Executive Summary

Planning permission was granted during 2004 by Mayo County Council for the development of a gas terminal at Bellagelly South, Bellanaboy Bridge, and associated peat deposition site at Srahmore and Attavally, Bangor-Erris, Co Mayo. A condition (Condition No. 29 of Pl 16.207212) in the subsequent An Bord Pleanála decision relating to the necessity for a baseline salmonid study was included in a list of conditions for the development. The 2004 survey included fish stock assessment of the Bellanaboy sub-catchment and the littoral zone of Carrowmore Lake in the vicinity of Bellanaboy. Habitat type was classified and quantified using aerial photographic surveys and a Geographic Information System (GIS) was used in analysis of this dataset. A combination of habitat quantification and estimation of fish biomass has allowed for the estimation of the potential smolt output for the Bellanaboy River and downstream lacustrine habitat.

Water quality in both the Bellanaboy and Carrowmore Lake would appear to be deteriorating with ortho-phosphate levels in the streams and chlorophyll and ortho-phosphate concentrations in the lake both giving rise to concern.

Juvenile salmonid stocks in Bellanaboy were relatively low and when combined with the habitat classification, a yield of some 500+ salmon smolts was estimated. There was evidence that salmon and trout may be moving downstream and utilising lake habitat as nursery area. Tentative estimates of between 4,500 and 9,000 smolts were derived for the lacustrine habitat, but these estimates require considerable further refinement. The impact, if any, of the algal blooms in 2003 and 2004 has not been quantified, but it is likely to be detrimental. Brook lamprey, a protected species, was found in the Bellanaboy river, and stickleback and minnow (an introduced species) were present in both the lake and the river.

This survey, in combination with previous surveys by the MI, NWRFB & AQUENS Ltd, provides a useful baseline for the monitoring of juvenile salmonids in the Bellanaboy during the construction and operation phases of the gas terminal. A further programme of stock assessment, including an annual audit of existing sites is proposed. Inclement weather conditions in late 2004 left a number of important sites unsurveyed and these will be completed in 2005.

CONTENTS

1.

INTRODUCTION

Planning permission was granted during 2004 by Mayo County Council for the development of a gas terminal at Bellagelly South, Bellanaboy Bridge, and associated peat deposition site at Srahmore and Attavally, Bangor-Erris, Co Mayo. A condition (Condition No. 29 of Pl 16.207212) in the subsequent An Bord Pleanála decision relating to the necessity for a baseline salmonid study was included in a list of conditions for the development. The North Western Regional Fisheries Board (NWRFB) and the Marine Institute (MI) were contracted by Shell E&P Ireland Limited to undertake a baseline assessment of the salmonid habitat in the Owenmore catchment, adjacent to the proposed development area.

The scope and degree of monitoring for the study was agreed during consultations with Shell in 2004. The work programme included stock assessment using beach seining, a semi-quantitative methodology developed by the MI for fishing the littoral zones in lacustrine (lake) habitat, and electrofishing of streams. Habitat type was classified and quantified using aerial photographic surveys, which were carried out by Compass Informatics, and a Geographic Information System (GIS) was used in further analysis of this dataset. A combination of habitat quantification and estimation of fish biomass has allowed for the estimation of the potential smolt output for the Bellanaboy River and downstream lake habitat. Survival indices for salmon populations obtained from research projects undertaken in the Burrishoole catchment, and from other studies quoted in the literature, have been applied where available. Sampling of the instream gravel and cobble substrate, at locations above and below the probable discharge from the terminal development, was carried out in order to provide an assessment of the status of the potential spawning habitat.

Existing datasets were also used to assist in the determination of the productivity of the system. These included annual electrical surveys completed by AQUENS for the period 2001 to 2003. The completion of a project on the quantification of the freshwater salmon habitat asset in Ireland, by the Central Fisheries Board (CFB), has resulted in the provision of a dataset that allows for the calculation of the "wetted area" for individual stream segments and tributaries within catchments, and has assisted in the quantification of fluvial habitat (McGinnity *et al*. 2003). A series of investigations carried out by the NWRFB to determine the causes of the decline in water quality in the catchment were also included to provide a comprehensive overview and trophic classification for the watercourses under study. A bathymetric survey of Carrowmore Lake was carried out by the NWRFB during 2004.

Fieldwork and GIS modelling of the area was completed during March 2005 and this report summarises the results of this work. Inclement weather conditions during the sampling period prevented the completion of some of the fieldwork (Owenmore/Muinhin) scheduled for the 2004 work programme and it is hoped to incorporate these into the 2005 audit programme.

2.

SITE DESCRIPTION

The Shell gas terminal development is located in north Count Mayo in the Owenmore catchment. The development consists of the construction and operation of a gas terminal which is located principally in the Bellanaboy sub-catchment of Carrowmore Lake. A peat deposition site located to the south approximately 12 km away. The peat deposition area is a significant undertaking in its own right and is located adjacent to sensitive fisheries habitat of the Munhin and Owenmore Rivers.

Both Carrowmore Lake and the Owenmore River are renowned for the quality spring salmon, grilse and sea trout angling that they provide, as a recently produced Fisheries Catchment Management Plan has examined (NWRFB 2004). The construction of this terminal and peat deposition area represents a considerable industrial development in a sensitive location from the perspective of the fisheries resource located in close proximity to it.

The Bellanaboy River is the largest sub-catchment of Carrowmore Lake and contains important spawning and nursery areas salmon and trout. The river also hosts a population of Brook Lamprey *Lampetra planeri*, an Annex species under the EU Habitats Directive. Carrowmore Lake is a candidate Special Area of Conservation. The Munhin River is the outflow river from Carrowmore Lake and consists of deeper, low gradient channel that is more significant in terms of migrating salmonids rather than a productive juvenile habitat, although the presence of indigenous brown trout and eel populations would also be expected. It is occasionally fished by anglers and ownership is held privately.

A section of the Owenmore River is also included in this study as it is the location for discharges from a number of silt ponds emanating from the peat deposition area. The Owenmore River is vested in private ownership at this location and it is a valuable property right.

3.

WATER CHEMISTRY

3.1 Methods

Carrowmore Lake

Carrowmore Lake experienced serious algal blooms of Cyanobacteria, *Anabaena* spp. during the 2003 and 2004 seasons, with the result that angling on the lake had to cease during the summer months and with substantial loss of revenue to the local economy. In response to these conditions in the lake the NWRFB initiated a programme of water quality analysis under the Catchment Management initiative, to provide a source of baseline information for future strategies aimed at restoring affected watercourses. As part of these studies, monthly water samples on two stations in Carrowmore Lake were delivered to the EPA Regional Inspectorate in Castlebar for analysis.

Bellanaboy River

Also in response to the accelerated eutrophication in Carrowmore Lake, sampling of the major tributaries of Carrowmore Lake was undertaken by the NWRFB during 2004. Weekly grab samples (No. = 48) were taken on the lower reaches of the Bellanaboy River from the 19th August 2003 to the 29th July 2004.

3.2 Results

Carrowmore Lake

Annual mean chlorophyll concentrations of 26 µg/l (n = 11) and annual mean total phosphorous concentrations of 43 µg/l (n = 10), recorded for 2004, place the lake in a eutrophic category according to the classification scheme proposed by the O.E.C.D (Vollenweider & Kerekes, 1982).

The EPA, in their programme of lake water quality assessments, measures the annual maximum chlorophyll concentration. The trophic status of Carrowmore Lake had been categorized as mesotrophic or oligotrophic during the period 1995 to 1999, by this modified version of the O.E.C.D scheme. Annual maximum chlorophyll concentrations of 41 µg/l and 46 µg/l during 2003 and 2004 categorize the lake as strongly eutrophic.

The recent deterioration in water quality in Carrowmore Lake, leading to extended algal blooms has given rise to considerable concern, although to date there has been no apparent effect on dissolved oxygen levels in the lake. It is a reasonable assumption that juvenile fish densities and water quality in Carrowmore Lake may be correlated. Generally speaking, this decrease in water quality, especially during the summer period, results in a shift from a benthic habitat and macrophyte dominated system to a more open water phytoplankton and zooplankton dominated ecology. The overall effect on salmonid densities is uncertain, although the decrease in water transparency could possibly result in a decrease in feeding opportunities for fish. Deoxygenation in the water column, although not recorded to date, is possible during bloom conditions and also following the subsequent collapse and decay of the bloom during the autumn period. Irritations to fish from the algal concentrations in the lake are possible and sampling of juvenile salmonids in the Munhin River during 2003 revealed thickening and swelling in their epithelial gill tissue (NWRFB pers com.). The impact of the deterioration in water quality on fish production and smolt output has not been quantified.

Bellanaboy River

The Environmental Protection Agency (EPA) in their series of reports entitled "Water Quality in Ireland" has been emphasising the increasing impact of eutrophication on rivers and lakes as the main problem in the surface waters of the state. This is due in most cases to excess input of phosphorous (EPA 2002). In 1998 the Department of the Environment and Local Government issued a set of Phosphorus Regulations aimed at controlling eutrophication of Irish Rivers (DELG 1998).

The S.I. No. 258/1998: Local Government (Water Pollution) Act, 1997 (Water Quality Standards for Phosphorus) Regulations, 1998 set out the quality standards for rivers based on Biological Quality (Q-value) and molybdate-reactive phosphate median concentrations. The classification system is summarised in Table 1. Summary water quality statistics for Ortho-Phosphate concentrations (µg/l P) in the Bellanaboy River are contained in Table 2.

Table 1. Water Quality Standards for Rivers.

Biological Quality (Q value)	Molybdate-Reactive Phosphate Median Concentration (µg P/L)	Status
Q5	15	Unpolluted
Q4 - 5	20	Unpolluted
Q4	30	Unpolluted
Q3 - 4	30	Slightly Polluted
Q3	50	Moderately Polluted
Q2 - 3	70	Moderately Polluted
Q ≤ 2	70	Seriously Polluted

Table 2. Ortho-Phosphate Statistics Bellanaboy River 2003/2004 (n = 48).

Bellanaboy River Ortho-Phosphate (µg/l P)	
Mean	47.0
Standard Error	2.3
Median	46.0
Standard Deviation	15.8
Minimum	26.0
Maximum	113.0
Confidence Level (95.0%)	4.6

Ortho-phosphate results indicate that the Bellanaboy River is tending towards a moderately polluted status (Table 2). A further sampling programme initiated during the period August to September 2004 of lower order streams (no. = 5) revealed even higher ortho-phosphate concentrations than measured within the main channel (52 – 79 µg/l P). The high phosphorus measured in the Bellanaboy provides evidence for a deterioration in water quality and trophic status.

