catchment in recent years. However several cohorts were detected and the size range of lampreys recorded was 4.5 cm to 12.6 cm. Mean lamprey density was 1.20 individuals m^{-2} with a maximum density of 3.80 individuals m^{-2}.

4.4.5 Deel

Five sites (100 m^2) were investigated on the River Deel. Lampreys (*P. marinus* and *Lampetra* sp.) were present at three out of the five sites investigated. The Deel River upstream of Crossmolina was the only area of the Moy catchment which was not affected by the 1960s arterial drainage scheme. Extensive lamprey habitats are present in this area, and also in some of the drained stretches. However, the recent construction of deflectors to improve salmonid angling in the river may have reduced the extent of lamprey nursery habitats in some areas of the lower river. An apparently impassable natural barrier to lamprey migration on the river is present in the middle reaches of the river. Water quality has been recorded as being satisfactory in the Deel catchment in the past; however growths of filamentous algae at a number of sites upstream of Crossmolina may indicate some recent organic pollution. Sea lamprey densities ranged from 0.00 to 0.80 individuals m^{-2}. Recent spawning of sea lampreys (during 2004 and 2003) occurred in the river as evidenced by the presence of YOY, 1+ and older cohorts. Lengths of sea lampreys captured during the survey ranged from 2.8 to 14.3 cm indicating a healthy self replicating population. Densities of *Lampetra* sp juveniles ranged from 0.00 to 3.05 individuals m^{-2}. The results suggest that recent spawning of this group (during 2004 and 2003) has also occurred in the river. Lengths of *Lampetra* sp. juveniles captured during the survey ranged from 2.2 to 14.2 cm.

4.4.6 Brusna/Glenree

Two sites were investigated in the Brusna/Glenree catchment. A series of natural falls on the lower reaches of the river has apparently prevented the colonisation of much of this catchment by lampreys. Lampreys (both groups) were present in the lower site investigated only. Examination of the size

frequency distributions of captured individuals provided no evidence of recent lamprey spawning. Sea lampreys dominate the juvenile lampreys populations in the lower Brusna/Glenree (12 of the 13 individuals recorded at site M55).

4.4.7 Mullaghanoe/Sonnagh

The Mullaghanoe and Sonnagh rivers are two relatively low gradient tributaries of the middle reaches of the Moy. They are relatively important tributaries for lampreys and 6 out of the 7 sites investigated in these sub-catchments contained lampreys. Although sea lampreys were present at one site located on the lower Mullaghanoe River, it would seem that no recent spawning of sea lampreys has occurred in this catchment. The sea lamprey captured was a transformer of 14.6 cm. Lengths of *Lampetra* sp. juveniles intercepted ranged from 4.30 cm to 18.20 cm at the Mullaghanoe sites, and from 7.10 cm to 12.10 cm in the Sonnagh. None of the captured juveniles from these rivers were of the YOY size class. Densities of *Lampetra* sp. juveniles ranged from 0.13 to 4.00 individuals m^{-2} on the Mullaghanoe. The maximum density of this group recorded on the Sonnagh was 0.60 individuals m^{-2}. Water quality in the Mullaghanoe River downstream of Charlestown was assessed as being unsatisfactory by McGarrigle *et al* (2002).

4.4.8 Einagh

Juvenile lampreys *(Lampetra sp.)* were present at the two sites investigated on the River Einagh. No evidence of recent spawning was found and the length of lampreys encountered ranged from 5.6 cm to 13.6 cm. Lamprey density was 1.00 and 2.00 individuals m^{-2}.

4.4.9 Spaddagh

The Spaddagh is a minor tributary of the middle Moy which was subjected to extensive instream development works for salmonids during the mid-1990s. Although the extent of lamprey nursery habitat in this stream prior to these works is unknown, only two small patches of habitat no remain in the developed section – both at animal drinking slipways. One site was investigated in the developed stretch where two *Lampetra* sp. ammocoetes (5.9 cm and 9.8 cm) were recorded in an area of 5 m^2. On an undeveloped stretch of the river a density of 4.40 individuals m^{-2} was recorded (size range 5.7 cm to 13.4 cm). The sizes of ammocetes recorded suggest that no spawning occurred in this catchment during 2004. Water quality in the middle and lower reaches of this catchment was assessed as being unsatisfactory by McGarrigle *et al* (2002).

4.4.10 Strade

Two sites were investigated in the Strade sub-catchment; one on the main channel of the Strade and one on its tributary, the Little River. Both of these rivers were severely channelised during the 1960s scheme. Although water quality in the sub-catchment was classified as satisfactory by McGarrigle *et al* (2002), water quality in both of these channels appears to have declined since then as evidenced by elevated turbidity and excessive filamentous algal growths in some areas during the current survey. A total of 14 *Lampetra* sp. juveniles ranging from 6.6 cm to 15.70 cm in length were recorded; spawning has not occurred recently in this sub-catchment but a number of cohorts are present. Density of lampreys recorded was 0.80 individuals m^{-2} on the Strade and 0.29 individuals m^{-2} on the Little River.

4.4.11 Yellow (Foxford)

Two sites were investigated in this sub-catchment and lampreys were present at one site only. Both sea lamprey (density 0.20 individuals m^{-2}) and *Lampetra* sp. (density 0.80 individuals m^{-2}) ammocetes were present at the upper site. At least three cohorts of *Lampetra* sp. lampreys were present.

4.4.12 Bunnifinglas River

The Bunnifinglas River is a minor tributary which enters the Moy below Foxford. Both sea lamprey (density 0.60 individuals m^{-2}) and *Lampetra* sp. juveniles were recorded from this site. It is possible that the sea lamprey larvae (4.2 cm, 5.0 cm, 5.0 cm) recorded here originated from the main Moy channel which is known to back up into the surveyed area during high flows. The site on the Bunnilingus stream was considered (by the ecologists undertaking the work) to be ideal habitat for juvenile lampreys. A density of 9.60 *Lampetra* sp. individuals m^{-2} was recorded – the highest density recorded during the 2004 survey.

4.4.13 Tobergal River

The Tobergal River is a minor tributary of Lough Cullin. Both sea lamprey (density 0.16 individuals m^{-2}) and *Lampetra* sp. (density 1.96 individuals m^{-2}) juveniles were recorded from this site. Two cohorts of juvenile sea lampreys may be present (3.2 cm to 4.6 cm length range). Several cohorts of *Lampetra* sp. juveniles were present (1.8 cm to 13.4 cm length range). This may be the smallest river

in the Moy catchment where sea lampreys have spawned recently. Habitat is ideal for lampreys and a lake in the upper area of this catchment may ensure that water levels are stable. This coupled with the fact that the area surveyed is close to the lake may explain the presence of sea lampreys here – a species which is more typical of larger rivers.

4.4.14 Other areas investigated

Other areas surveyed included the connection between Lough Conn and Lough Cullin at Pontoon and the Swinford Stream. Lampreys were absent from both of these areas.

4.5 Influence of environmental conditions

A Principle Components Analyses (PCA) of environmental data collected during the 75 site survey was undertaken. The results of these analyses are presented in Figures 18-21. The first three PCA axes accounted for 42.7% of the observed variation in the macro-environmental data, and 63.5% of the observed variation in the micro-environmental data. The relationship between lamprey abundance to the environmental conditions described by the PCA axes was investigated by means of Spearman Rank Correlation Analyses.

4.5.1 Macro-environmental data

The presence of *P. marinus* larvae was significantly negatively correlated (R^2=-0.412, p=0.000) with component 1 of the which reflects increasing mean depth, wetted width, bank height, pool (%) and fine substrate (%). The presence of *P. marinus* larvae was also significantly negatively correlated (R^2 = -0.327, p=0.004) with component 2 which reflects the role of shade/canopy cover and pool/riffle presence of the abundance of lamprey larvae. The presence of *Lampetra* sp. larvae was significantly negatively correlated (R2 = -0.318 p=0.006) with this component. The presence of *P. marinus* larvae was also significantly negatively correlated (R^2 = -0.322, p=0.005) with component 3 which again reflects the role of shade/canopy cover and bank height, and also fine substrate (%) on the abundance of lamprey larvae. No significant relationship between water quality Q-value (McGarrigle *et al*, 2002) and lamprey abundance was apparent from these analyses

4.5.2 Micro-environmental data

The abundance of *Lampetra* sp. larvae was significantly negatively correlated (R^2 = -0.232, p=0.047) with component 2. This component reflects the importance of silt (%) as a habitat predictor for larval

lampreys in the Moy catchment. There was no correlation between the data on *P. marinus* abundance and the derived components.

4.6 Quantitative electrical fishing assessments

Quantitative assessments were undertaken at three sites (Lower Moy, Bunnifinglas, and Einagh). The results of these assessments are provided in Figure 22 and Table 23. During the quantitative electrical fishing assessments at three sites an overall 83.1% of the lampreys present in the three sites were captured during the first fishing. On completion of the electric fishing, a steel framed net was used to scrape through the upper 50-100mm of sediment in each enclosure. No further juveniles or young-of-the-year larvae were recorded during this process at these three sites.

4.7 Observations of spawning areas

The current survey was undertaken during the period July/August and no spawning of lampreys was observed. Areas which may be important for sea lamprey spawning in the catchment are shown in Figure 23.

4.8 By-catch and other ecological observations

During the survey, information on the distribution of other aquatic species was also recorded. A total of 15.3 Kg of other fish comprising 10 species was recorded during the electrical fishing activities. McGarrigle *et al* (1998) reported that at 14 fish species had been recorded in the Moy catchment. A list of bycatch species captured in provided in Table 24. European eel *Anguilla anguilla* was the most important bycatch species, followed by the salmonids *Salmo trutta* and *S. salar.* The recently introduced cyprinid *Rutilus rutilus* is now widespread in the catchment. The minnow *Phoxinus phoxinus* was only recorded as a bycatch species on the River Deel.

Two previously unknown populations of the endangered Annex II listed pearl mussel *Margaritifera margaritifera* were recorded on the River Deel (sites M73, M74). It was outside the scope of the current survey to assess these populations in detail, but they are thought to be significant. Dead shells of this species were also recorded on the Tobergal River (site M69), and the upper Moy at Cooleen Bridge (M12). Further surveying in the areas where dead shells were found may well uncover live mussels. Electrical fishing was suspended in both areas where live individuals were noted.

The Annex II listed white clawed crayfish *Austropotamobius pallipes* was common in the Castlebar, Manulla, Toormore, Deel, and Knock (Yellow) Rivers. Otter activity was recorded on many of the

river channels appraised. In almost all areas where lamprey larvae were found, large numbers of the mayfly nymph *Ephemera danica* were also present. At one site on the Gweestion (M 23) and one site on the upper Moy (M 14), horsehair worms (Phylum Nematomorpha) were present. Not much is known about this group which has an erratic distribution. The larval stage of these worms is parasitic on various insect hosts, while the free-living adult enters water to breed in spring and summer. The rare hemipteran *Aphelocheirus montandoni* was recorded at one site on the River Deel (M 71). This brightly coloured bug belongs to the family Aphelocheiridae and is sporadically found on gravely bottoms of fast-flowing streams. The ampipod crustacean *Gammarus duebeni* was present at sites located throughout the catchment and was regularly attracted to the anode in large numbers. This species is of interest because it is believed to be a glacial relic and is only found in freshwater in Ireland and Brittany.

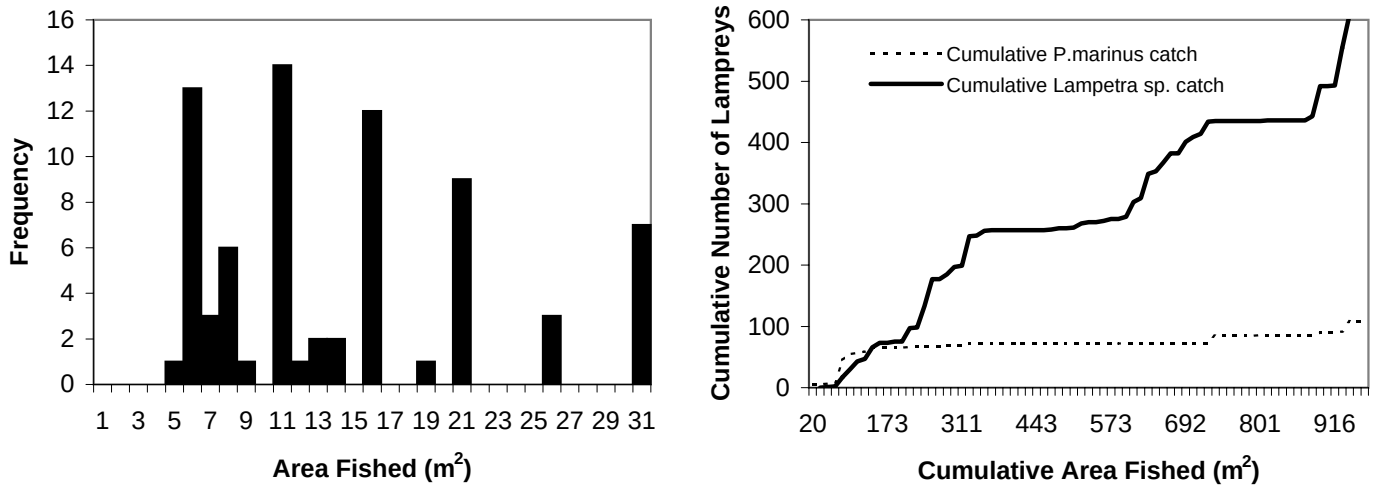


Figure 3 Frequency distribution of area fished (left) and cumulative lamprey catch and cumulative area fished (right).

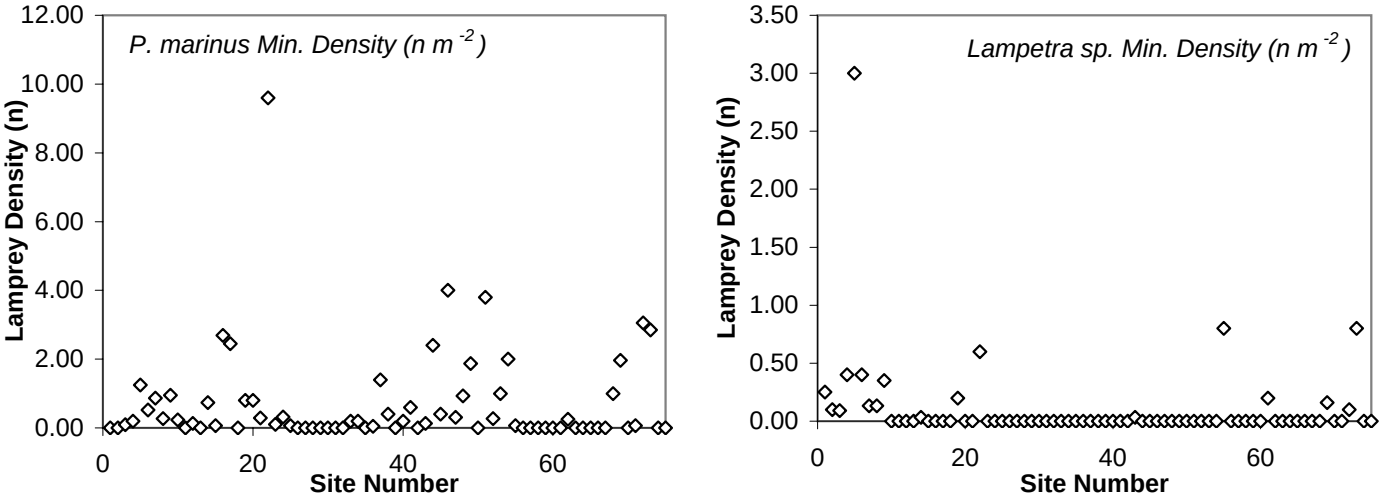


Figure 4 The minimum density (n m^{-2}) of *P. marinus* (left) and *Lampetra* sp. (right) captured at each site.