Recent studies carried out by the CFB (T. Champ, *pers. comm.*) correlating the presence or absence of individual fish species to water quality (Q values) indicated that there was a relationship between juvenile salmon distribution and water quality Q values (McGinnity *et al.* 2003). The CFB "wetted area" study used a Q value cut off point of Q-4, below which a stream was characterised as being likely to be compromised for juvenile salmon production.

Stocks of juvenile salmonids in the Bellanaboy System are generally low with particularly low numbers of 1+ parr present (See Section 5.2). It is not known to what extent these have been influence by the low water quality and it is also not known how the presence of Carrowmore Lake downstream might compensate for poor stream survival by providing productive habitat for downstream displaced fish. It is possible that a combination of factors have compensated for the low water quality and have made the stream habitable for fish. The sustainability of this situation in the longterm is a matter that will have to be evaluated. The status of the habitat quality in relation to salmon and lamprey should be assess in order to comply with the EU Directives and protect the species.

4.

HABITAT CLASSIFICATION

4.1 Methods

A Geographical Information System, GIS, software system, ArcView 3.2a was used in the analysis of the fisheries habitat in the catchment. Dataset series within the GIS developed for the Regional Fisheries Boards by Compass Informatics and the Marine Institute and further updated using the recent "Wetted Area" study were used.

A bathymetric survey of Carrowmore Lake was carried out by the NWRFB from a boat, using a Lowrance echo sounder, incorporating a handheld GPS (accuracy approx. 7 metres). Individual geo-referenced depths, from transects of the lake area, were modelled using software within the Spatial Analyst module of ArcView to yield a continuous surface of the lake bottom using an inverse distance weighted (IDW) interpolation technique. This allowed for the quantification of the littoral lake habitat area available to fish populations for any specified depth profile.

Compass Informatics Ltd were contracted in 2003 to capture aerial photography of the Owenmore Catchment. Digital aerial photography was captured at approximately 30cm resolution using the Compass GeoFoto camera system. This produced digital true colour images which were then georectified to fit to Irish National Grid using specialist software. Georectification and associated image mosaicing enabled the imagery to be viewed in the Geographical Information System (GIS) in association with many other maps layers.

In Autumn 2004 Compass Informatics Ltd were directed to further analyse this imagery in order to extract wetted width and wetted area for approximately 20km of the Munhin and Bellanaboy rivers, and to classify approximately 10km of the Owenmore by river habitat type. Wetted width delineation was carried out by on-screen digitising within the project GIS. This generated polygons from which the wetted area could be readily calculated. Image classification and habitat extraction followed a more in-depth process consisting of 'unsupervised classification' in an image processing software. This process analyses the digital information in the imagery and highlights the spectral differences in the imagery that are not readily identifiable by eye. Expert interpretation of this unsupervised classification was then undertaken, drawing on data captured via a ground truth field survey. This field survey utilised GPS and digital camera imagery to accurately record the actual features on the ground. By combining the knowledge gathered through field survey and image processing, a series of digital map polygons classified by habitats type were generated via on-screen delineation of habitat areas. This data is directly usable in a GIS that provides good management focused information on the Owenmore and neighbouring rivers.

4.2 Results
Fluvial Habitat

23.5 km kilometres of river channel were photographed and further processing of datasets was completed as set out in Table 3.

Table 3. Extent of digital aerial photography and type of analysis.

	Length (km)	*Analysis Completed*
Bellanaboy River	12.58km	Wetted Area
Munhin River	4.0km	Wetted Area
Owenmore River	7.0km	Habitat Classification

Owenmore River
Spectral analysis of the Owenmore River aerial photography was completed for the stretch from above the Salmon Weir in the townland of Goolamore to the bridge at Bangor Erris. This allowed for the classification of the river channel into a number of discrete habitat types and a calculation of their area to be made. The results of this survey are shown in Figure 1 and Table 4. Fluvial habitat within main stem river channels can provide a relatively important percentage of the available habitat in a catchment, especially if they remain in an undrained condition. Electrical fishing of discrete habitat type within this sub reach will be completed during 2005, which should allow for the productivity of this area to be established in more detail.

Table 4. Habitat classification & quantification for the Owenmore River.

Owenmore River - Habitat Classification

	Area (m^2)	*% Of Wetted Area*
Bankfull Area	276,299	
Wetted Area	184,627	
Riffle	33,785	18.30%
Glide	27,980	15.15%
Deep Glide	22,240	12.05%
Pool	95,899	51.94%
Back Eddy	2,187	1.18%
Back Pool	2,536	1.37%
Islands	3,419	
Bank Erosion	450	
Cobble	8,917	
Point Bars & Gravel Banks	77,378	
Fords & Weirs	478	
Mud Bank	1,030	

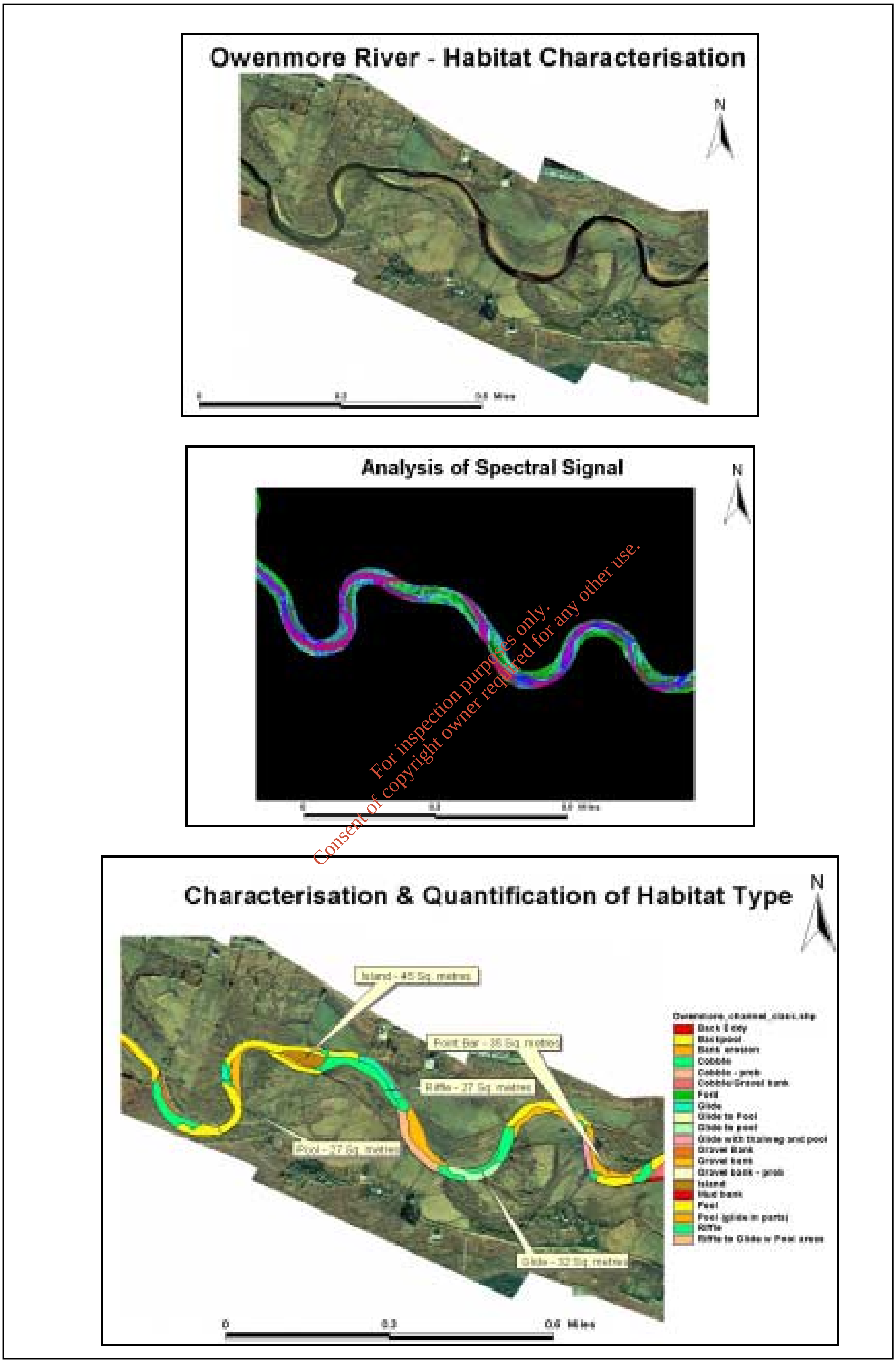


Fig. 1. Stages in the classification and quantification of habitat type in the Owenmore River.

Bellanaboy River

Due to quality constraints inherent in the Munhin and Bellanaboy River aerial datasets, only a wetted area classification was completed for these rivers. For comparison purposes, the wetted area calculated from the CFB's study is compared with that derived from this projects aerial photography (see Table 5). Overall, the comparisons between the two data sources are within expected ranges although further analysis within a sub reach of the Bellanaboy River reveals an even closer correlation, (by excluding unproductive habitat area below Bellanaboy Bridge). A query of the database from the CFB study revealed an underestimation of the extrapolated "wetted width" for the sub-reach below Bellanaboy Bridge.

A comparison of the calculated wetted area, extrapolated from the two datasets, within the Owenmore River was also made. It appears that the wetted width from the CFB study for this section of the river may also be an underestimate.

The wetted area estimate for the Bellanaboy River was calculated using the aerial dataset where available; otherwise the CFB wetted area dataset was used (particularly for 1st order streams).

Table 5. Comparison of Wetted area from aerial photographic survey and CFB model.

River	Compass Survey *(m²)*	CFB Survey *(m²)*
Bellanaboy River (Total Fluvial Habitat)	59,544	46,912
Bellanaboy River (Productive Salmon Habitat)	37,415	33,674
Munhin River	33,674	34,588
Owenmore River	184,627	137,454

4.3 Sediment Analysis

A possible impact from the construction of the terminal was for the potential release of large quantities of suspended solids, with the subsequent impairment of sensitive spawning locations within the Bellanaboy River. This siltation would impair salmonid spawning and reduce habitat quality for all fish species including lamprey.

A methodology developed by the Salmon Research Station in Bushmills Co. Antrim was used to obtain sediment cores (O'Connor & Andrew, 1998) from this river. Liquid nitrogen was used to freeze the substrate in the vicinity of a stainless steel corer, which was then removed from the streambed by a winch.