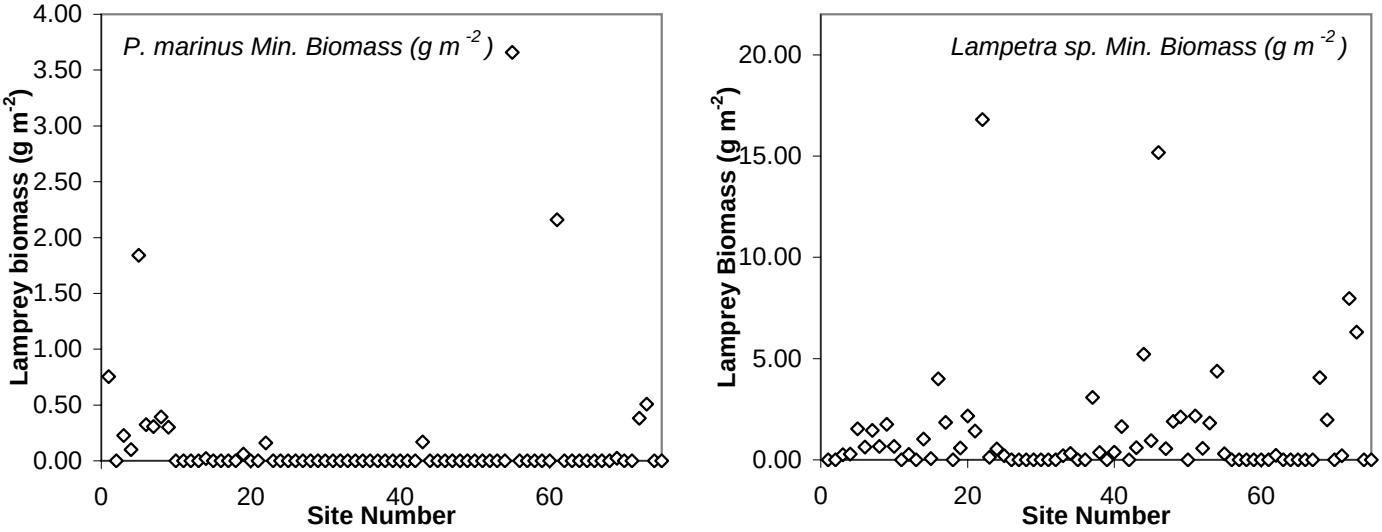


Figure 5 The minimum biomass (g m^{-2}) of *P. marinus* (left) and *Lampetra* sp.(right) captured at each site.

Table 7 Summary statistics for density (number m-^{2}) of *P. marinus* in rivers investigated in the Moy catchment during 2004.

River	Observations (N)	Lamprey number (n)	Mean density (n m^{-2})	Min density (n m^{-2})	Max density (n m^{-2})	St. Dev.
Moy	17	67	0.29	0.00	3.00	0.71
Gweestion	14	0	0.00	0.00	0.00	0.00
Clydagh	10	1	0.02	0.00	0.20	0.06
Owengarve	6	0	0.00	0.00	0.00	0.00
Deel	5	18	0.18	0.00	0.80	0.35
Brusna	4	12	0.20	0.00	0.80	0.40
Mullaghanoe	4	1	0.01	0.00	0.03	0.02
Sonnagh	3	0	0.00	0.00	0.00	0.00
Einagh	2	0	0.00	0.00	0.00	0.00
Spaddagh	2	0	0.00	0.00	0.00	0.00
Strade	2	0	0.00	0.00	0.00	0.00
Yellow (Foxford)	2	2	0.10	0.00	0.20	0.14
Bunfinglas	1	3	0.60	0.60	0.60	
Pontoon	1	0	0.00	0.00	0.00	
Swinford	1	0	0.00	0.00	0.00	
Tobergal (Crumlin)	1	4	0.16	0.16	0.16	

Table 8 Summary statistics for density (g m-^{2}) of *P. marinus* in rivers investigated in the Moy catchment during 2004.

River	Observations (N)	Lamprey weight (g)	Mean density (g m^{-2})	Min density (g m^{-2})	Max density (g m^{-2})	St. Dev.
Moy	17	65.4	0.25	0.00	1.84	0.46
Gweestion	14	0.0	0.00	0.00	0.00	0.00
Clydagh	10	10.8	0.22	0.00	2.16	0.68
Owengarve	6	0.0	0.00	0.00	0.00	0.00
Deel	5	17.8	0.18	0.00	0.51	0.25
Brusna	4	54.9	0.92	0.00	3.66	1.83
Mullaghanoe	4	5.1	0.04	0.00	0.17	0.09
Sonnagh	3	0.0	0.00	0.00	0.00	0.00
Einagh	2	0.0	0.00	0.00	0.00	0.00
Spaddagh	2	0.0	0.00	0.00	0.00	0.00
Strade	2	0.0	0.00	0.00	0.00	0.00
Yellow (Foxford)	2	0.6	0.03	0.00	0.06	0.04
Bunfinglas	1	0.8	0.16	0.16	0.16	
Pontoon	1	0.0	0.00	0.00	0.00	
Swinford	1	0.0	0.00	0.00	0.00	
Tobergal (Crumlin)	1	0.6	0.02	0.02	0.02	

Table 9 Summary statistics for density (number m-^{2}) of *Lampetra sp.* in rivers investigated during the 2004 survey.

River	Observations (N)	Lamprey number (n)	Mean density (n m^{-2})	Min density (n m^{-2})	Max density (n m^{-2})	St. Dev.
Moy	17	177	0.61	0.00	2.69	0.83
Gweestion	14	14	0.07	0.00	0.32	0.10
Clydagh	10	8	0.13	0.00	1.00	0.32
Owengarve	6	60	1.20	0.00	3.80	1.44
Deel	5	119	1.19	0.00	3.05	1.61
Brusna	4	1	0.02	0.00	0.07	0.03
Mullaghanoe	4	74	1.73	0.13	4.00	1.82
Sonnagh	3	5	0.27	0.00	0.60	0.31
Einagh	2	25	1.50	1.00	2.00	0.71
Spaddagh	2	9	0.90	0.40	1.40	0.71
Strade	2	14	0.54	0.29	0.80	0.36
Yellow (Foxford)	2	8	0.40	0.00	0.80	0.57
Bunfinglas	1	48	9.60	9.60	9.60	
Pontoon	1		0.00	0.00	0.00	
Swinford	1		0.00	0.00	0.00	
Tobergal (Crumlin)	1	49	1.96	1.96	1.96	

Table 10 Summary statistics for density (g m-^{2}) of *Lampetra sp.* in rivers investigated during the 2004 survey.

	Observations (N)	Lamprey weight (g)	Mean density (g m^{-2})	Min density (g m^{-2})	Max density (g m^{-2})	St. Dev.
Moy	17	246.2	0.85	0.00	4.00	1.04
Gweestion	14	22	0.10	0.00	0.54	0.17
Clydagh	10	29.3	0.43	0.00	4.06	1.28
Owengarve	6	80.6	1.22	0.00	2.16	0.95
Deel	5	288.4	2.89	0.00	7.97	3.92
Brusna	4	4.6	0.08	0.00	0.31	0.15
Mullaghanoe	4	236.2	5.49	0.60	15.17	6.79
Sonnagh	3	12	0.67	0.00	1.64	0.86
Einagh	2	52.8	3.10	1.82	4.37	1.80
Spaddagh	2	17.2	1.72	0.36	3.08	1.92
Strade	2	42.5	1.80	1.43	2.17	0.52
Yellow (Foxford)	2	5.9	0.30	0.00	0.59	0.42
Bunfinglas	1	84	16.80	16.80	16.80	
Pontoon	1	0	0.00	0.00	0.00	
Swinford	1	0	0.00	0.00	0.00	
Tobergal (Crumlin)	1	49.2	1.97	1.97	1.97	

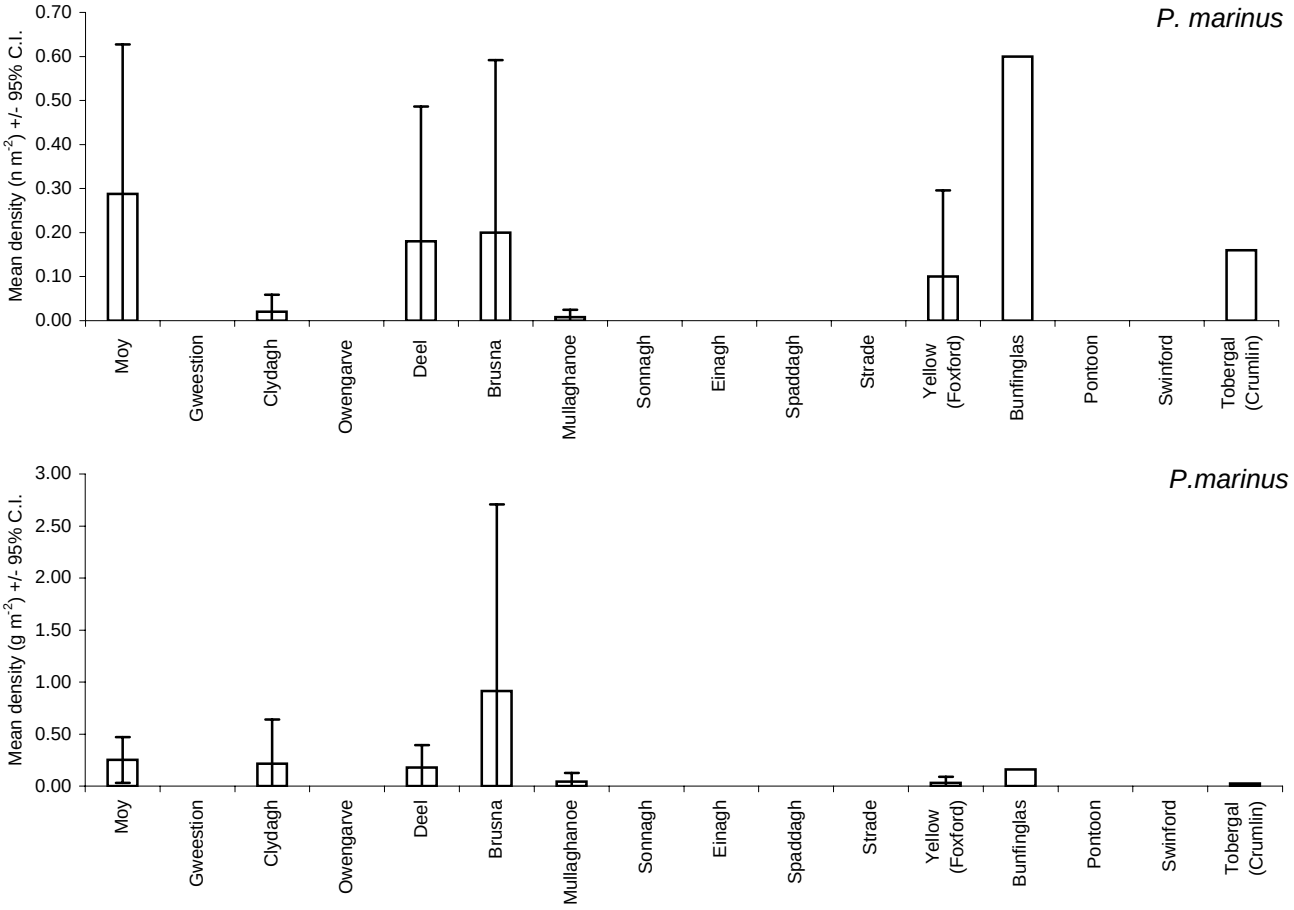


Figure 6 Mean minumum density (number per m^{-2} and biomass m^{-2}) +/- 95% C.I. for *P. marinus* collected during the 2004 survey.

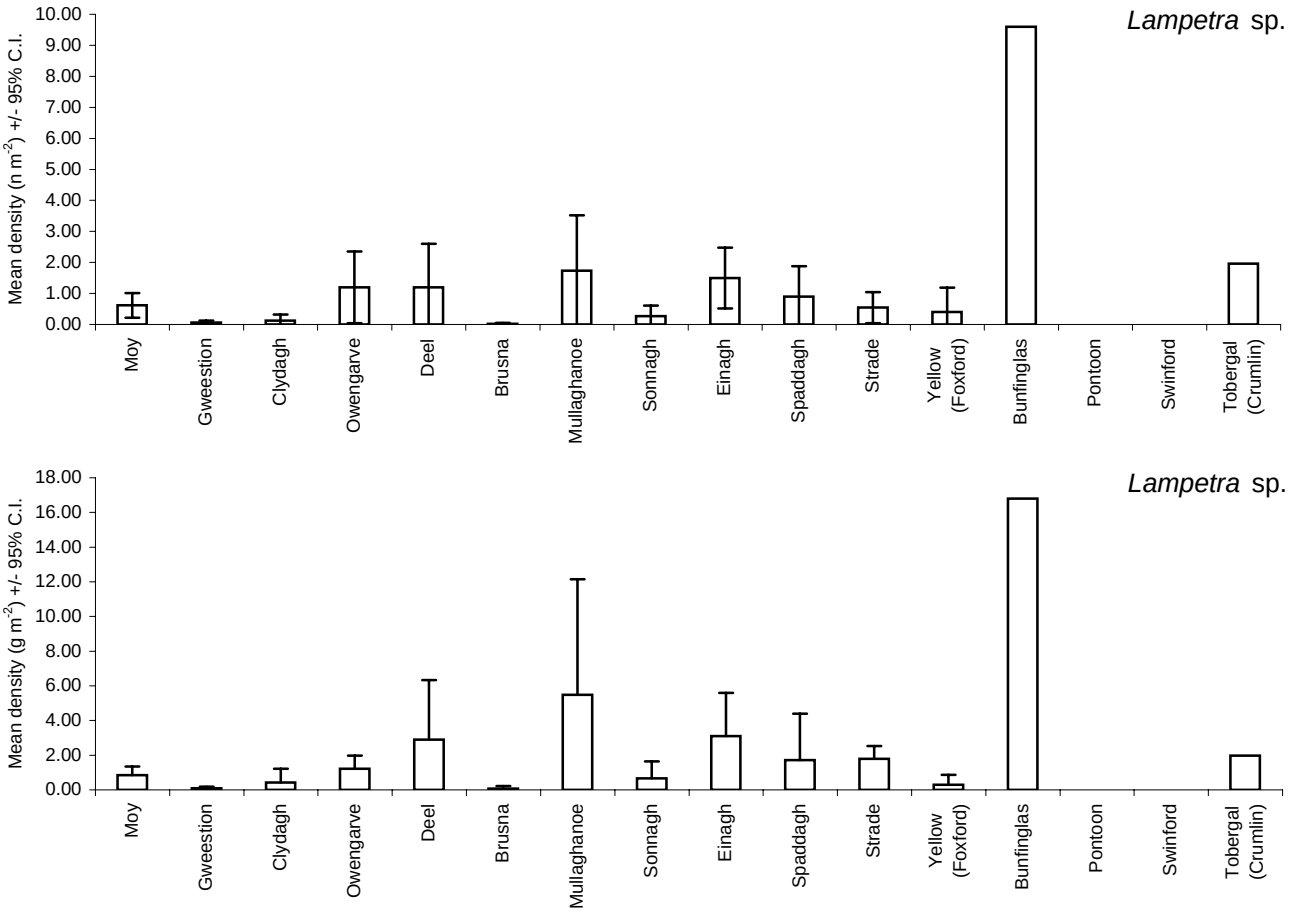


Figure 7 Mean minimum density (number per m^{-2} and biomass m^{-2}) +/- 95% C.I. for *Lampetra* sp. collected during the 2004 survey.