While potential spawning areas below the proposed discharge locations is limited, it was decided to proceed with the analysis of sediment cores at a location above and below the main discharge point. The data obtained will assist in the programme aimed at the determination of the constituents of spawning gravels within the Owenmore catchment. The extent of spawning habitat below the site of discharge was limited to one ford area and six sediment cores were taken for analysis. A further ten samples were removed adjacent to Bellanaboy Bridge, upstream of the discharge location.

Processing of samples will be carried out during 2005 using a Retsch 300a Orbital shaker and 32mm – 32µm sieve series. Preliminary examination of the sediment cores revealed heavy peat deposits in two of the downstream samples, probably associated with the localised bank erosion adjacent to the sampling area.

5.

FISH STOCK SURVEY

5.1 Methods

Electrical Fishing

Quantitative electrofishing was used to assess fish stocks in the stream and river sites (Fig. 2). All sites were electro-fished from bottom to top, three times, using a 12-volt Safari Research 550D backpack electrofisher. The three fishing depletion method was used at each site with stunned fish being netted out and retained in bins of freshwater. All the catches from each fishing were held separately in the bins of water, until all fishings at each site were complete. The fish were then identified, counted and measured, (fork length ± 1mm) and returned to the water. The length of each site, and five random widths, were measured, to quantify the area fished.

Length frequency distributions of salmon and trout were determined for all the sites fished. The length range for each age class was estimated from length frequency histograms. Salmon and trout population estimates and population densities (± 95% C.I.) for 0+ and 1+ age classes were calculated for each site using the Zippin method (1958). Minimum numbers ($n.m^{-2}$) were used where it was not possible to obtain an estimated density.

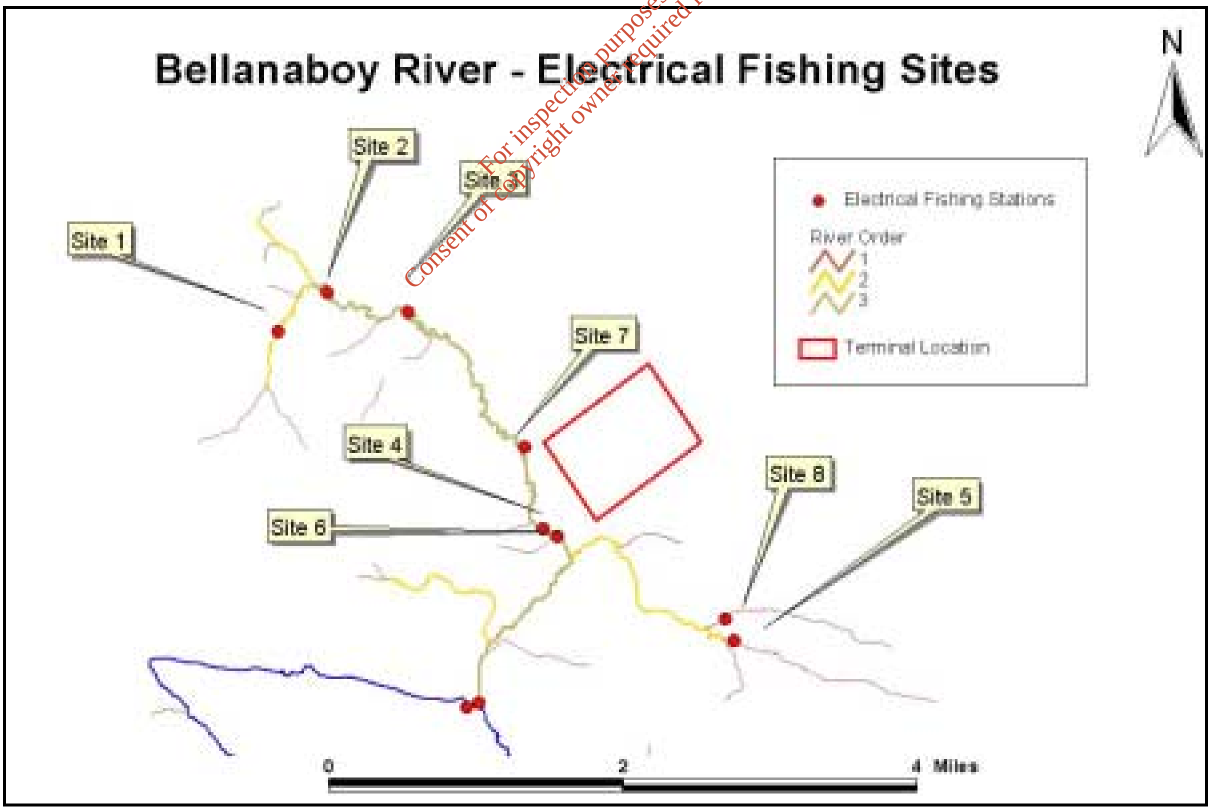


Fig. 2. Map of the Bellanaboy sub-catchment indicating stream order and the locations of the 2004 electrofishing survey locations.

Seine Netting

Seven locations (Fig. 3) on Carrowmore Lake were sampled for juvenile fish using a beach seine on two days in September and November 2004. Netting took place during daylight hours. The net was 60m long and 3m deep and was constructed from 9mm (6mm bar) No 210/24 knotless nylon. There was a 'bulge' built into the middle section. The top rope was 10mm nylon with 100mm floats fitted at 0.5 metre intervals. The bottom rope was 0.5kg/m lead rope.

The net was set by loading onto a deck fitted to the stern of a lake boat. One operator remained on the shore holding one end of a 10m rope attached to the head rope of the net. The boat was then rowed in a semi-circle allowing the net to unfurl over the transom. The distance rowed was judged so that the end of the net was approximately 10m from the shore. Both ends of the net were then hauled together, tightening the net into a circle and hauled to the shore. The net was hauled slowly, with frequent pauses, to allow water to pass through the fine mesh without the bottom of the net rising to allow fish to escape. The fish were eventually gathered into the bulge of the net in shallow water. Fish were then transferred to bins for identification and measurement.

The full sweep of the net enclosed approximately 950 m^2. It is believed that fish tend to ignore a boat until it comes within 2 or 3 m (Pierce *et al.* 1990), so we assumed that evasion or other movements into or out of the enclosed area during setting of the seine were negligible. Catch per unit effort (CPUE) was calculated as the total number of fish of each species per haul of the net at each site and inshore fish density was calculated as the number of fish divided by the total area covered by the net when fully deployed (950m^2) (Matthews *et al*. 1997).

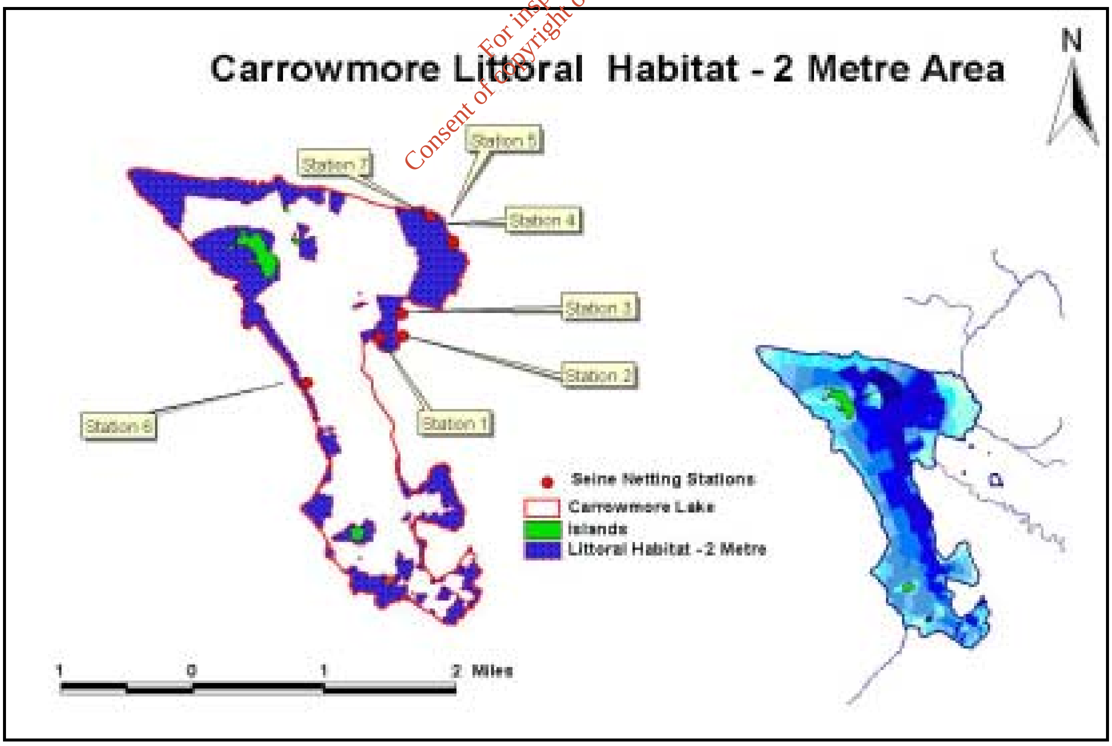


Fig. 3. Maps of Carrowmore Lake showing locations of beach seining stations and littoral habitat area. Insert map shows bathymetry in 1 metre contours.

5.2 Results

Bellanaboy River

Electrofishing surveys were carried out on 8th September, 2004. Eight sites were fished on the Ballinaboy river (Table 6 & Fig. 2). Sites scheduled for surveying in 2004 on the lower reaches of the Owenmore and Muinhin rivers had to be postponed due to the height of the water in both rivers.

In addition to salmon *Salmo salar*, and brown trout, *Salmo trutta*, four other fish species were recorded. These were three-spine stickleback *Gasterosteus aculeatus*, minnow *Phoxinus phoxinus*, eel *Anguilla anguilla*, and brook lamprey *Lampetra planeri*.

Figures 4 & 5 show mean density by site data for salmon and trout respectively in the Bellanaboy River. Summary length statistics are presented for all fish species captured in Table 7 and length frequency distributions (no significant difference in length of salmon or trout between riverine sites) showed two age classes for salmon (Fig. 6) and three age classes for trout (Fig. 7) and the length at age breakdowns are given for salmon and trout in Table 8. These length ranges were used for separating each age class when estimating population density and biomass.

Salmon
Table 9 gives the summary density data for salmon and Table 10 presents the details for each fishing. Salmon fry (0+ age) were recorded at all sites in the survey. Numbers of 0+ fish were generally low apart from site 5, the Muingingaun tributary, where 0.3 fish m^{-2} were recorded. One year old (1+ age) salmon were recorded at six sites, but at relatively low densities. Salmon densities in general were low at sites 1, 2, and 3, the upper reaches of the river, but improved at the more downstream sites.