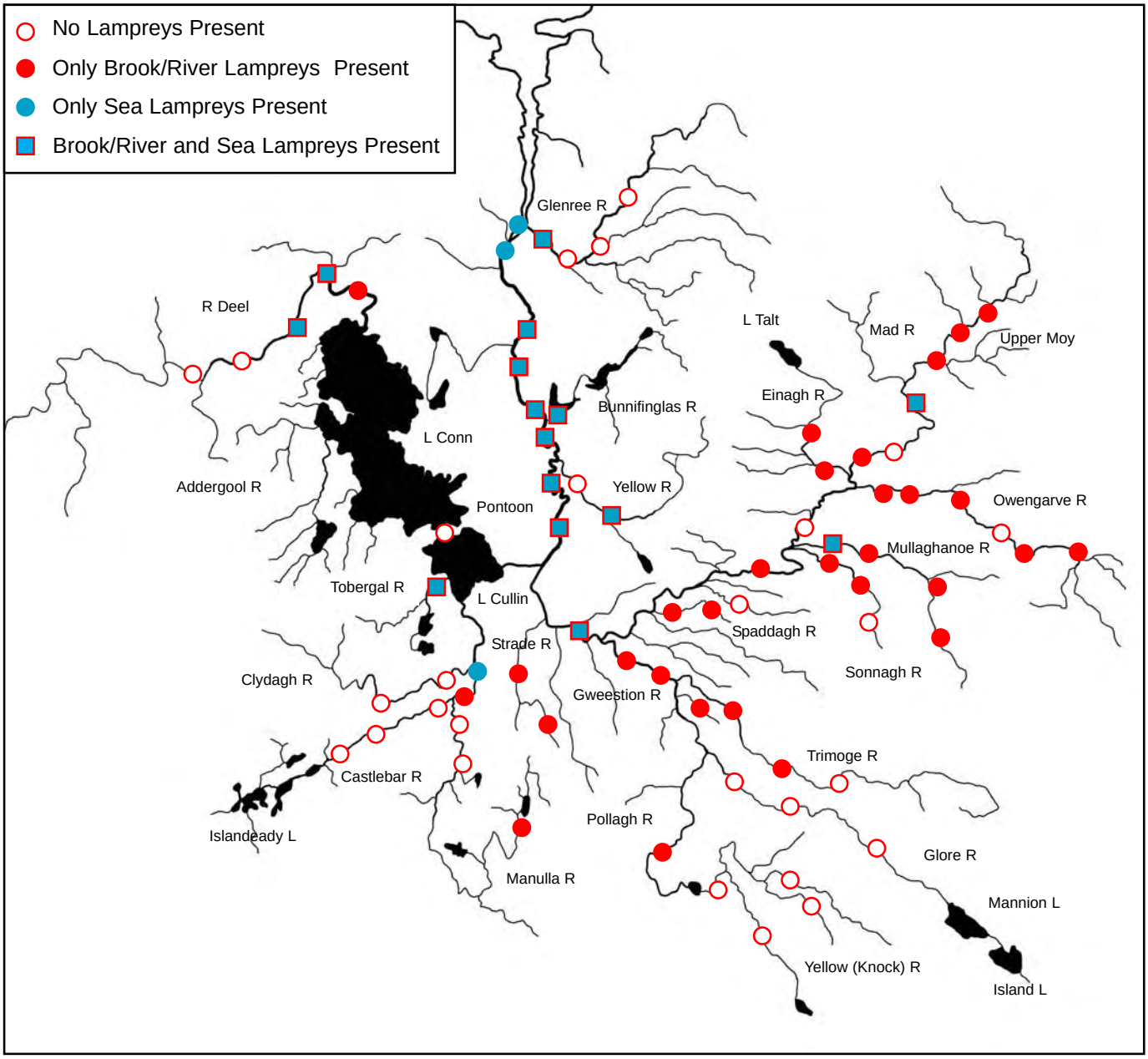
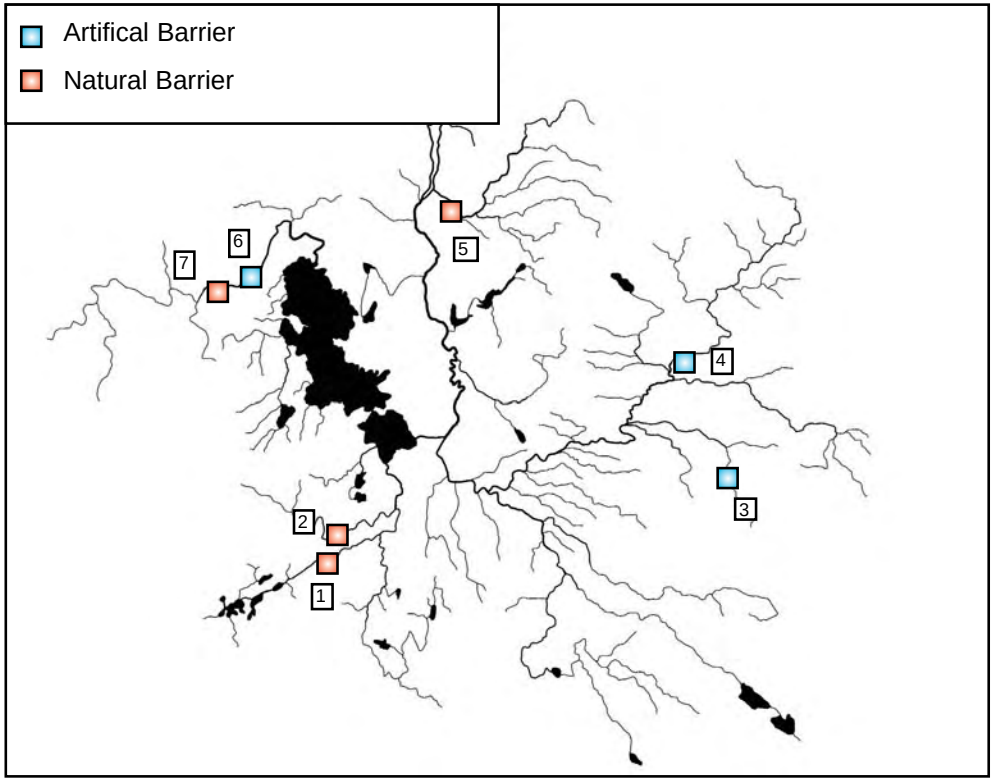
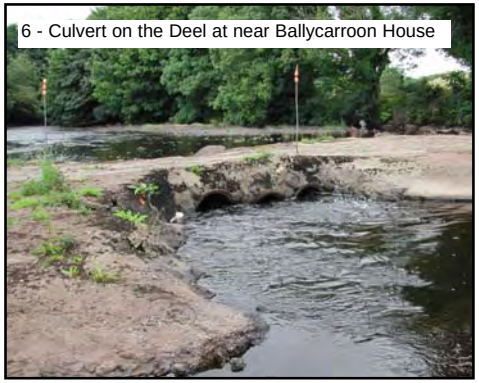


Figure 8 Map of the Moy catchment illustrating the distribution of juvenile lampreys at the 75 sites investigated during the 2004 survey.





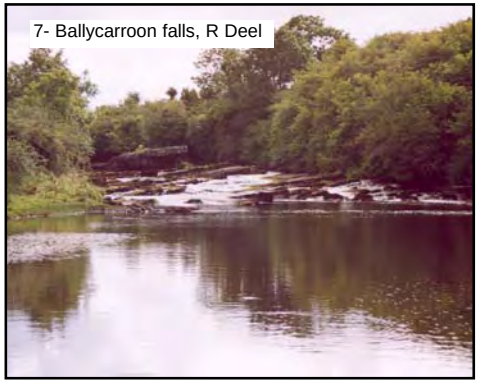


Figure 9 Map of the Moy catchment, with photographs, illustrating the location of known potential barriers to the upstream migration of lampreys.

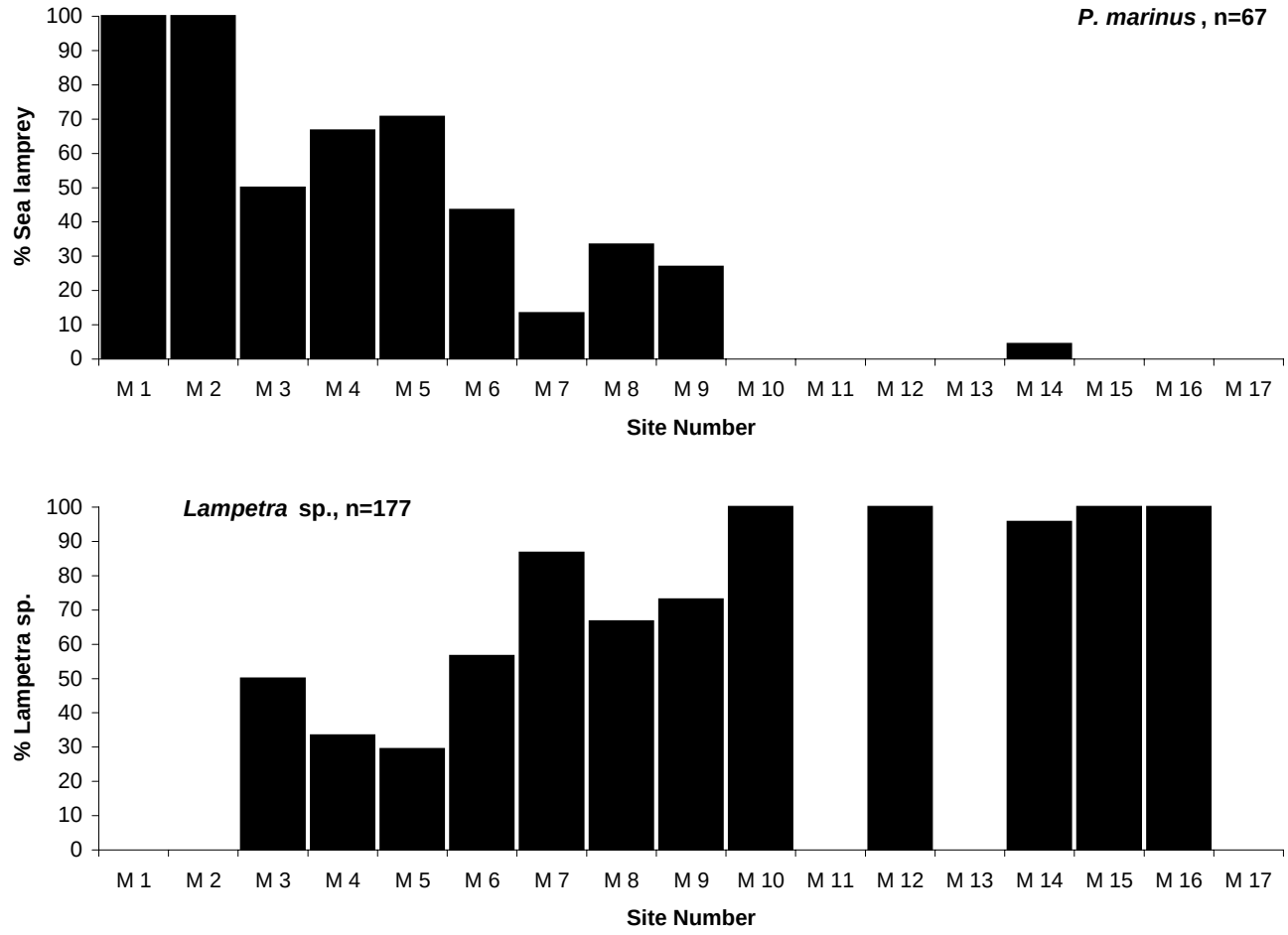


Figure 10 Percentage of juvenile *P.marinus* (top) and *Lampetra* sp. present at sites located longitudinally along the main River Moy channel.

Table 11 Descriptive statistics for length (cm) for juvenile *P. marinus* captured during the 2004 survey.

River	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Moy	*P. marinus*	67	7.04	2.50	14.60	3.26	10.63	0.78
Deel	*P. marinus*	18	6.19	2.80	14.30	4.18	17.51	1.93
Brusna	*P. marinus*	12	13.97	10.90	15.70	1.32	1.74	0.75
Tobergal (Crumlin)	*P. marinus*	4	3.85	3.20	4.60	0.60	0.36	0.59
Bunfinglas	*P. marinus*	3	4.73	4.20	5.00	0.46	0.21	0.52
Yellow (Foxford)	*P. marinus*	2	4.00	3.80	4.20	0.28	0.08	0.39
Clydagh	*P. marinus*	1	17.60	17.60	17.60			
Mullaghanoe	*P. marinus*	1	14.60	14.60	14.60			

Table 12 Descriptive statistics for weight (g) for juvenile *P. marinus* captured during the 2004 survey.

River	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Moy	*P. marinus*	67	0.99	0.10	5.00	1.13	1.28	0.27
Deel	*P. marinus*	18	0.88	0.10	4.50	1.53	2.33	0.70
Brusna	*P. marinus*	12	4.58	2.10	6.70	1.27	1.61	0.72
Tobergal (Crumlin)	*P. marinus*	4	0.15	0.10	0.20	0.06	0.00	0.06
Bunfinglas	*P. marinus*	3	0.27	0.20	0.30	0.06	0.00	0.07
Yellow (Foxford)	*P. marinus*	2	0.30	0.30	0.30	0.00	0.00	
Clydagh	*P. marinus*	1	10.80	10.80	10.80			
Mullaghanoe	*P. marinus*	1	5.10	5.10	5.10			

Table 13 Descriptive statistics for length (cm) for juvenile *Lampetra* sp. captured during the 2004 survey.