Trout
Table 11 gives the summary density data for trout and Table 12 presents the details for each fishing. Trout were only recorded at seven of the eight sites; none were recorded for site 4. Trout fry (0+) numbers in the upper reaches of the river, sites 1, 2, and 3, were quite good, ranging from 0.2 to 0.9 fish m^{-2}. As with the salmon, the highest density was recorded at site 5. Numbers of 1+ trout were low, apart from site 3 where 0.2 fish m^{-2} were recorded. Two year old trout were only recorded at two sites.

Other Species
Brook lamprey, three spine stickleback, eel and minnow were recorded in the Bellanaboy and Muingingaun Rivers (Table 13). Lamprey, stickleback and eel were all recorded at the majority of sites but minnow were only at sites 4, 6 & 7 – the more sluggish deeper sites.

Carrowmore Lake

Beach seine samples were taken on Carrowmore L. on the 2nd September and 9th November 2004. The lake proved difficult to survey due to the number of bottom obstructions, such as rocks and sunk logs or bog deal outcrops. Seven sites were fished (Fig. 3) in overall, six in September and four in November (Table 14). Five species of fish were recorded, salmon (*Salmo salar*), trout (*Salmo trutta*), three-spine stickleback (*Gasterosteus aculeatus*), minnow

(*Phoxinus phoxinus*), and one flounder (*Platichthys flesus*) was observed escaping from the net.

Summary data is presented for each species captured in the beach seine in Table 14 and length frequency distributions in Figures 6, 7, 8 & 9. The catch per unit effort and the estimated density (no./m^2) are given in Table 15. These figures should only be used as indicative as weather conditions were not ideal for beach seining.

Salmon

Salmon parr were recorded in small numbers in both September and November in Carrowmore Lake (Table 14). The length frequency distribution (Fig. 6) would indicate that the majority were probably 1+ parr. The salmon in November were significantly larger than those in September (p<0.0001), although, due to low numbers, it is difficult to assess the significance of this. The CPUE was 2.17 in September and 4.75 in November (Table 15). Given the paucity of 1+ salmon in the Bellanaboy River, it is likely that there is downstream movement of fry and parr from the river into the lake, supported by the increase in the CPUE in the lake between September and November.

Trout

Low numbers of trout were also recorded in the lake in September and November (Table 14). The mean length of trout (Table 7) was significantly lower in November that in September (Fig. 7; p<0.01) with both higher numbers of 0+ parr and lower numbers of older age classes being captured. This is probably indicative, as with the salmon, of a movement of 0+ fish into the lake from the streams. It is also possible that the older trout moved back into the streams towards spawning time. The CPUE increased from 4.00 to 12.00 between September and November (Table 15), indicating probable downstream movement of trout fry and parr into the lake. This vacating of spawning areas to make space available for spawning has been observed previously and is discussed in Matthews *et al*. (1997)

Stickleback

Stickleback were fairly common in the lake in both months with CPUEs of 37.67 and 13.25 in September and November respectively (Table 15). There was no difference in the lengths between September and November (Table 7). Stickleback ranged in length from 2.9 to 6.9 cm (Fig. 8).

Minnow

Minnow were only recorded at the mouth of the Bellanaboy River in September (Table 7). They ranged in length from 4.7 to 7.8 cm (Table 7; Fig. 9).

Table 6. Electrofishing site locations, grid references and descriptions on the Bellanaboy system, 2004.

River name	Site no	X coordinate	Y coordinate	Substratum	Instream characteristics	Bank cover
Knocknalower	1	IF82558	334539	silt, gravel	pool, riffle	rushes, grasses, draining from overgrassed peatland, flood damage
Muingerron	2	IF83118	334999	gravel, cobble	riffle, glide	rushes, grasses
Aghoos	3	IF84052	334773	gravel, cobble	riffle, glide	rushes, grasses
U/S Ballinaboy Br.	4	IF85602	332273	gravel. cobble	riffle, glide/pool	rushes, grasses/alders?
Muingingaun	5	IF87810	330973	gravel, boulder	riffle, glide/pool	rushes, grasses, rhododendron
D/S Ballinaboy Br.	6	IF85773	332177	gravel, cobble	glide, riffle	gorse bushes, grass
near site 7 2003	7	IF85392	333211	gravel, cobble, sand	riffle, pool	gorse bushes, grass
Beside site 5	8	IF87699	331229	gravel, boulder	riffle, pool	gravel & rock bank, recently cleared banks and river downstream

Table 7. Lengths of all fish species captured in the Bellanaboy River and in Carrowmore Lake, September to November 2004.

Location	Statistics	Salmon	Trout	Eel	Stickleback	Minnow	Lamprey *sp.*
Bellanaboy River	Mean	7.4	8.0	20.5	4.0	5.9	9.8
	Median	6.8	7.5	20.0	3.8	6.6	10.0
	Std Err.	0.22	0.20	1.8	0.17	0.27	0.72
	Max.	12.2	19.1	35.0	5.7	9.2	13.0
	Min.	4.7	5.1	11.0	3.1	2.3	5.0
	n	66	114	19	18	46	11
Carrowmore Lake September	Mean	10.0	11.8	-	5.0	5.9	-
	Median	9.9	12.0	-	4.9	5.9	-
	Std Err.	0.3	0.94	-	0.09	0.16	-
	Max.	11.5	21.0	-	6.7	7.8	-
	Min.	8.0	5.9	-	3.0	4.7	-
	n	14	27	0	81	20	0
Carrowmore Lake November	Mean	11.8	9.5	-	5.1	-	-
	Median	11.6	8.7	-	5.1	-	-
	Std Err.	0.3	0.48	-	0.09	-	-
	Max.	10.5	29.5	-	6.9	-	-
	Min.	15.9	6.8	-	2.9	-	-
	n	21	62	0	100	0	0

Table. 8. Length ranges for each age class of salmon and trout at each site on the Bellanaboy system 2004.

Site	Salmon 0+ (cm)	Salmon 1+ (cm)	Trout 0+ (cm)	Trout 1+ (cm)	Trout 2+ (cm)
1 Knocknalower	≤ 8.1	8.2+	≤ 8.9	9.0 +	
2 Muingerron north	≤ 9.1	9.2+	≤ 9.6	9.7 - 13	13+
3 Aghoos	≤ 6.2	6.3+	≤ 7.8	7.9+	
4 above Ballinaboy Br	≤ 9.1	9.2+			
5 Muingingaun	≤ 7.0	7.1+	≤ 8.8	8.9+	
6 below Ballinaboy Br	≤ 9.1	9.2+	≤ 6.2	6.3+	
7 near site 7 2003	≤ 7.0	7.1+		13.6+	
8 new site beside site 5	≤ 7.1	7.2+	≤ 7.6	7.7+	

Table 9. Total salmon data for all sites fished in the Bellanaboy system, 2004.

River	Site	Area m2	Total Catch	Density	95% CI	Min Est	Density	95% CI	Min Est	Density	95% CI	Min Est
Knocknalower	1	46.9	1			0.02						0.02
Muingerron	2	63.75	9	0.10	0.04		0.05	0.01				
Aghoos	3	50.25	5			0.04	0.06	0.01		0.10	0.01	
U/S Ballinaboy Br	4	71.12	8	0.14	0.16				0.01			
Muingingaun	5	44.1	15	0.31	0.05				0.05	0.38	0.11	
D/S Ballinaboy Br	6	139.2	17	0.11	0.03		0.03	0.04				
near site 7 2003	7	49.4	8	0.16	0.09		0.04	0.03				
Beside site 5	8	49.3	2	0.04	0.03		0.00			0.04	0.03	

Table 10. Catches of **Salmon** for each fishing, estimated population (+/- 95% CI) and for population density (+/- 95%CI) for each site in the Bellanaboy system, 2004.

Site	Area	Age Class	Count 1	Count 2	Count 3	Est. Pop No.	+/- 95% CI	Pop. Den No. / Sq.m	+/- 95% CI
1	46.9*	S 0+	1	0	0			0.02	
		S 1+	0	0	0			0	
2	63.75	S 0+	3	3	0	6.56	2.65	0.10	0.04
		S 1+	2	1	0	3.07	0.72	0.05	0.01
3	50.25	S 0+	2	0	0			0.04	
		S 1+	2	1	0	3.07	0.72	0.06	0.01
4	71.12	S 0+	4	1	2	9.65	11.28	0.14	0.16
		S 1+	1	0	0			0.01	
5	44.1	S 0+	9	3	1	13.53	2.09	0.31	0.05
		S 1+*	0	1	1			0.05	
6	139.2	S 0+*	9	3	2	15.30	4.05	0.11	0.03
		S 1+	1	2	0	3.83	5.19	0.03	0.04
7	49.4	S 0+	3	4	0	8.07	4.42	0.16	0.09
		S 1+	1	1	0	2.19	1.53	0.04	0.03
8	49.3	S 0+*	1	1	0	2.19	1.53	0.04	0.03
		S 1+*	0	0	0			0	

* Refers to sites where it was only possible to get a minimum population density per M^2

- Site 1 = Knocknalower
- Site 2 = Muingerron
- Site 3 = Aghoos
- Site 4 = Above Ballinaboy bridge
- Site 5 = Muingingaun
- Site 6 = D/s Ballinaboy bridge
- Site 7 = Near site 7 2003
- Site 8 = Beside site 5

Table 12. Catches of **trout** for each fishing, estimated population (+/- 95% CI) and for population density (+/- 95%CI) for each site in the Bellanaboy system, 2004.

Site	Area	Age Class	Count 1	Count 2	Count 3	Count 4	Est. Pop No.	+/- 95% CI	Pop. Den No. / Sq.m	+/- 95% CI
1	46.9	T 0+	3	3	2		18.68	66.13	0.40	1.41
		T 1+	0	0	0					
		T 2+	0	0	0					
2	63.75	T 0+	15	7	6		36.22	16.97	0.57	0.27
		T 1+	3	1	0		4.05	0.53	0.06	0.01
		T 2+*	1	0	0				0.02	
3	50.25	T 0+	5	2	2		11.48	8.98	0.23	0.18
		T 1+	8	2	0		10.05	0.54	0.20	0.01
		T 2+	0	0	0					
4	71.12	T 0+	0	0	0				0	
		T 1+	0	0	0				0	
		T 2+*	0	0	0				0	
5	44.1	T 0+	26	4	6		38.66	5.4	0.88	0.12
		T 1+*	0	3	1				0.09	
		T 2+	0	0	0					
6	139.2	T 0+*	1	0	0				0.01	
		T 1+	0	0	0					
		T 2+	0	0	0					
7	49.4	T 0+	0	0	0					
		T 1+	1	1	0		2.19	1.53	0.04	0.03
		T 2+*	1	0	0				0.02	
8	49.3	T 0+*	8	0	0				0.16	
		T 1+*	2	0	0				0.04	
		T 2+	0	0	0					

* Refers to sites where it was only possible to get a minimum population density per M^2

- Site 1 = Knocknalower
- Site 2 = Muingerron
- Site 3 = Aghoos
- Site 4 = Above Ballinaboy bridge
- Site 5 = Muingingaun
- Site 6 = D/s Ballinaboy bridge
- Site 7 = Near site 7 2003
- Site 8 = Beside site 5

Table 13. Population estimates for non-salmonid species from the Bellanaboy system.