River	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Moy	*Lampetra* sp.	177	8.30	1.80	14.70	2.93	8.59	0.43
Deel	*Lampetra* sp.	119	10.77	2.20	14.20	2.20	4.83	0.39
Mullaghanoe	*Lampetra* sp.	74	11.37	4.30	18.20	3.03	9.18	0.69
Owengarve	*Lampetra* sp.	60	8.57	4.50	12.60	2.54	6.47	0.64
Tobergal (Crumlin)	*Lampetra* sp.	49	6.75	1.80	13.40	3.48	12.14	0.98
Bunfinglas	*Lampetra* sp.	48	9.64	3.50	11.90	1.58	2.50	0.45
Einagh	*Lampetra* sp.	25	9.97	5.60	13.60	2.52	6.37	0.99
Gweestion	*Lampetra* sp.	14	9.91	6.50	12.10	1.71	2.92	0.90
Strade	*Lampetra* sp.	14	11.34	6.60	15.70	2.80	7.84	1.47
Spaddagh	*Lampetra* sp.	9	9.96	5.70	13.40	2.57	6.58	1.68
Clydagh	*Lampetra* sp.	8	12.01	6.70	15.00	3.19	10.16	2.21
Yellow (Foxford)	*Lampetra* sp.	8	6.80	3.10	9.30	2.41	5.79	1.67
Sonnagh	*Lampetra* sp.	5	10.60	7.10	12.10	2.10	4.43	1.84
Brusna	*Lampetra* sp.	1	14.10	14.10	14.10			

Table 14 Descriptive statistics for weight (g) for juvenile *Lampetra* sp. captured during the 2004 survey.

River	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Moy	*Lampetra* sp.	177	1.39	0.10	4.90	1.14	1.31	0.17
Deel	*Lampetra* sp.	119	2.43	0.10	4.60	1.12	1.24	0.20
Mullaghanoe	*Lampetra* sp.	74	3.19	0.20	10.30	2.34	5.48	0.53
Owengarve	*Lampetra* sp.	60	1.34	0.20	3.50	0.94	0.88	0.24
Tobergal (Crumlin)	*Lampetra* sp.	49	1.02	0.10	3.90	1.10	1.20	0.31
Bunfinglas	*Lampetra* sp.	48	1.75	0.10	3.10	0.63	0.40	0.18
Einagh	*Lampetra* sp.	25	2.11	0.40	4.30	1.28	1.64	0.50
Gweestion	*Lampetra* sp.	14	1.61	0.50	3.00	0.61	0.37	0.32
Strade	*Lampetra* sp.	14	3.04	0.60	6.70	1.82	3.32	0.96
Spaddagh	*Lampetra* sp.	9	1.91	0.40	3.70	1.06	1.12	0.69
Clydagh	*Lampetra* sp.	8	3.66	0.60	5.80	2.35	5.51	1.63
Yellow (Foxford)	*Lampetra* sp.	8	0.74	0.10	1.30	0.47	0.23	0.33
Sonnagh	*Lampetra* sp.	5	2.40	0.80	3.00	0.92	0.86	0.81
Brusna	*Lampetra* sp.	1	4.60	4.60	4.60			

Table 15 Descriptive statistics for length (cm) for juvenile *P. marinus* captured at sites on the main channel of the River Moy during the 2004 survey.

River	Site Number	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Moy	M 1	*P. marinus*	5	11.46	7.80	14.60	2.95	8.68	2.58
Moy	M 2	*P. marinus*	1	6.70	6.70	6.70			
Moy	M 3	*P. marinus*	1	11.40	11.40	11.40			
Moy	M 4	*P. marinus*	2	4.40	4.30	4.50	0.14	0.02	0.20
Moy	M 5	*P. marinus*	36	6.12	2.50	13.50	3.19	10.18	1.04
Moy	M 6	*P. marinus*	10	6.95	4.90	11.70	2.16	4.69	1.34
Moy	M 7	*P. marinus*	2	11.30	11.20	11.40	0.14	0.02	0.20
Moy	M 8	*P. marinus*	2	11.60	11.10	12.10	0.71	0.50	0.98
Moy	M 9	*P. marinus*	7	6.44	4.00	9.50	2.10	4.41	1.56
Moy	M 14	*P. marinus*	1	7.00	7.00	7.00			

Table 16 Descriptive statistics for weight (g) for juvenile *P. marinus* captured at sites on the main channel of the River Moy during the 2004 survey.

River	Site Number	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Moy	M 1	*P. marinus*	5	3.02	0.80	5.00	1.90	3.60	1.66
Moy	M 2	*P. marinus*	1	0.60	0.60	0.60			
Moy	M 3	*P. marinus*	1	2.50	2.50	2.50			
Moy	M 4	*P. marinus*	2	0.25	0.20	0.30	0.07	0.01	0.10
Moy	M 5	*P. marinus*	36	0.61	0.10	2.50	0.79	0.63	0.26
Moy	M 6	*P. marinus*	10	0.81	0.30	2.70	0.75	0.56	0.46
Moy	M 7	*P. marinus*	2	2.30	2.30	2.30	0.00	0.00	
Moy	M 8	*P. marinus*	2	2.95	2.70	3.20	0.35	0.13	0.49
Moy	M 9	*P. marinus*	7	0.86	0.20	1.70	0.55	0.30	0.41
Moy	M 14	*P. marinus*	1	0.60	0.60	0.60			

Table 17 Descriptive statistics for length (cm) for juvenile *Lampetra* sp. captured at sites on the main channel of the River Moy during the 2004 survey.

River	Site Number	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Moy	M 3	*Lampetra* sp.	1	11.30	11.30	11.30			
Moy	M 4	*Lampetra* sp.	1	9.10	9.10	9.10			
Moy	M 5	*Lampetra* sp.	15	7.93	4.50	11.40	2.58	6.64	1.30
Moy	M 6	*Lampetra* sp.	13	7.96	3.80	12.40	2.60	6.75	1.41
Moy	M 7	*Lampetra* sp.	13	9.36	6.30	11.90	1.91	3.65	1.04
Moy	M 8	*Lampetra* sp.	4	10.63	9.50	12.50	1.35	1.82	1.32
Moy	M 9	*Lampetra* sp.	19	9.82	6.10	12.00	1.73	3.00	0.78
Moy	M 10	*Lampetra* sp.	7	11.53	10.30	12.30	0.67	0.45	0.50
Moy	M 12	*Lampetra* sp.	2	10.40	9.20	11.60	1.70	2.88	2.35
Moy	M 14	*Lampetra* sp.	22	9.21	6.20	11.90	1.82	3.32	0.76
Moy	M 15	*Lampetra* sp.	1	8.30	8.30	8.30			
Moy	M 16	*Lampetra* sp.	35	7.74	1.80	14.70	4.16	17.28	1.38
Moy	M 17	*Lampetra* sp.	44	6.63	3.60	14.70	2.38	5.66	0.70

Table 18 Descriptive statistics for weight (g) for juvenile *Lampetra* sp. captured at sites on the main channel of the River Moy during the 2004 survey.

River	Site Number	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Moy	M 3	*Lampetra* sp.	1	2.80	2.80	2.80			
Moy	M 4	*Lampetra* sp.	1	1.40	1.40	1.40			
Moy	M 5	*Lampetra* sp.	15	1.23	0.20	2.50	0.87	0.75	0.44
Moy	M 6	*Lampetra* sp.	13	1.21	0.20	3.00	0.90	0.81	0.49
Moy	M 7	*Lampetra* sp.	13	1.67	0.50	3.10	0.81	0.66	0.44
Moy	M 8	*Lampetra* sp.	4	2.50	1.90	3.50	0.71	0.51	0.70
Moy	M 9	*Lampetra* sp.	19	1.85	0.50	3.30	0.80	0.63	0.36
Moy	M 10	*Lampetra* sp.	7	2.86	2.10	3.40	0.44	0.20	0.33
Moy	M 12	*Lampetra* sp.	2	2.00	1.20	2.80	1.13	1.28	1.57
Moy	M 14	*Lampetra* sp.	22	1.40	0.50	2.80	0.74	0.54	0.31
Moy	M 15	*Lampetra* sp.	1	1.00	1.00	1.00			
Moy	M 16	*Lampetra* sp.	35	1.49	0.10	4.90	1.64	2.68	0.54
Moy	M 17	*Lampetra* sp.	44	0.76	0.20	4.90	0.93	0.87	0.28

Table 19 Descriptive statistics for length (cm) for juvenile *Lampetra* sp. captured at sites on the tributaries of the River Moy during the 2004 survey.

River	Site Number	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Yellow (Foxford)	M 19	*Lampetra sp.*	8	6.80	3.10	9.30	2.41	5.79	1.67
Strade	M 20	*Lampetra sp.*	12	10.88	6.60	14.30	2.68	7.18	1.52
Strade	M 21	*Lampetra sp.*	2	14.10	12.50	15.70	2.26	5.12	3.14
Bunfinglas	M 22	*Lampetra sp.*	48	9.64	3.50	11.90	1.58	2.50	0.45
Gweestion	M 23	*Lampetra sp.*	1	9.00	9.00	9.00			
Gweestion	M 24	*Lampetra sp.*	8	10.36	8.20	11.20	1.06	1.13	0.74
Gweestion	M 25	*Lampetra sp.*	1	12.10	12.10	12.10			
Gweestion	M 33	*Lampetra sp.*	1	6.80	6.80	6.80			
Gweestion	M 34	*Lampetra sp.*	2	10.75	10.50	11.00	0.35	0.13	0.49
Gweestion	M 36	*Lampetra sp.*	1	6.50	6.50	6.50			
Spaddagh	M 37	*Lampetra sp.*	7	10.56	5.70	13.40	2.37	5.61	1.75
Spaddagh	M 38	*Lampetra sp.*	2	7.85	5.90	9.80	2.76	7.61	3.82
Sonnagh	M 40	*Lampetra sp.*	2	9.60	7.10	12.10	3.54	12.50	4.90
Sonnagh	M 41	*Lampetra sp.*	3	11.27	10.20	12.10	0.97	0.94	1.10
Mullaghanoe	M 43	*Lampetra sp.*	4	13.75	11.40	16.80	2.55	6.52	2.50
Mullaghanoe	M 44	*Lampetra sp.*	24	10.43	6.40	12.60	1.68	2.81	0.67
Mullaghanoe	M 45	*Lampetra sp.*	6	10.45	4.30	12.30	3.04	9.25	2.43
Mullaghanoe	M 46	*Lampetra sp.*	40	11.83	5.30	18.20	3.52	12.37	1.09
Owengarve	M 47	*Lampetra sp.*	4	9.40	4.50	12.60	3.47	12.03	3.40
Owengarve	M 48	*Lampetra sp.*	14	10.87	8.60	12.10	1.17	1.37	0.61
Owengarve	M 49	*Lampetra sp.*	15	7.96	4.60	11.60	2.55	6.52	1.29
Owengarve	M 51	*Lampetra sp.*	19	6.44	4.60	8.50	1.07	1.14	0.48
Owengarve	M 52	*Lampetra sp.*	8	10.30	7.70	12.30	1.84	3.37	1.27
Einagh	M 53	*Lampetra sp.*	5	9.76	7.40	12.30	2.35	5.50	2.06
Einagh	M 54	*Lampetra sp.*	20	10.03	5.60	13.60	2.62	6.87	1.15
Brusna	M 55	*Lampetra sp.*	1	14.10	14.10	14.10			
Clydagh	M 62	*Lampetra sp.*	1	9.20	9.20	9.20			
Clydagh	M 68	*Lampetra sp.*	7	12.41	6.70	15.00	3.22	10.35	2.38
Tobergal (Crumlin)	M 69	*Lampetra sp.*	49	6.75	1.80	13.40	3.48	12.14	0.98
Deel	M 71	*Lampetra sp.*	1	12.10	12.10	12.10			
Deel	M 72	*Lampetra sp.*	61	11.17	6.40	13.40	1.54	2.37	0.39
Deel	M 73	*Lampetra sp.*	57	10.32	2.20	14.20	2.69	7.23	0.70

Table 20 Descriptive statistics for length (cm) for juvenile *Lampetra* sp. captured at sites on the tributaries of the River Moy during the 2004 survey.

River	Site Number	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Yellow (Foxford)	M 19	*P. marinus*	2	4.00	3.80	4.20	0.28	0.08	0.39
Bunfinglas	M 22	*P. marinus*	3	4.73	4.20	5.00	0.46	0.21	0.52
Mullaghanoe	M 43	*P. marinus*	1	14.60	14.60	14.60			
Brusna	M 55	*P. marinus*	12	13.97	10.90	15.70	1.32	1.74	0.75
Clydagh	M 61	*P. marinus*	1	17.60	17.60	17.60			
Tobergal (Crumlin)	M 69	*P. marinus*	4	3.85	3.20	4.60	0.60	0.36	0.59
Deel	M 72	*P. marinus*	2	13.55	12.80	14.30	1.06	1.13	1.47
Deel	M 73	*P. marinus*	16	5.28	2.80	13.30	3.41	11.65	1.67

Table 21 Descriptive statistics for weight (g) for juvenile *Lampetra* sp. captured at sites on the tributaries of the River Moy during the 2004 survey.