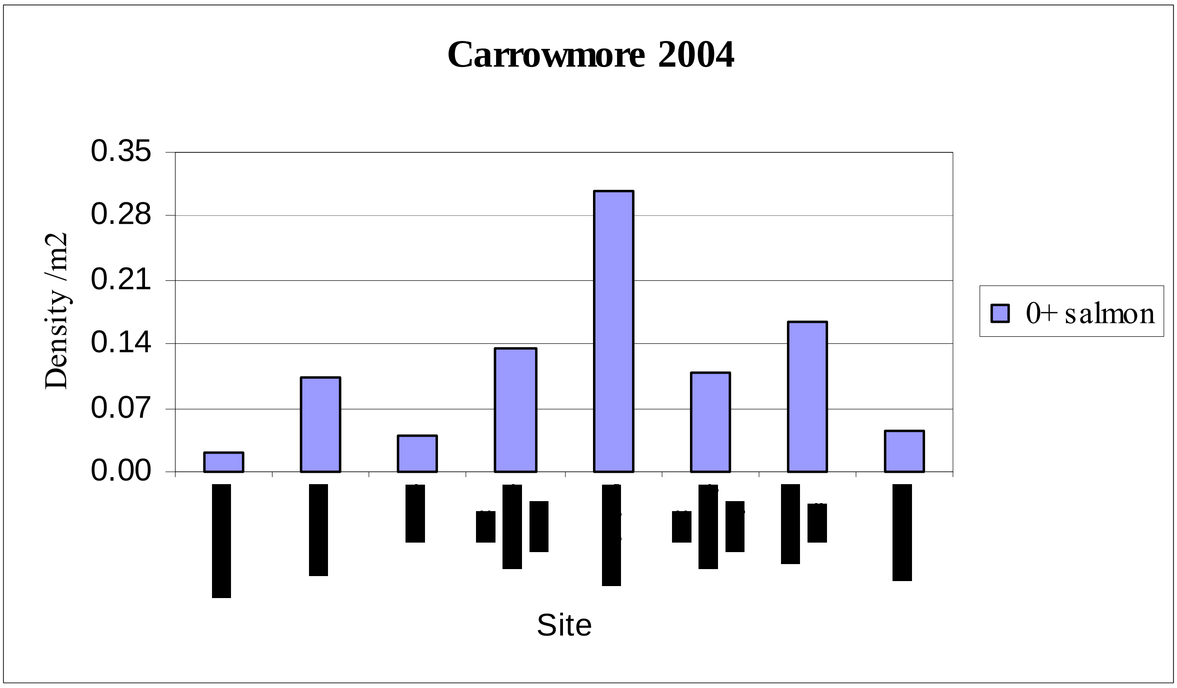
Site number		Lamprey	Stickleback	Eel	Minnow
1	Est.Pop No	5.88	162.80		
	+/-95% CI	4.24	38.30		
	Pop. Den No. / Sq.m	0.13	3.47		
	+/-95% CI	0.09	0.82		
	Min Est			0.02	0.00
2	Est.Pop No	21.45	113.83		
	+/-95% CI	19.20	30.09		
	Pop. Den No. / Sq.m	0.34	1.79		
	+/-95% CI	0.30	0.47		
	Min Est			0.02	0.00
3	Est.Pop No		27.33		
	+/-95% CI		1.38		
	Pop. Den No. / Sq.m		0.54		
	+/-95% CI		0.03		
	Min Est	0.02		0.00	0.00
4	Est.Pop No		16.14		9.22
	+/-95% CI		6.25		1.24
	Pop. Den No. / Sq.m		0.23		0.13
	+/-95% CI		0.09		0.02
	Min Est	0.01		0.00	
5	Est.Pop No				
	+/-95% CI				
	Pop. Den No. / Sq.m				
	+/-95% CI				
	Min Est	0.02	0.00	0.05	0.00
6	Est.Pop No				21.36
	+/-95% CI				8.57
	Pop. Den No. / Sq.m				0.15
	+/-95% CI				0.06
	Min Est	0.01	0.01	0.02	
7	Est.Pop No		3.83		23.83
	+/-95% CI		5.19		23.18
	Pop. Den No. / Sq.m		0.08		0.48
	+/-95% CI		0.11		0.47
	Min Est	0.02		0.02	
8	Est.Pop No			11.73	
	+/-95% CI			2.81	
	Pop. Den No. / Sq.m			0.24	
	+/-95% CI			0.06	
	Min Est	0.00	0.02		0.00

Table 14. Site locations for beach seining on Carrowmore Lake with details of the species catch.

Month	Site	Lat./Long. WGS84	Species	Catch
September	1	54 11.678N 009 46.584W	Salmon Trout Stickleback	2 3 5
	2	54 11.710N 009 46.368W	Trout Stickleback Flounder	2 4 1 (observed)
	3	54 11.778N 009 46.354W	Salmon Stickleback	6 3
	4	54 12.504N 009 45.921W	Salmon Trout Stickleback Minnow	5 10 137 8
	5	54 12.504N 009 45.921W	Trout Stickleback Minnow	4 14 1
	6	54 11.404N 009 47.546W	Trout Stickleback	5 63
	7	54 12.475N 009 46.041W	Not Fished	
November	1		Not Fished	
	2		Not Fished	
	3		Not Fished	
	4		Salmon Trout Stickleback	6 14 11
	5		Salmon Trout Stickleback	9 20 18
	6		Salmon Trout Stickleback	4 4 13
	7		Trout Stickleback	10 11

Table 15. Catch per unit effort (CPUE) and estimated density (No./m^2) of fish species captured in Carrowmore lake, 2004.

Species	Number of hauls	CPUE	Density No./m^2
September			
Salmon	6	2.17	0.002
Trout	6	4.00	0.004
Stickleback	6	37.67	0.040
Minnow	6	1.50	0.002
November			
Salmon	4	4.75	0.005
Trout	4	12.00	0.013
Stickleback	4	13.25	0.014
Minnow	4	0	0
Average			
Salmon	10	3.20	0.003
Trout	10	7.20	0.008
Stickleback	10	27.90	0.029
Minnow	10	0.90	0.001



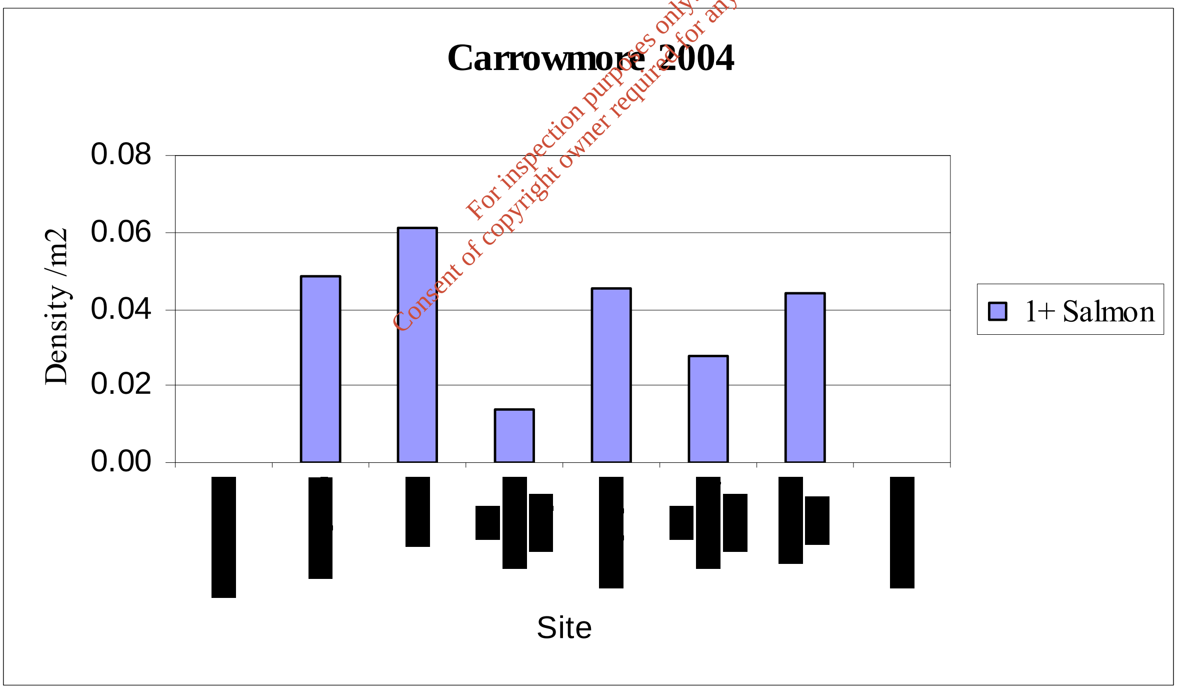
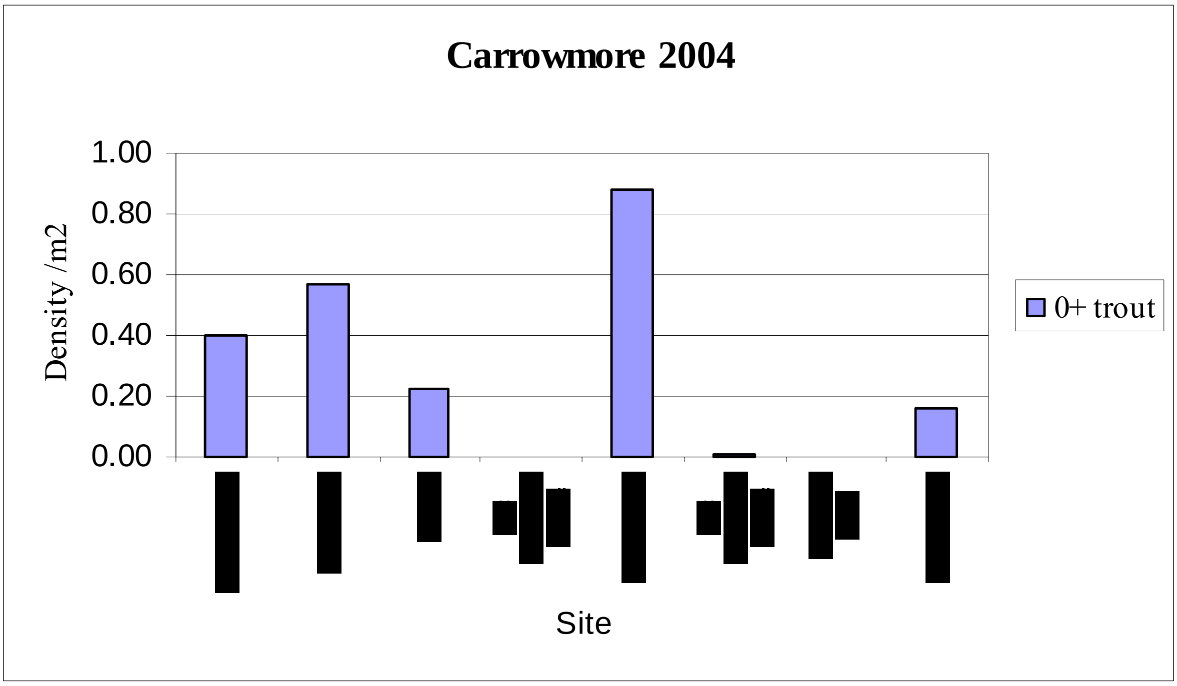