River	Site Number	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Yellow (Foxford)	M 19	*Lampetra sp.*	8	0.74	0.10	1.30	0.47	0.23	0.33
Strade	M 20	*Lampetra sp.*	12	2.71	0.60	5.30	1.61	2.58	0.91
Strade	M 21	*Lampetra sp.*	2	5.00	3.30	6.70	2.40	5.78	3.33
Bunfinglas	M 22	*Lampetra sp.*	48	1.75	0.10	3.10	0.63	0.40	0.18
Gweestion	M 23	*Lampetra sp.*	1	1.20	1.20	1.20			
Gweestion	M 24	*Lampetra sp.*	8	1.70	1.10	2.20	0.39	0.15	0.27
Gweestion	M 25	*Lampetra sp.*	1	3.00	3.00	3.00			
Gweestion	M 33	*Lampetra sp.*	1	1.00	1.00	1.00			
Gweestion	M 34	*Lampetra sp.*	2	1.60	1.50	1.70	0.14	0.02	0.20
Gweestion	M 36	*Lampetra sp.*	1	0.50	0.50	0.50			
Spaddagh	M 37	*Lampetra sp.*	7	2.20	0.40	3.70	0.99	0.97	0.73
Spaddagh	M 38	*Lampetra sp.*	2	0.90	0.40	1.40	0.71	0.50	0.98
Sonnagh	M 40	*Lampetra sp.*	2	1.90	0.80	3.00	1.56	2.42	2.16
Sonnagh	M 41	*Lampetra sp.*	3	2.73	2.40	2.90	0.29	0.08	0.33
Mullaghanoe	M 43	*Lampetra sp.*	4	4.53	2.20	8.00	2.66	7.09	2.61
Mullaghanoe	M 44	*Lampetra sp.*	24	2.18	0.50	3.90	0.89	0.79	0.36
Mullaghanoe	M 45	*Lampetra sp.*	6	2.37	0.30	3.40	1.09	1.20	0.88
Mullaghanoe	M 46	*Lampetra sp.*	40	3.79	0.20	10.30	2.79	7.80	0.87
Owengarve	M 47	*Lampetra sp.*	4	1.80	0.20	3.50	1.35	1.83	1.33
Owengarve	M 48	*Lampetra sp.*	14	2.03	0.90	3.10	0.70	0.49	0.37
Owengarve	M 49	*Lampetra sp.*	15	1.13	0.20	2.50	0.75	0.56	0.38
Owengarve	M 51	*Lampetra sp.*	19	0.57	0.20	1.20	0.24	0.06	0.11
Owengarve	M 52	*Lampetra sp.*	8	2.16	0.70	3.00	0.95	0.89	0.66
Einagh	M 53	*Lampetra sp.*	5	1.82	0.80	3.10	1.14	1.30	1.00
Einagh	M 54	*Lampetra sp.*	20	2.19	0.40	4.30	1.33	1.77	0.58
Brusna	M 55	*Lampetra sp.*	1	4.60	4.60	4.60			
Clydagh	M 62	*Lampetra sp.*	1	0.90	0.90	0.90			
Clydagh	M 68	*Lampetra sp.*	7	4.06	0.60	5.80	2.23	4.97	1.65
Tobergal (Crumlin)	M 69	*Lampetra sp.*	49	1.02	0.10	3.90	1.10	1.20	0.31
Deel	M 71	*Lampetra sp.*	1	3.00	3.00	3.00			
Deel	M 72	*Lampetra sp.*	61	2.61	0.40	4.60	0.94	0.89	0.24
Deel	M 73	*Lampetra sp.*	57	2.22	0.10	4.60	1.26	1.58	0.33

Table 22 Descriptive statistics for weight (g) for juvenile *P. marinus* captured at sites on the tributaries of the River Moy during the 2004 survey.

River	Site Number	Species	N	Mean	Min	Max	St.Dev.	Variance	95% C.I.
Yellow (Foxford)	M 19	*P. marinus*	2	0.30	0.30	0.30	0.00	0.00	
Bunfinglas	M 22	*P. marinus*	3	0.27	0.20	0.30	0.06	0.00	0.07
Mullaghanoe	M 43	*P. marinus*	1	5.10	5.10	5.10			
Brusna	M 55	*P. marinus*	12	4.58	2.10	6.70	1.27	1.61	0.72
Clydagh	M 61	*P. marinus*	1	10.80	10.80	10.80			
Tobergal (Crumlin)	M 69	*P. marinus*	4	0.15	0.10	0.20	0.06	0.00	0.06
Deel	M 72	*P. marinus*	2	3.80	3.10	4.50	0.99	0.98	1.37
Deel	M 73	*P. marinus*	16	0.52	0.10	4.10	1.14	1.30	0.56

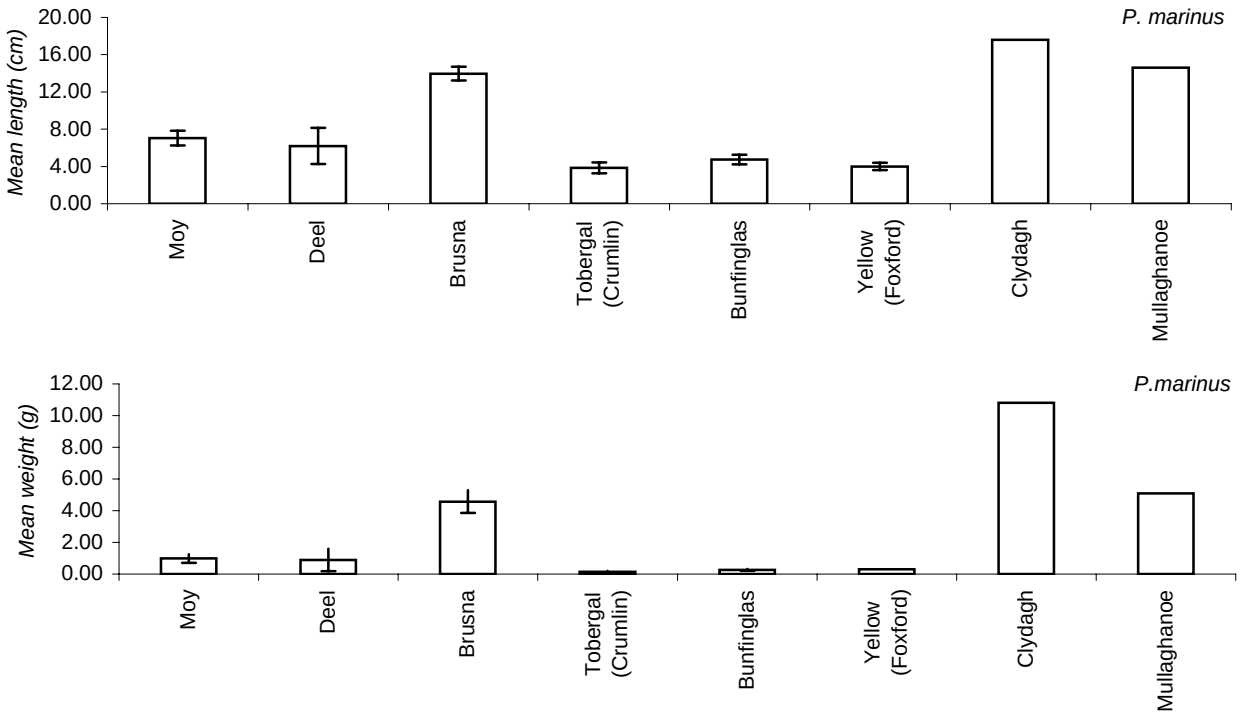


Figure 11 Mean length (cm) and weight (g) +/- 95% C.I. for *P. marinus* collected during the 2004 survey.

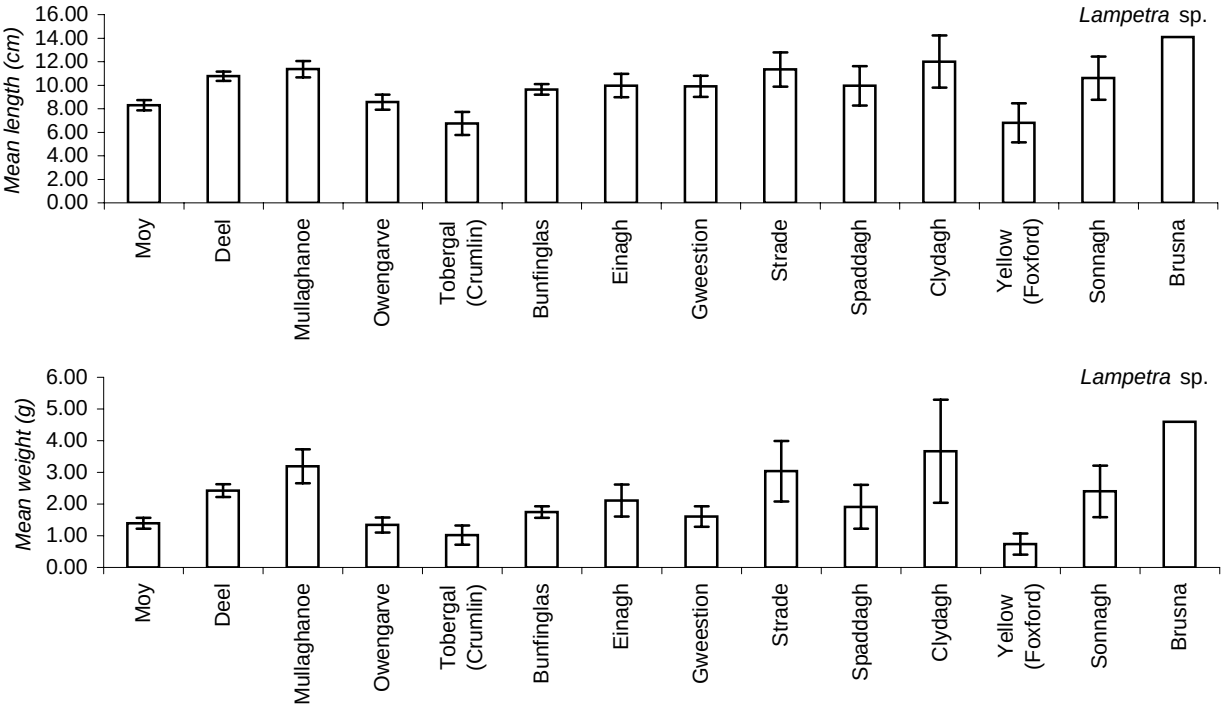


Figure 12 Mean length (cm) and weight (g) +/- 95% C.I. for *Lampetra* sp. collected during the 2004 survey.

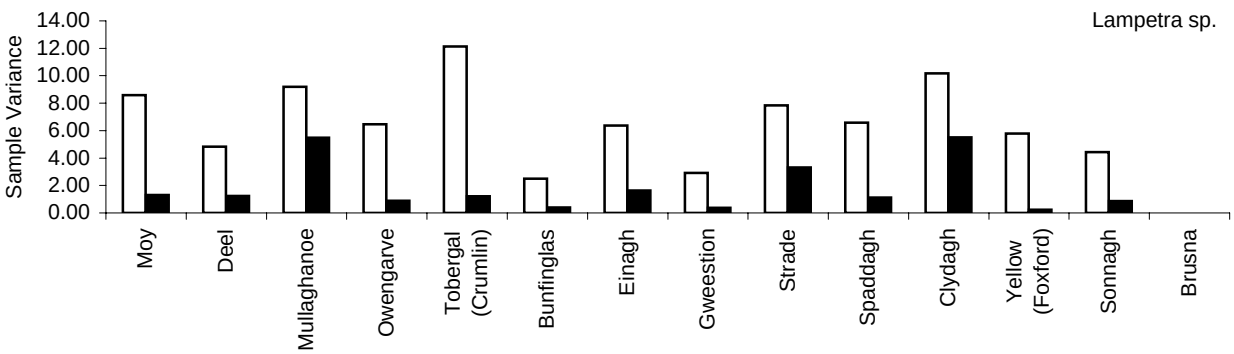
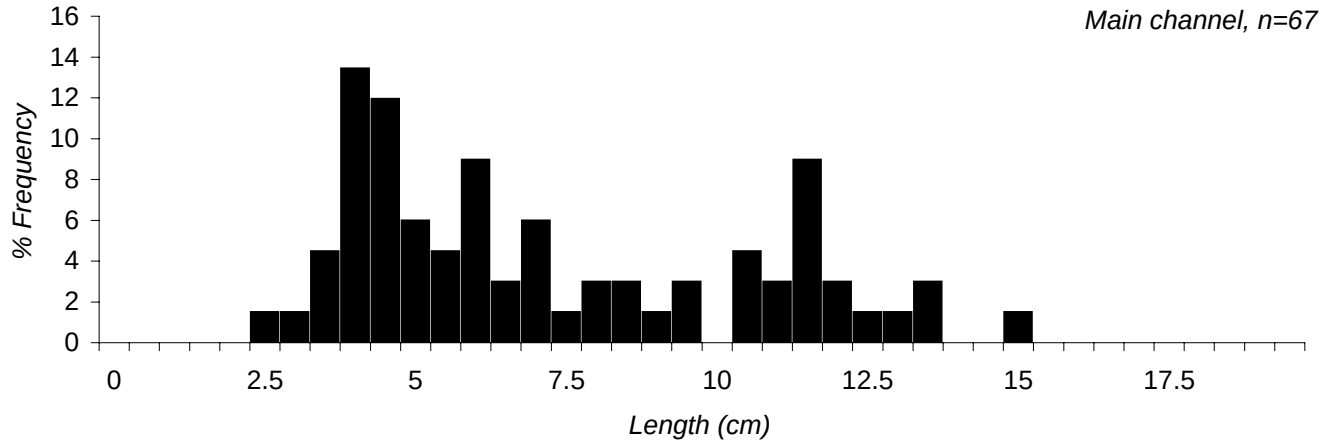
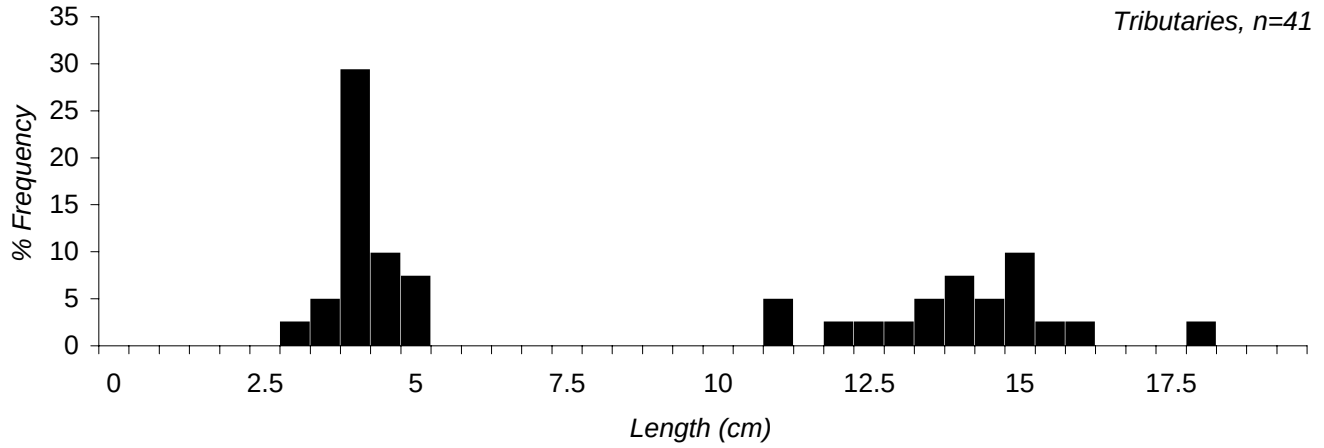
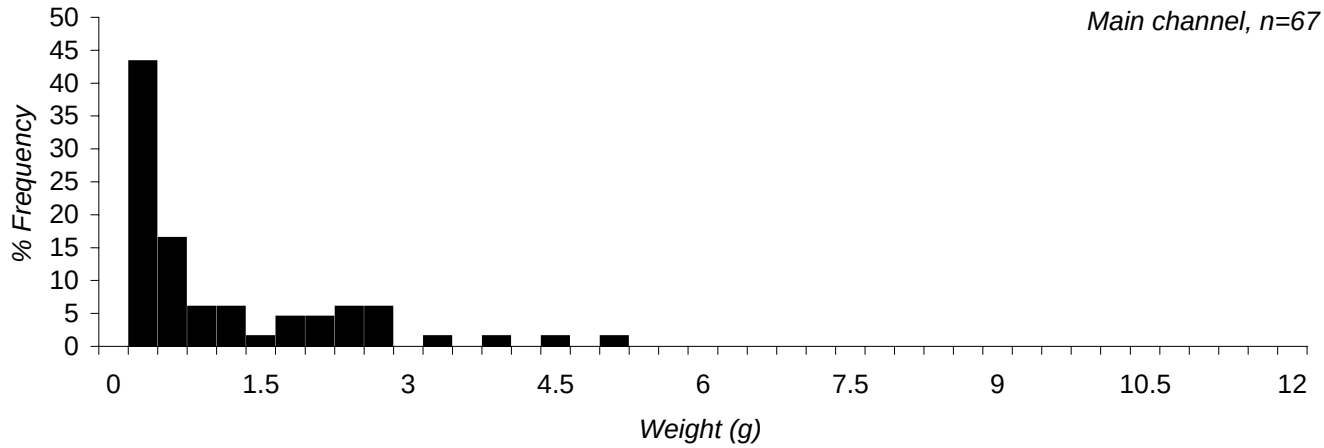


Figure 13 Sample variances for Length and weight for *Lampetra* sp.samples collected during the 2004 survey.







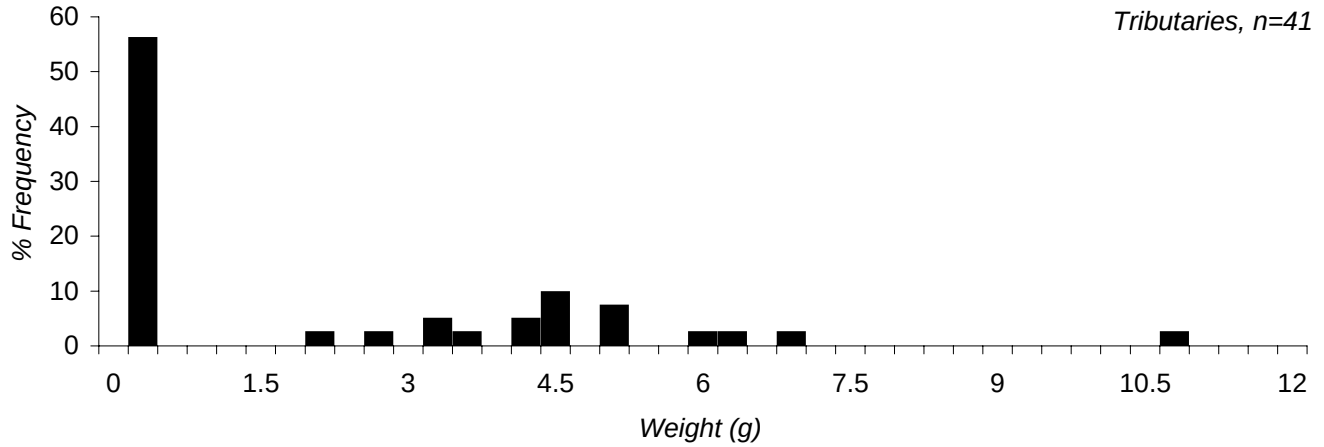


Figure 14 Length and weight percentage frequency distributions of *P. marinus* collected from the main channel of the River Moy and its tributaries during the 2004 electrical fishing survey.

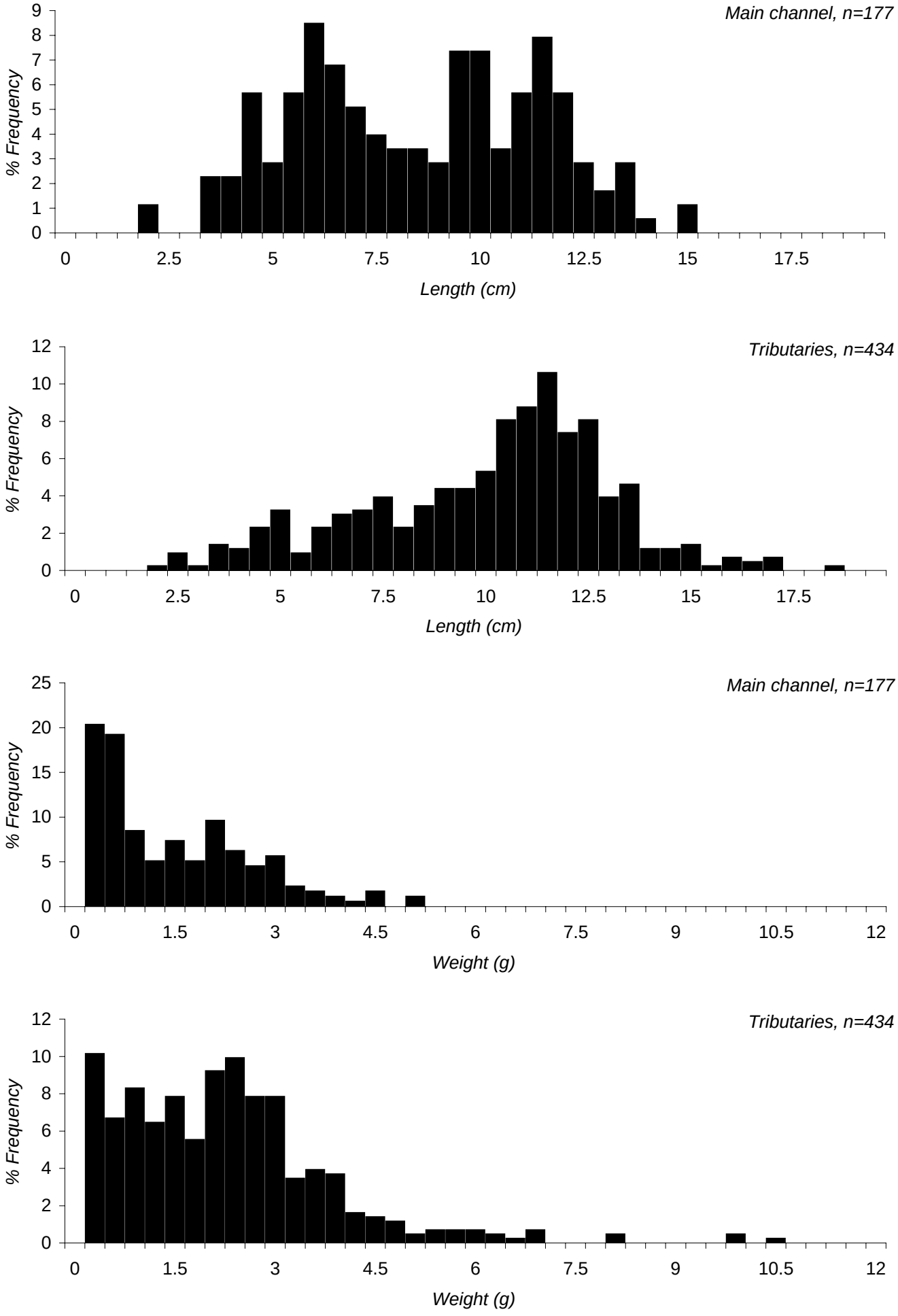


Figure 15 Length and weight percentage frequency distributions of *Lampetra* sp. collected from the main channel of the River Moy and its tributaries during the 2004 electrical fishing survey.

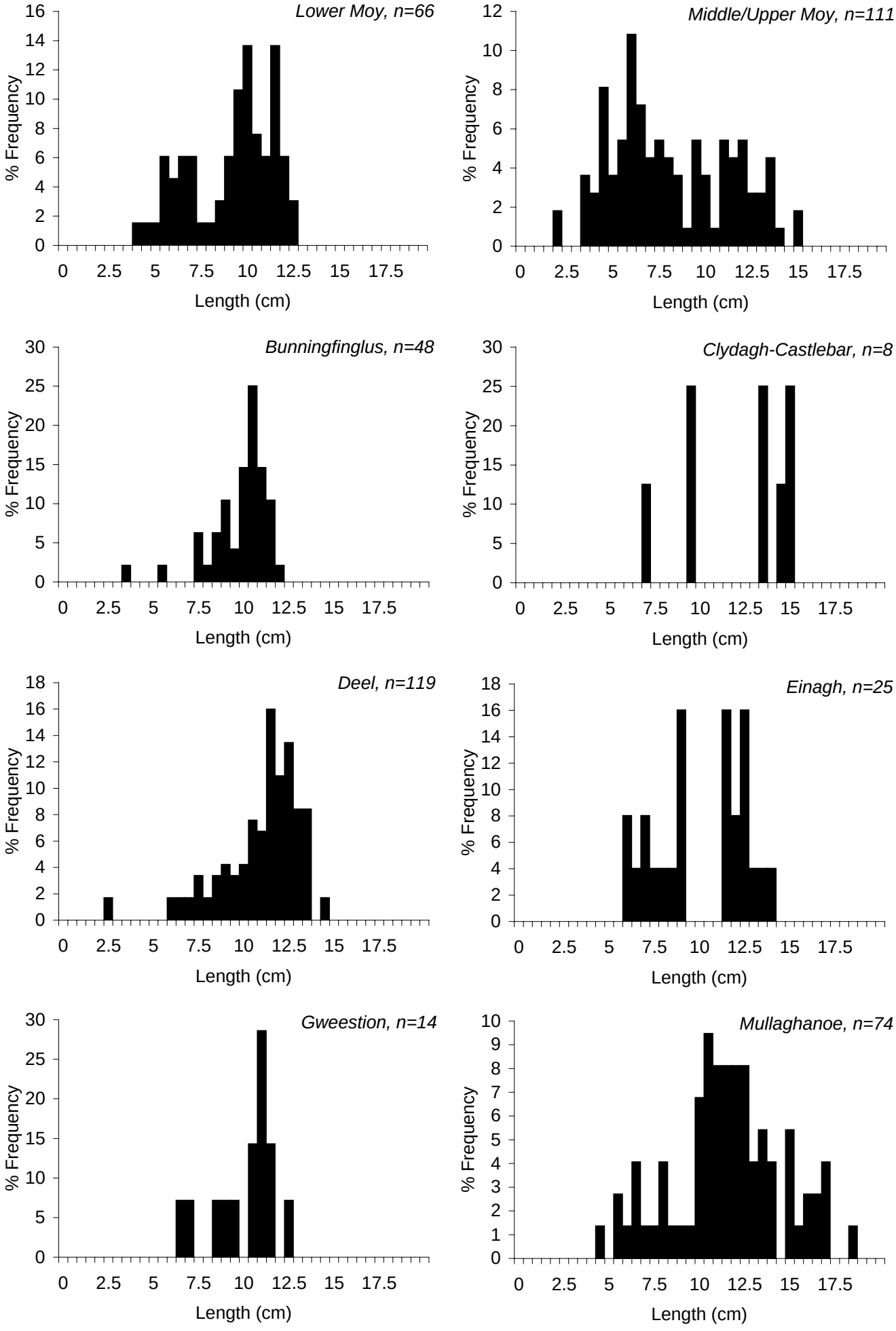


Figure 16 Length percentage frequency distributions of *Lampetra* sp. collected from selected areas of the Moy catchment during the 2004 electrical fishing survey.

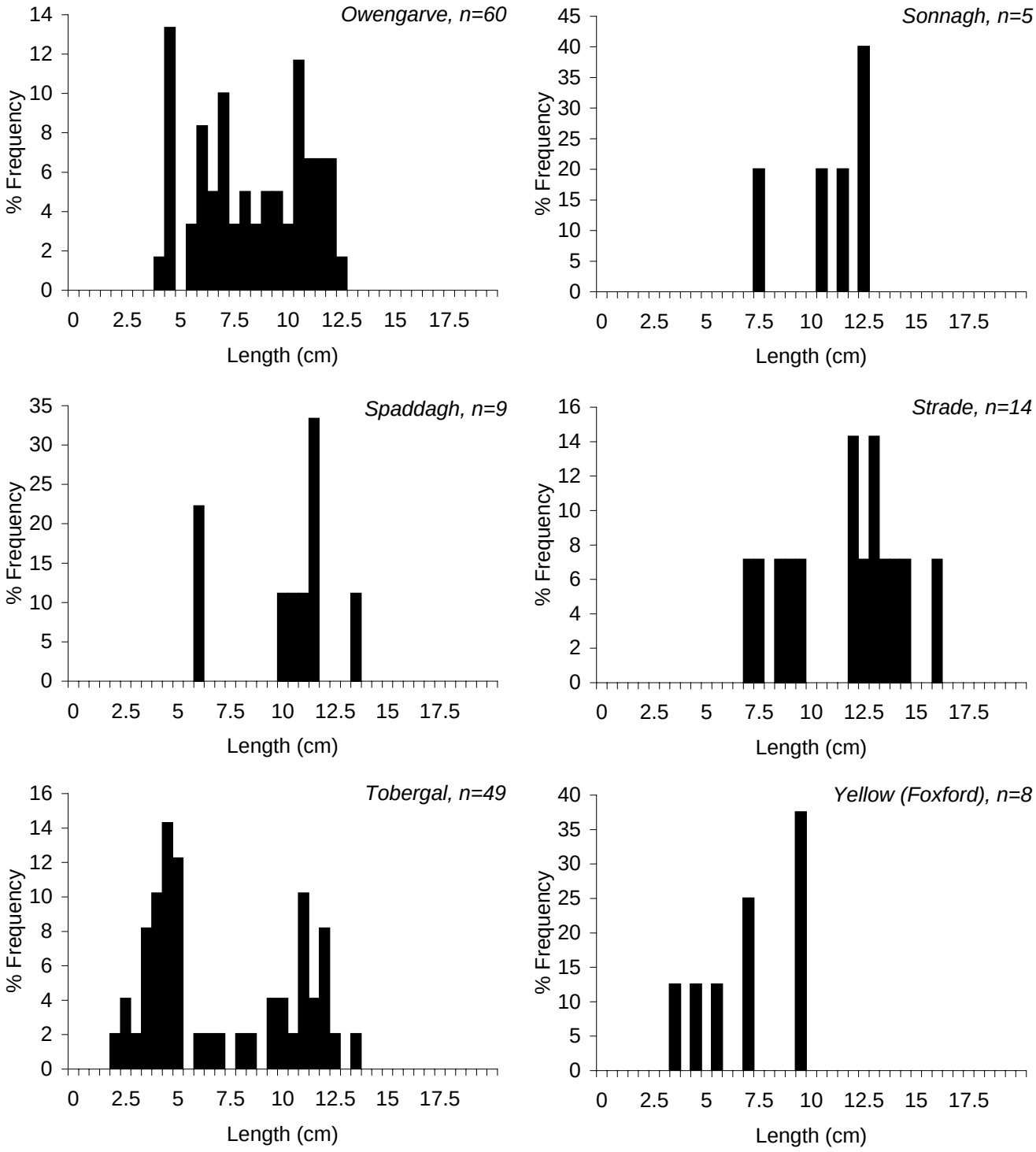


Figure 17 Length percentage frequency distributions of *Lampetra* sp. collected from selected areas of the Moy catchment during the 2004 electrical fishing survey.