Fig. 4. Mean density data for 0+ and 1+ salmon at the eight sites on the Bellanaboy system, Carrowmore, 2004.



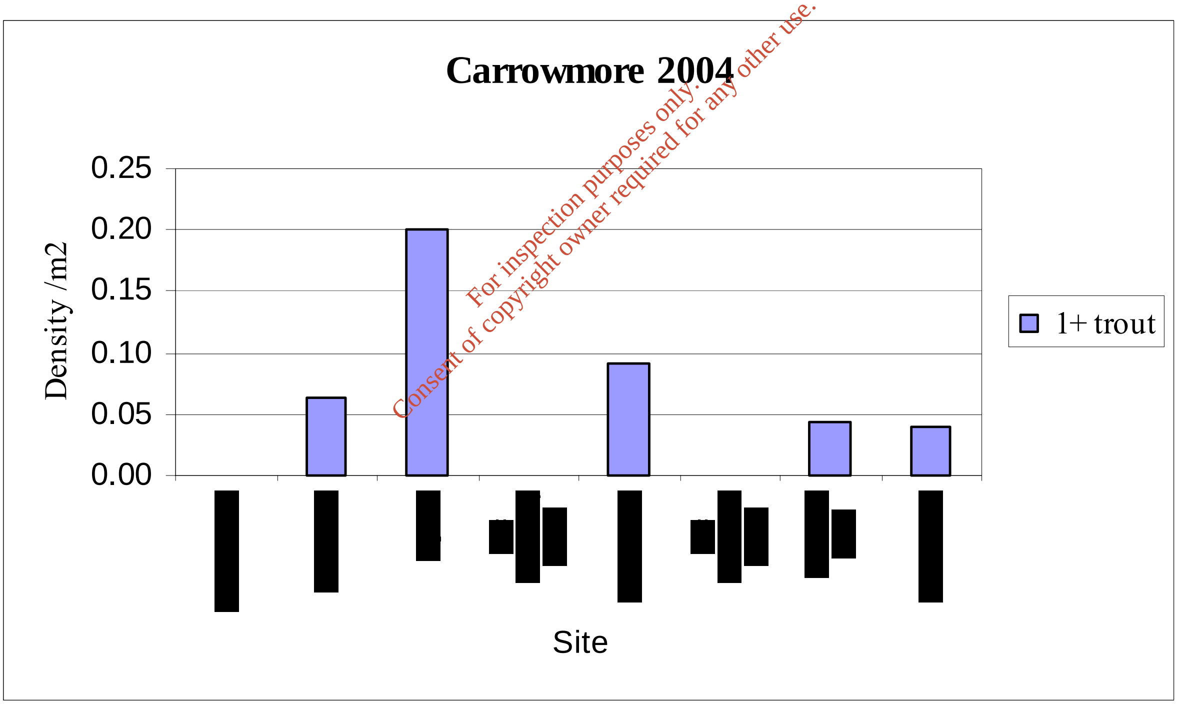


Fig. 5. Mean density data for 0+ and 1+ trout at the eight sites on the Bellanaboy system, Carrowmore, 2004.

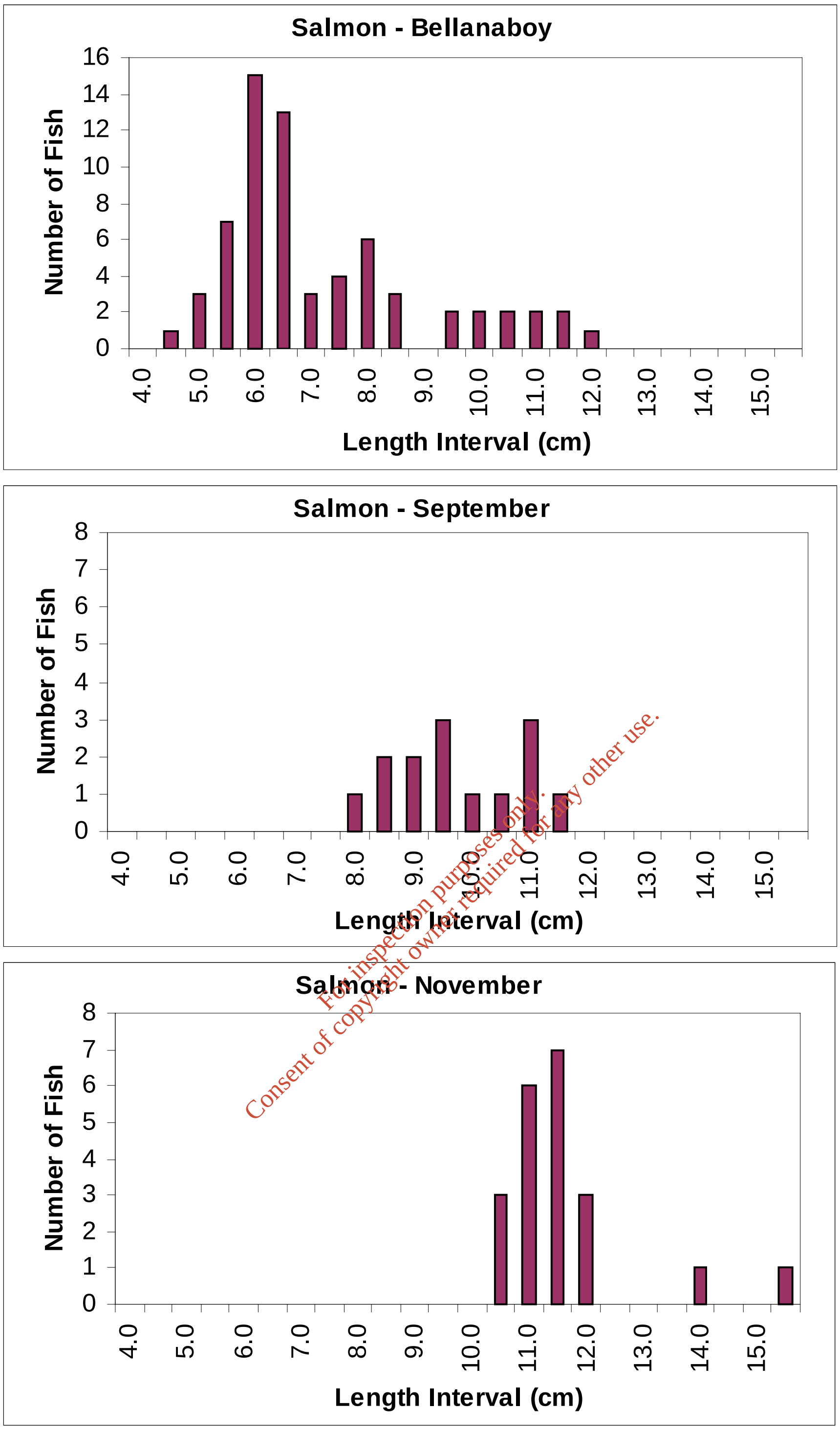


Fig. 6. Length frequency distributions of salmon captured in the Bellanaboy system and Carrowmore Lake in 2004.

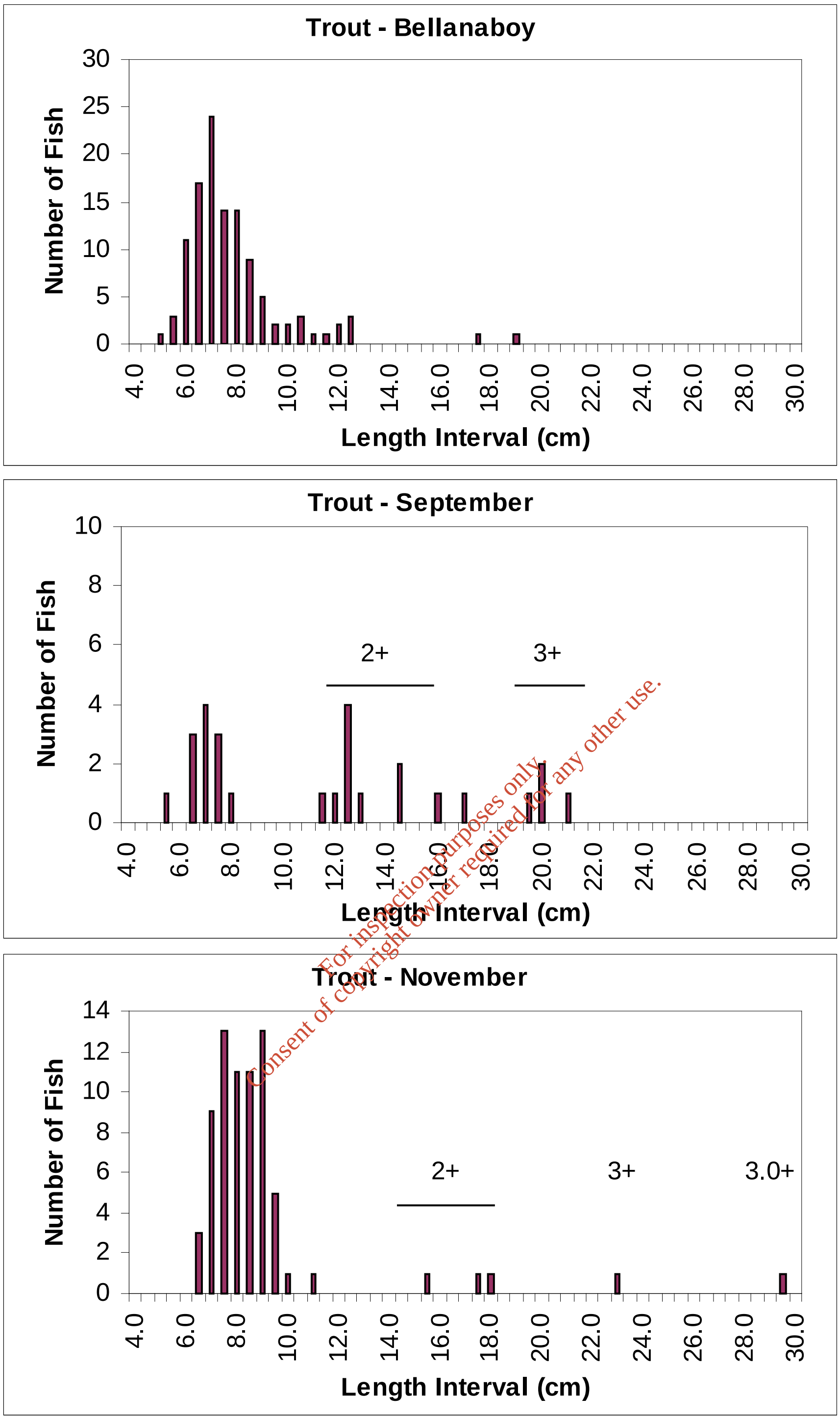


Fig. 7. Length frequency distributions of trout captured in the Bellanaboy system and Carrowmore Lake in 2004.

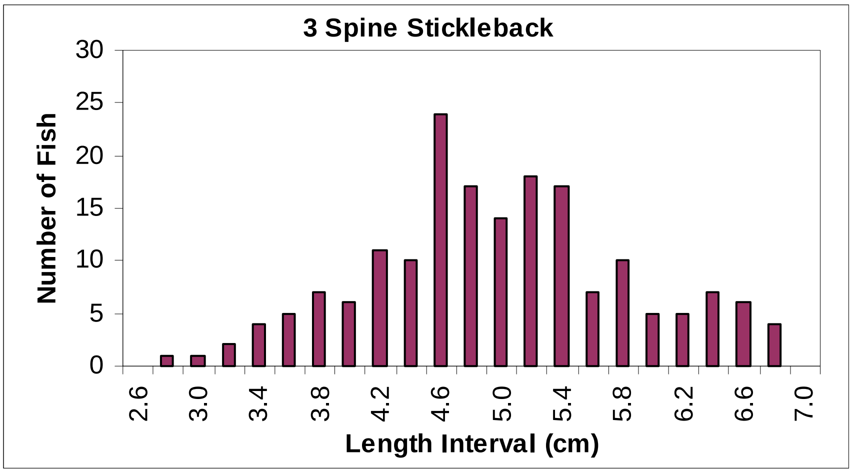


Figure 8. Length frequency distribution of 3-spine stickleback captured in Carrowmore Lake in 2004.

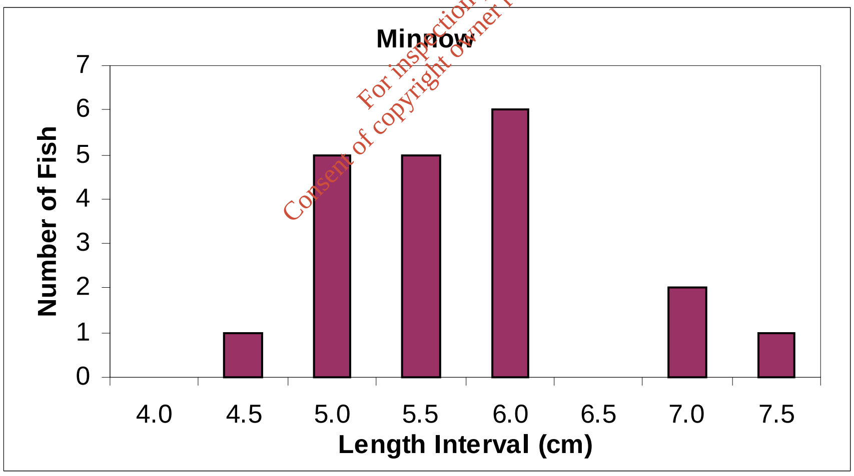


Figure 9. Length frequency distribution of minnow captured in Carrowmore Lake in 2004.

5.3 Comparison of Salmonid Densities with other Systems

Comparative salmon data are presented for other Irish systems along with the Bellanaboy system (Table 16). The population densities for juvenile salmon in the Bellanaboy system were generally lower than those recorded in other systems. Fry densities were generally lower than in the other systems surveyed in north-west Mayo in 2004. The parr densities were considerably lower. This may due to one or a combination of the flowing factors; little suitable habitat in the Bellanaboy for salmon, poor water quality as discussed earlier and a propensity to migrate down stream and utilise the lake habitat for parr production.

Table 16. Comparative salmon data from other Irish systems surveyed. * denote minimum estimates.

Catchment	No.Sites	Salmon Fry 0+	Salmon Parr 1+	Total	Data Source
River Inny (Co. Kerry)	16	0.3	0.08	0.38	(Whelan + Roche, 1988)
L. Currane (Co. Kerry)	8	0.35	0.08	0.43	(Whelan, 1985)
R. Erriff (Co. Galway)	14	0.43	0.18	0.61	(O'Farrell, 1984)
Upper Blackwater (Co. Cork)	24	0.27	0.11	0.38	(Gargan + Roche, 1992)
R. Feale (Co. Kerry)	18	0.25	0.1	0.35	(Whelan et al., 1989)
L. Melvin Tribs.(Co. Leitrim)	11	0.82	0.32	1.14	(Gargan + Roche, 1993)
Swilly R. (Co Donegal)	15	0.068	0.08	0.15	(Roche, 1995)
L. Currane	25	0.5	0.11	0.61	(Roche & Gargan 1996)
R. Diffreen (Main river)	6	1.181	0.28	1.461	Poole et al., 2000
R. Diffreen (Tributaries)	14	0.504	0.138	0.642	Poole et al., 2000
R. Drumcliffe	4	1.29	0.353	1.643	Poole et al., 2000
Owengarve	8	0.06	0.05	0.10	NWRFB 2004 Report
Owenduff	8	0.25	0.31	0.56	NWRFB 2004 Report
Newport	9	0.32	0.11	0.43	NWRFB 2004 Report
Glenamoy	5	0.29	0.17	0.46	NWRFB 2004 Report
Owenmore	9	0.94	0.22	1.16	NWRFB 2004 Report
Ballinaboy 2004	Site 1	0.02*	0.00	0.02	This study
Ballinaboy 2004	Site 2	0.10	0.05	0.15	This study
Ballinaboy 2004	Site 3	0.04*	0.06	0.10	This study
Ballinaboy 2004	Site 4	0.14	0.01*	0.15	This study
Ballinaboy 2004	Site 5	0.31	0.05*	0.35	This study
Ballinaboy 2004	Site 6	0.11	0.03	0.14	This study
Ballinaboy 2004	Site 7	0.16	0.04	0.21	This study
Ballinaboy 2004	Site 8	0.04	0.00	0.04	This study

5.4 Estimate of Smolt Production

Electrofishing surveys are usually carried out to determine juvenile salmonid stock levels throughout a catchment. Comparisons of densities can be made between sites within the catchment and with sites surveyed in other systems to assess the status of the stocks. The current survey indicated the range of densities at various sites and years throughout the Bellanaboy system. However, this type of information provides little indication of the relative importance of individual sub-catchments within the system in terms of juvenile production. The potential contribution of any sub-catchment will largely be dictated by its size, suitability for spawning and nursery function together with the actual stock densities recorded. As representative sites within typical habitat types, or zones, were electrofished in the Bellanaboy, it was possible to estimate total juvenile salmonid production for the system. The possibility that movement of fish occurs between the river and Carrowmore Lake, particularly at the late 0+ age, makes it difficult to carryout accurate estimates of smolt production.

Habitat - Rivers

Production estimates were calculated by multiplying the fish densities against the wetted area estimates. Trout and salmon habitat was divided into sub reaches (Figs. 10 & 11). Fish density data for the determination of a production estimate for each sub-reach were calculated by averaging the density estimates from a number of electro fishing sites within the particular sub-reach. The choice of electro fishing sites for the calculation of an average fish density for a sub reach, was based on the proximity of the electro fishing site to the sub reach in question. A 2nd order stream located in the lower reaches of the Bellanaboy River did not contain any electrical fishing sites and production estimates for trout were based on an average of the fish densities recorded from 1st and 2nd order sites in the upper Bellanaboy and Muingingaun rivers. This stream was not used in the calculation of a production estimate for salmon.

The CFB Salmon Habitat study (McGinnity *et al.* 2003) did not include any 1st order watercourses in their model quantifying the freshwater salmon habitat asset. Electrical fishing within one of the 1st order streams draining this catchment (Site 5) revealed a relatively high salmon density. This is probably due to its close proximity to an important spawning location several metres downstream in a 2nd order river channel.

In general, most 1st order watercourses were removed from the production estimates based on their perceived unsuitability for juvenile salmonid habitat. However, the wetted area of sub-reaches within certain 1st order streams were retained in the calculation of production estimates based on local knowledge (Figs. 10 & 11). The upstream limit of suitable habitat was identified from the gradient datasets and aerial photography in the GIS. Field inspections of all of these locations will be undertaken during 2005.

Fluvial habitat below Bellanaboy Bridge, the Bungurra, was not included in the production estimate for 2004, as no electrical fishing of this habitat type could be carried out due to high water flows and its unsuitability for back pack electrical fishing surveys. This sub-reach consists of deeper, low gradient habitat and is probably significant for indigenous brown trout populations. Data from a previous study on smolt production (McGinnity *et al.* 1999) was included for comparison.