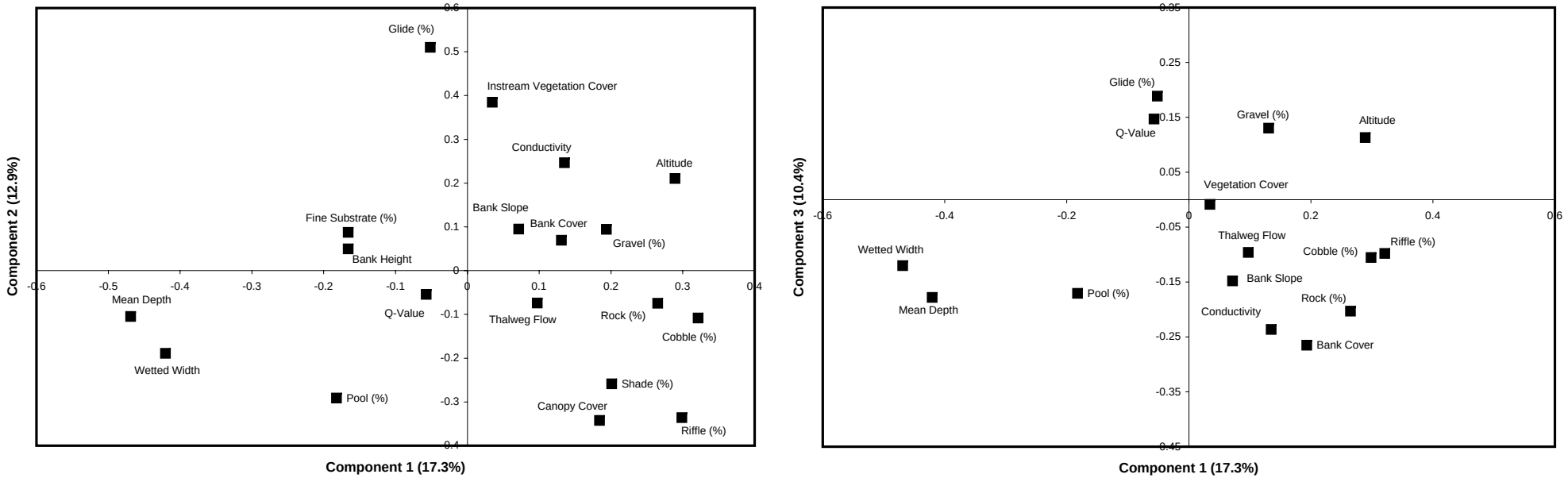


Figure 18 Principle Component Analyses (PCA) of macro-environmental data recorded at the 75 sites investigated during the 2004 survey (PCA Co-efficients).

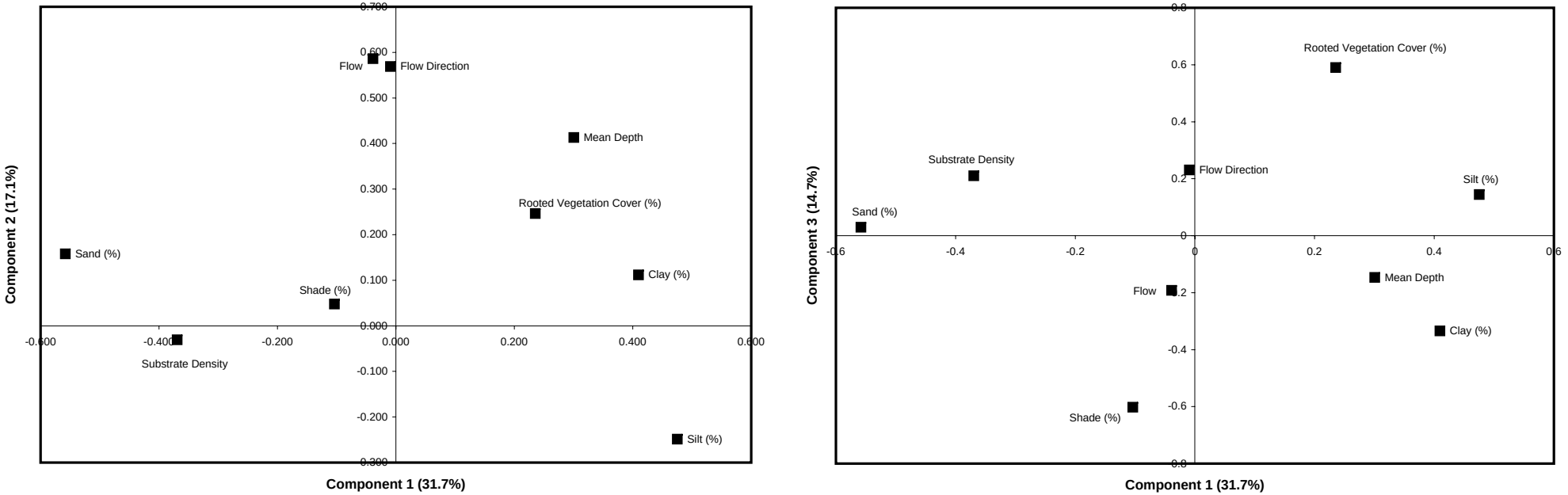


Figure 19 Principle Component Analyses (PCA) of micro-environmental data collected during the 75 site survey of the Moy catchment (PCA Co-efficients)..

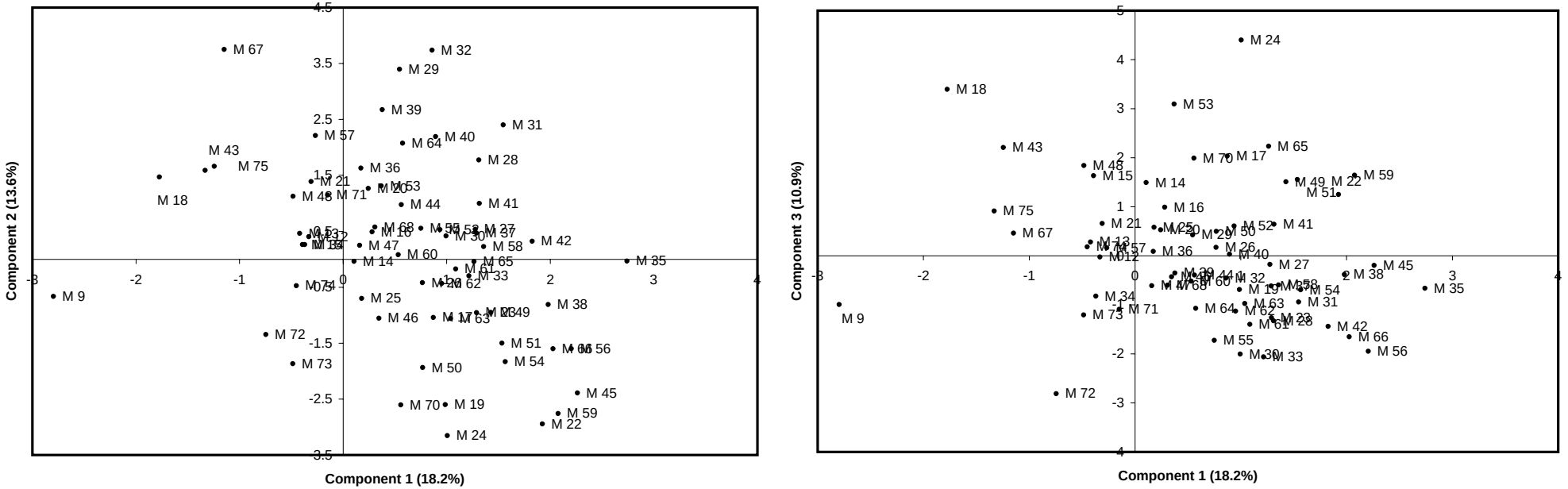


Figure 20 PCA ordination of the 75 sites using general environmental data collected during the 2004 survey (PCA Scores).

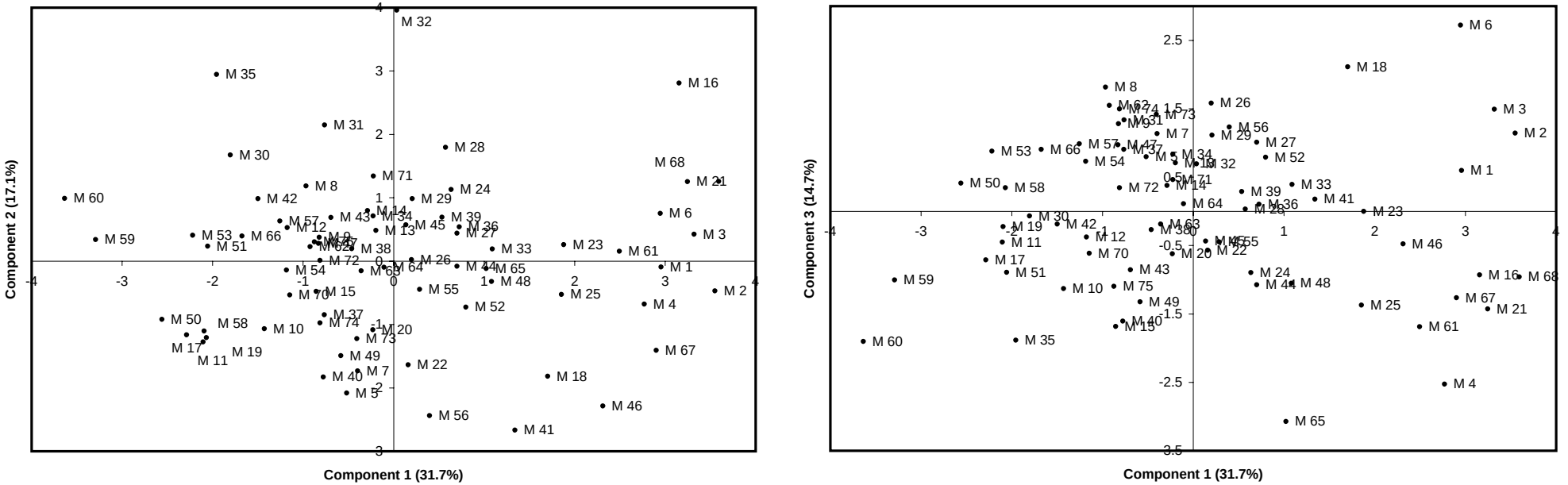
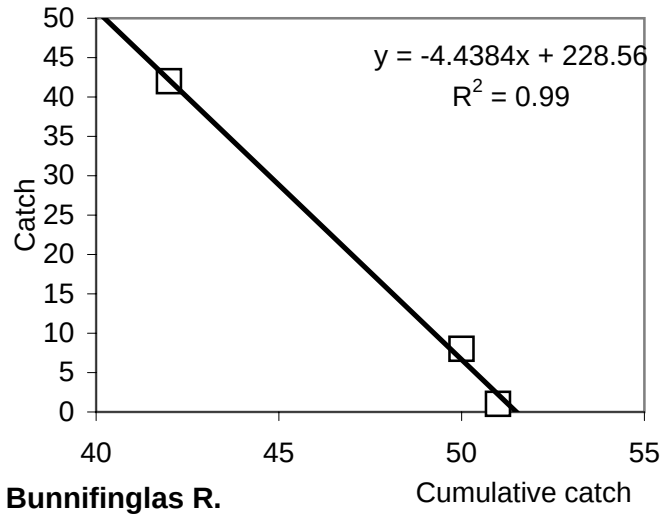
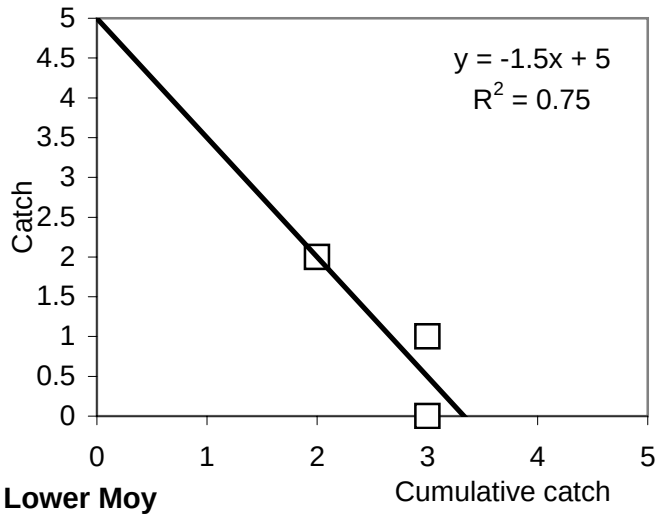


Figure 21 PCA ordination of the 75 sites using detailed environmental data collected from the actual surveyed area during the 2004 investigation (PCA Scores).





Lower Moy		Bunnifinglas R.		Einagh R.		% I[st] Catch
						59
Catch	Cumulative catch	Catch	Cumulative catch	Catch	Cumulative catch	
2	2	42	42	5	5	83.1
1	3	8	50	0	5	15.3
0	3	1	51	0	5	1.7

Figure 22 Results of the quantitative electrical fishing investigations at three sites.Depletion lines, Leslie-Davies method, for the total numbers of juvenile lamprey captured, are given for two sites. No depletion was obtained at the site investigated on the R. Einagh.

Table 23 Density estimations (fish m^{-2}) for juvenile lampreys at the 2 sites where depletions were obtained.

Site	Equation	R^2	Population estimate	Density (lamprey m^{-2})
1	y = -4.4384x + 228.56	0.99	51	9.27
2	y = -1.5x + 5	0.75	3	0.60
3	Could not be estimated	n/a	n/a	n/a

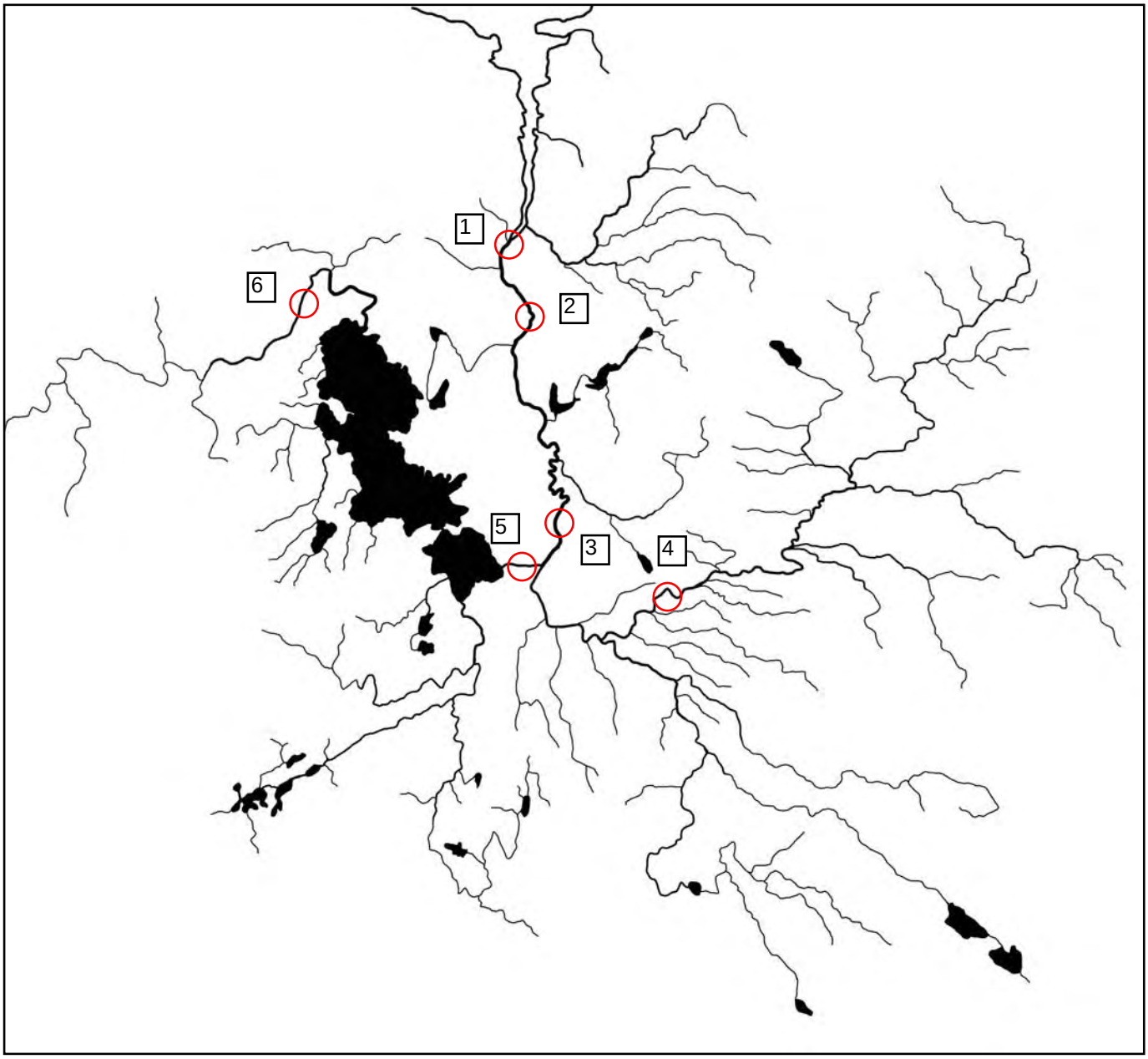


Figure 23 Areas of the Moy catchment which may be of importance for sea lamprey spawning. (1) Ballina and the 'Ridge Pool', (2) A short stretch of river at Mount-Falcon, (3) Foxford, (4) Lower end of Ballintemple Fishery, (5) The Cross or Lake River, (6) The Lower River Deel.

Table 24 The distribution and total weight (g) of bycatch fish species recorded during the 75 site survey of the Moy catchment during 2004.

River	**Salmo salar (g)**	**Salmo trutta (g)**	**Anguilla anguilla (g)**	**Gasterosteus aculeatus (g)**	**Perca fluviatilis (g)**	**Esox lucius (g)**	**Rutilus rutilus (g)**	**Phoxinus phoxinus (g)**	**Platichthys flesus (g)**	**Barbatua barbatua (g)**	**Total Bycatch (g)**
Gweestion	1536	1673	885	16.6	1	86	10	0	0	0	4207.6
Moy	133	547	2278	190.7	34	0	68	0	60	1.2	3311.9
Clydagh	120	239	1261	7	27	0	50.4	0	0	15.5	1719.9
Brusna	79	232	1179	11	0	0	0	0	79	0	1580
Strade	954	21	21	28	0	0	0	0	0	0	1024
Owengarve	112.6	151.5	593	58	0	0	0	0	0	3.6	918.7
Mullaghanoe	143	455	22	61.2	0	0	41.1	0	0	3	725.3
Swinford	190	75	123	16.8	0	0	0	0	0	0	404.8
Sonnagh	252.4	104	16	5.5	0	0	0	0	0	2.5	380.4
Spaddagh	127	96.7	150	3.5	0	0	0	0	0	0	377.2
Pontoon	0	0	190	0	0	0	31	0	0	0	221
Deel	10	84	5	3	2	0	30	15.5	0	0	149.5
Einagh	54	66	0	4	0	0	0	0	0	2.2	126.2
Yellow (Foxford)	15	22	30	2	0	0	0	0	0	0	69
Bunfinglas	0	0	60	0	0	0	0	0	0	0	60
Tobergal (Crumlin)	4	9	0	6.4	0	0	0	0	0	0	19.4
Total (g)	3730	3775.2	6813	413.7	64	86	230.5	15.5	139	28	

5. DISCUSSION

Electrical fishing is regarded as the most effective, non-destructive sampling procedure for fishes in small to medium sized streams (Zalewski & Cowx, 1990; Schill & Beland, 1995; Kolz *et al*, 1998; Pusey *et al*, 1998; Reynolds & Holliman, 2000). However, numerous authors have reported that electrical fishing methods can create bias in population sampling procedures (McKenzie & Pring 1988; Pusey *et al*. 1998; Temple *et al*. 1998). This is because galvanotaxic and galvanonarcotic responses can vary among species and size classes (Larimore, 1961; Kolz *et al*, 1998; Onorata *et al*, 1998; Pusey *et al*, 1998; Reynolds & Holliman, 2000). Electrical fishing efficiency can also vary with factors such as water conductivity, voltage, direction of movement of target fish within the electric field, and water temperature (Vibert 1967; Kolz *et al*, 1998). Disturbance and fright-bias (Temple *et al*, 1998), stream width (Pusey *et al*, 1998) and a range of other biological, environmental and technical factors have also been reported to affect electrical fishing sampling abilities (Zalewski & Cowx, 1990). However, despite its limitations electrical fishing is generally regarded as a good relative measure of population density. The back-pack electrical fishing method employed in the current study is widely utilized for sampling juvenile lampreys in the USA (Tribbles, 1959; Braem & Ebel, 1961; Weisser & Klar, 1990, & Moser & Close, 2003) where it has been shown to have a high degree of predictive ability in relation to juvenile lampreys.

The current survey was limited to areas <0.4m deep and the majority of surveys were carried out within the same one-month period under similar climatic conditions (good weather, normal flows). The densities of lampreys recorded were relatively low and a dip net was used to remove lampreys that failed to be captured by the operator. These factors are thought to have ensured that the methodology used was efficient and that the catches broadly reflected the populations of present in the surveyed areas. Steeves *et al* (2003) found that a higher proportion of larvae of all sizes were collected per unit sampling effort when sample sites were shallower and contained fewer larvae. Steeves *et al* (2003) also found that similar length distributions were found between sea lamprey larvae collected using electrical fishing gear and those collected using a suction dredge. However, it is likely that the efficiency of capturing YOY larvae during the current survey was lower than that for older cohorts. It was thought that the small size of these larvae could make them difficult to detect under certain circumstances (i.e. due to poor visibility caused by shade, turbidity or other factors, and in deeper water). Knights *et al*, (1996) reported that small eels (*Anguilla anguilla*) can be particularly difficult to capture when electrical fishing and this is also likely to be the case for YOY lampreys (which are much smaller).

The impact of the 1960s Moy arterial drainage scheme on lamprey production in the catchment was probably highly significant. Many areas of the catchment, including areas along the main Moy along with extensive stretches of tributaries such as the Manulla, Gweestion and Glore, can no longer support lamprey populations due to absence of suitable nursery habitat. In many areas juvenile lampreys generally occur only in artificially created backwaters such as excavated cattle drinking areas. Recent instream development works for salmonids seem to have done little to improve lamprey nursery habitats in the catchment, but may have improved spawning habitats. Water quality is a problem in other areas, such as the Castlebar River. However, despite the drainage works, the Moy remains a significant habitat for lampreys. Extensive areas of secondary nursery habitat occur on the depositing side of the meanders on the lower river Moy – areas such as the 'Rinnaney bends' were deepened but not channelised during the 1960s scheme. Sluggish rivers such as the Mullaghanoe also have significant lamprey populations. However recent recruitment has not been a feature of this river, possibly due to declining water quality. Existing lamprey habitat in the catchment is under threat from drainage maintenance, physical impacts of farm animals, and pollution.

The possibility of enhancing lamprey populations in the catchment through development works should be considered and provisions for lampreys should be included in any further works undertaken by the fisheries board or private fishery owners. Unlike other Irish river systems (i.e. Corrib, Erne, Lee, Shannon etc.), there are few barriers to the upstream migration of lampreys in catchment. This absence of barriers has ensured that lampreys are widely distributed in the Moy catchment. Lampreys do not appear to have significant difficulty in ascending through cascades, such as those at the 'boxes' in Ballina or downstream of Foxford, as significant populations were found upstream of these obstacles. However, the fact that many sea lampreys do not migrate further upstream than the ridge pool, where they are often observed spawning in significant numbers, may suggest that the cascades at the 'boxes' are a partial barrier or a barrier under certain flow conditions. Spawning activity in the ridge pool seems to contribute little to recruitment of larval sea lampreys in the river – as evidenced by the absence of younger size groups of larvae at the sites investigated in Ballina. Natural falls present at the Deel at Ballycarroon, and on the Glenree at Ballina mark the upstream limit in the distribution of lampreys in both these rivers. The main lamprey populations in the River Moy are currently protected within the existing SAC boundary area and no recommendations are made to extend the boundary area. During the current survey it was not possible to ascertain whether river lamprey *Lampetra fluviatilis* is present in the River Moy. It is recommended that lamprey spawning walkover/canoe surveys be undertaken during April to June

2005 when spawning adults can be assessed. This would also provide detailed information on the spawning sites of *P. marinus* in the catchment.

Including areas visited but not fished, the current survey had a sampling density of 0.048 sites per km^2 of catchment area. This is a relatively high resolution for a survey of its type and allowed the examination of sites in almost all river channels where lampreys were likely to occur. In the current study, an attempt was made to study lamprey abundance at two spatial scales – a macrohabitat and a microhabitat level. The macrohabitat level is the large spatial scale of the river channel. Variations on the macrohabitat scale (e.g. channel size) influence the formation of habitats on finer scales such as the microhabitats which larval lampreys inhabit. The presence of lamprey larvae at particular habitats is also dependent on recruitment to these areas. Lampreys were absent from sites, such as the River Deel upstream of Ballycarroon falls, despite the presence of suitable microhabitats. The presence of sea lamprey larvae along a river channel was found to be more influenced by macrohabitat features than microhabitat variables. This reflects the fact that influences on a macrohabitat scale, such as river channel size and distance from the sea have a greater influence on the presence of sea lamprey larvae that habitat influences on a smaller scale. The distribution and abundance of (likely to be resident) *Lampetra* sp. larvae was influenced by environmental factors on both scales. Drained rivers such as the Moy and its tributaries have much reduced heterogeneity on a macrohabitat scale and this results in a lower availability and higher homogeneity of microhabitats than in undrained rivers. This is unlikely to favour larval lampreys and may explain why lamprey abundances in the Moy catchment were generally lower that those reported for undrained channels by King & Linnane (2004).

Detailed studies on the distribution and abundance of larval lampreys have shown that populations are associated with patchy fluvial features, such as backwaters, eddies, insides of bends and the downstream end of sand bars, in which fine sediments (sand and silt) tend to accumulate (Torgersen *et al*, 2004). However, the probability of larvae occurring within these 'preferred' habitats is typically low (<50%) (Sugiyama & Goto, 2002). Torgersen *et al* (2004) concluded that twelve 1 m^2 samples distributed over 50m of stream were more effective in assessing larval lamprey abundance than a single 12 m^2 sample. In the current survey, suitable lamprey habitat was difficult to find in many areas. In these areas surveying was carried out at patches of habitat along up to 100m of River channel (e.g. Gweestion). However, at the sites where habitat was abundant, a single area was assessed (e.g. main Moy, Mullaghanoe, Owengarve). Because of this, the abundance of juvenile lampreys may have been underestimated in some areas. This spatial heterogeneity of lamprey

abundance, even in suitable habitats, may explain the absence of lampreys at a number of sites during the current survey (i.e. sites M27, M36 on the main Moy and site M77 on the Yellow Foxford River).

There are relatively few data available concerning the water quality requirements of lampreys; however they are generally regarded to be sensitive to pollution (Maitland, 2003). The influence of water quality on the presence and abundance of juvenile lampreys in the Moy catchment could not be demonstrated during the current study. Water quality was generally satisfactory in areas where lampreys were present and areas where water quality was poor coincided with the presence of poor physical habitats (i.e. Castlebar River). However, the absence of evidence of recent lamprey recruitment in rivers such as the Mullaghanoe, may be a result of poor water quality. Lampreys are important indicators of habitat diversity and their presence and abundance in rivers, along with other indicator species, could be used to assess the "good ecological status" of rivers as required by the Water Framework Directive.

Evidence from research on sea lampreys in North America suggests that sea lampreys do not home to natal streams (Bergstedt & Seelye, 1995) but instead respond to a bile acid based pheromone released by conspecific larval lamprey (Li *et al,* 1995; Bjerselius *et al,* 2000; Polkinghome *et al,* 2001; Vrieze and Sorensen, 2001). This has significant management implications for lampreys in the Moy catchment and other SACs. Should the stock of larval lampreys in a river decline, returning sea lampreys may in turn no longer select this river for spawning. This would subsequently lead to further declines and potential local extinction. Female sea lampreys are also attracted to the presence of other male conspecifics in a stream (Li *et al,* 2002). Although proposed for use in the North American great lakes as a lure to control exotic populations (Sorensen & Vrieze, 2003; Li *et al,* 2003), the artificial placement of adult males into streams could be used as a management tool for assisting in restoring runs to streams affected by, for example, pollution or drainage, or attracting lampreys into newly developed or restored spawning areas in the future.

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APPENDIX 1: Site Photographs

Site photographs of actual surveyed areas are provided on the CD-ROM.

Site M1

Site M2

Site M3

Site M4

Site M5

Site M6

Site M7

Site M8

Site M9

Site M10

Site M11

Site M12

Site M13

Site M14

Site M15

Plates 31-45 River sections investigated during the 2004 survey of the Moy catchment.

Site M16

Site M17

Site M18

Site M19

Site M20

Site M21

Site M22

Site M23

Site M24

Site M25

Site M26

Site M27

Site M28

Site M29

Site M30

Plates 46-60 River sections investigated during the 2004 survey of the Moy catchment.

Site M31

Site M32

Site M33

Site M34

Site M35

Site M36

Site M37

Site M38

Site M39

Site M40

Site M41

Site M42

Site M43

Site M44

Site M45

Plates 61-75 River sections investigated during the 2004 survey of the Moy catchment.

Site M46

Site M47

Site M48

Site M49

Site M50

Site M51

Site M52

Site M53

Site M54

Site M55

Site M56

Site M57

Site M58

Site M59

Site M60

Plates 76-90 River sections investigated during the 2004 survey of the Moy catchment.

Site M61

Site M62

Site M63

Site M64

Site M65

Site M66

Site M67

Site M68

Site M69

Site M70

Site M71

Site M72

Site M73

Site M74

Site M75

Plates 91-105 River sections investigated during the 2004 survey of the Moy catchment.