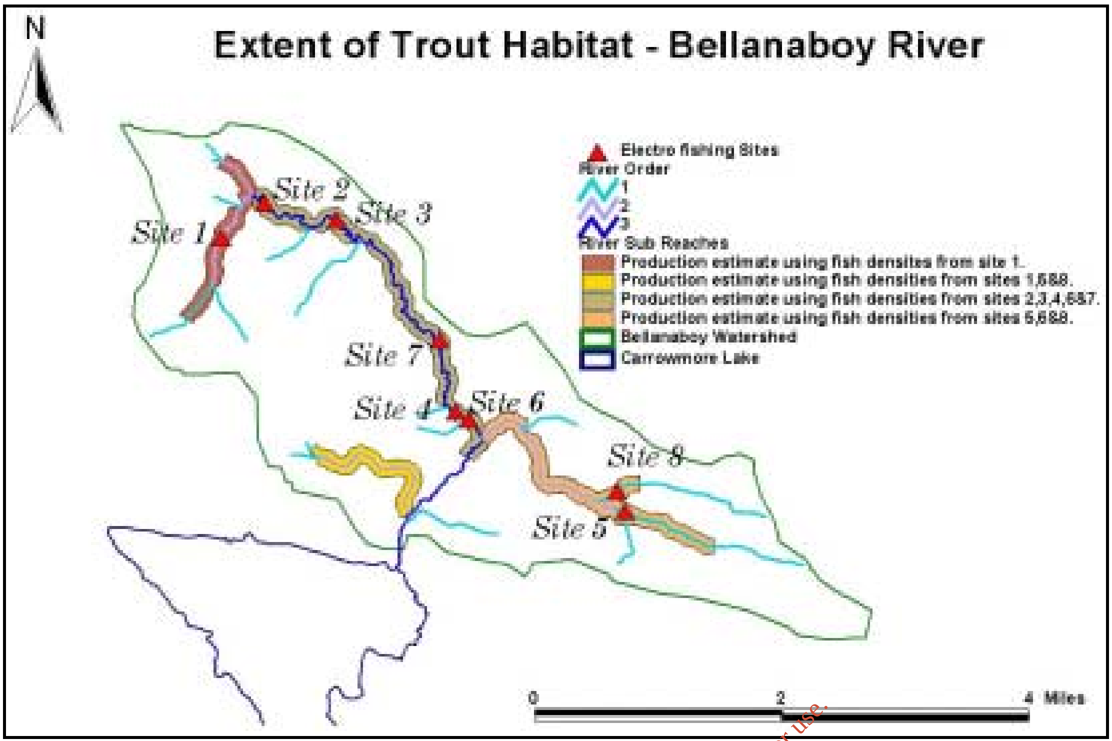


Fig. 10. The extent of the habitat designated for trout production in the Bellanaboy River.

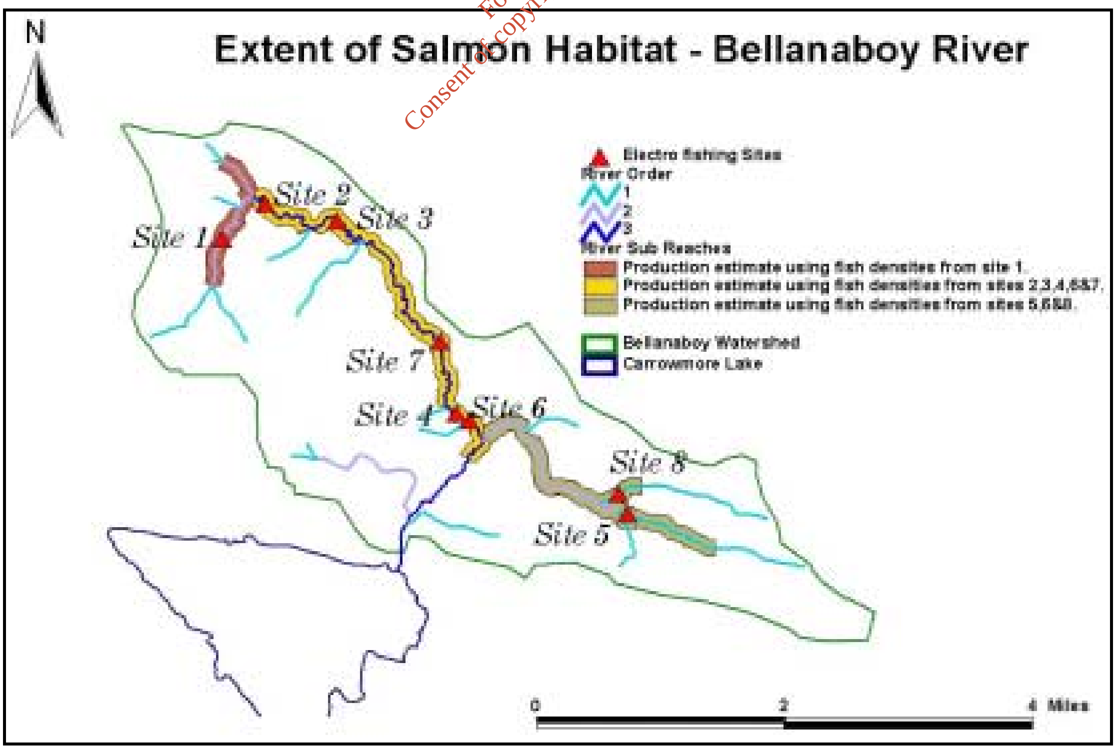


Fig. 11. The extent of the habitat designated for salmon production in the Bellanaboy River.

Habitat - Lake

The lake area, calculated to be less than or equal to 2 metres in depth, was used as an estimate of the littoral habitat area suitable for salmonid production for this survey. The shallow nature of Carrowmore Lake (Fig. 3; Table 17) causes regular resuspension of benthic sediments over the course of the season, resulting in a reduction of the littoral and photic zone within a shallow lake of this type. Fish densities reported by Matthews *et al.* (1997) were used in the calculation of an average production estimate for the lake.

Table 17. Quantification of habitat areas for Carrowmore Lake

Lacustrine Habitat

	m²	**% Of lacustrine area**
Total Lake Area	9,269,509	
Islands	166,254	
Water Surface Area	9,103,255	
Littoral Area (≤ 2M)	3,335,970	36.6%
Lake Area (2M< area <3M)	5,122,457	56.3%
Lake Area (≥ 3M)	644,828	7.1%

Production Estimation

An estimate of salmon smolt production is based on the 1+ salmon parr density estimates. In Ireland, a range of 1+ parr to smolt survivals of 34% to 65% have been reported by Dr. Gersham Kennedy in Harris (1994) for the river Bush. Parr to smolt survival values of 27.5% in 1992 and 18.5% in 1993 have been observed in the Srahrevagh river (McGinnity, 1997), a tributary of the Burrishoole River system. McGinnity *et al.* (1999) suggested a parr to smolt survival value of 27.5%, a figure based on the Srahrevagh parr to smolt survival estimate for 1992. This figure is supported by a number of pre-suppositions: 27.5 % is well within the range of other published values; the Srahrevagh river is located near the Bellanaboy; smolt production was determined using high specification trapping facility, capturing all migrating fish.

Recent studies suggest extensive use of lacustrine habitats by juvenile salmon in Newfoundland, Iceland, Scandinavia and most recently in Ireland (Matthews *et al*. 1997). Initial attempts to define productive area for juvenile salmon in lakes suggested that yearling and 1+ salmon parr were captured most often in shallow water less than two meters in depth around the lake perimeters and were not abundant at greater depths (Pepper *et al.* 1985). Matthews *et al*. (1997) defined lake habitat suitable for juvenile salmon as areas of lake bottom which were covered in water from a depth of three meters or less. There are no available data determining the extent of lake littoral zones in Ireland. The littoral zone of a lake is defined as the near shore of a lake, usually taken as the depth to which light can penetrate. Based on the above, the area of Carrowmore lake with less than 2m depth was estimated as 3,335,970m^2. It is not known what impact the reduced visibility due to recent algal blooms has had on the trophic zone, plankton and invertebrate communities or the fish populations in the lake.

Matthews *et al.* (1997) suggest juvenile 1+ salmon parr densities of 0.010 1+ parr/m^2 for lake littoral shore areas in the Burrishoole system. Data for Carrowmore gave an estimate of between 0.002 and 0.005 salmon (all age classes) per m^2, a mean of 0.003 /m^2 (Table 15), somewhat lower than in Burrishoole. Lake 1+ parr to smolt survival was assumed to be the same as that within the rivers (27.5%), although this estimate cannot be substantiated with supporting data.

Estimates for standing crop of 0+ and 1+ trout and salmon for the Bellanaboy River, including Muingingaun but not the Bungurra, are presented in Table 18a and for Carrowmore Lake in Table 18b. Given the tentative nature of the lake data, both the published figure of 0.01 parr/m^2 and 0.005 fish/m^2 were used in the calculations. Estimates for the number of smolts expected to be produced in 2005 were calculated on the basis of 27.5% survival from parr to smolt and these were compared to data from the north Mayo smolt production project (McGinnity *et al.* 1999) in Table 19.

The estimate for smolt production from the Bellanaboy using 2004 electrofishing data was 523 smolt, which compared favourably with that of McGinnity *et al* (1999) (Table 19). Including the McGinnity et al (1999) figure for the Bungurra produces an estimate for the Bellanaboy sub-catchment of between 837 and 867 salmon smolt from 1+ parr. A rough estimate of between 4,500 and 10,000 smolt has been calculated for Carrowmore Lake (Table 19) but this will need much refinement in future years.

Table 18a. Standing crop estimates for trout and salmon in the Bellanaboy system, based on electric fishing data from 2004.

Wetted Area for Trout Habitat	55,452	Area m^2
Wetted Area for Salmon Habitat	46,812	Area m^2
Estimate 0+ Trout	13,855	No. 0+ trout
Estimate 1+ Trout	2,738	No. 1+ trout
Estimate 0+ Salmon	5,929	No. 0+ salmon
Estimate 1+ Salmon	1,903	No. 1+ salmon

Table 18b. Standing crop estimates for salmon in Carrowmore Lake, based on beach seining data from 2004.

Littoral Area ($\leq$ 2M)	3,335,970	Area m^2
Fish density estimate	33,360	parr/m^2 @ 0.01 parr/m^2
Fish density estimate	16,680	parr/m^2 @ 0.005 parr/m^2

Table 19. Smolt production estimates for the Bellanaboy sub-catchment and for Carrowmore Lake using 2004 parr data, and compared with data from McGinnity *et al.* (1999).

Sub Catchment Name	2004	McGinnity *et al*. 1999
Bellanaboy		448
Muingingaun		105
Sub total	***523***	***553***
Bungurra		314
Sub total		***867***
Carrowmore Lake (0.01 parr/m^2)	9,174	
Carrowmore Lake (0.005 parr/m^2)	4,590	

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