The Location of High Risk & Moderate Barriers after GIS Analysis

Nore Main Channel

Based on the criteria set out, no barriers were deemed to be impassable, high, or moderate risk on the Nore main channel. Large weirs such as Bennetsbridge, Castletown, Brett's, etc. do cause difficulties for all fish species, including adult salmon, at low flow and may act to delay fish passage. Other effects such as injury, loss of eggs, mortality due to exhaustion, increased stress, etc may occur. O'Grady & Sullivan (1994) and Sullivan (2007) recommend that fish passage problems are eased under all conditions of flow with efficient fish passes that make the minimum demands on the migration of fish species and life-stages and these recommendations are very desirable. However, based on the distribution of juvenile salmon throughout the Nore catchment, in the context of the current risk analysis study, main channel weirs are not high risk.

Thomastown Weir

Dinin River

Sullivan (2007) describes a number of bridge sills on the Dinin as temporal barriers for adult salmonids which are only navigable in large spates. Many sites including Metal Bridge, Castlecomer Weir, Doonane Bridge on the Kileen River and Massford Bridge on the Deen River were surveyed and recommendations made regarding remedial works for fish passage.

Castlecomber weir

The GIS risk analysis has identified six high risk barriers on the Dinin tributary. High risk barriers include Castlecomber weir, Doonane Br, Ormonde Br, Killen Br, Mayo Br & Clogh Br. Castlecomber weir is the first high risk barrier on the main channel of the Dinan. There is approximately 2km of known spawning grounds between Castlecomber weir and Massford Bridge, the next barrier upstream. The risk analysis suggests that salmon are not migrating any further upstream on the main Dinin channel than Ormonde Bridge. The Killeen and Mayo bridges situated upstream of Ormonde bridge were assessed as no risk by the field based assessment. It is unlikely that these barriers would prevent further upstream migration of salmon. Castlecomber weir, Doonane Br, Ormonde & Clogh Br. were all assessed as high risk barriers during the SRFB field assessment and remain high risk under the GIS risk analysis.

Eight barriers on the Dinin were classified as moderate risk barriers post GIS risk analysis. A barrier on the Douglas tributary and one on the Monavea were assessed as moderate risk during the field based assessment and remained moderate risk post GIS analysis as there was no electrofishing data available upstream. A barrier on the Gloisha was assessed as no risk during the field based analysis as there is only one juvenile salmon year class present upstream it has been reclassified as moderate risk under the rule base analysis. Castlecomber Bridge has been downgraded from a high risk bridge to a moderate risk barrier post GIS analysis as two year classes were captured upstream in 2008. Cloonane Bridge & Massford Bridge were also assessed as moderate risk post GIS analysis as there was only one year class captured upstream in 1990 or 2008.

The Metal Bridge

The Metal bridge and a bridge at Coan were assessed as high risk during the field based analysis. As two year classes were captured upstream of these two weirs in 1990 both bridges have been reclassified as moderate risk barriers. In 2008 the SRFB modified the metal bridge to allow greater passage to salmon migration.

Little Arrigle

There is a diversion damn on the lower reaches of the Little Arrigle which channels water to a fish farm at Goatsbridge (Sullivan 2007). The field based assessment identified the barrier as moderate risk. Following the rules based risk analysis this barrier was reclassified as a low risk barrier as two year classes of juvenile salmon were present at a site surveyed upstream in 2008. The GIS analysis has classified the Derrynahinch Bridge on a tributary of the Little Arrigle as a high risk barrier as no juveniles were present at an upstream site surveyed in 1992. This bridge had been assessed as no risk during the field based analysis. The site surveyed in 1992 is located ~ 2km upstream of the bridge therefore the absence of juveniles may be related to poor habitat or water quality issues. A visual inspection of the bridge may be adequate in reclassifying the bridge as no risk.

Kings river

O'Grady & Sullivan (1994) identified three weirs on the lower reaches of the King's river which may inhibit the upstream migration of Atlantic salmon. These include Bradleys weir, Hutchinson's weir and Mullins weir. Two year classes of juvenile salmon were captured at a site surveyed in 1990 and another site in 2008, both located upstream of all three barriers. Under the rules based assessment Bradleys weir has now been classified as a moderate risk barrier. Hutchinson's and Mullins have both been classified as low risk. The only location on the Kings River sub-catchment where a barrier was deemed high risk post GIS analysis was on the Munster tributary. This was at one of the two bridges at Ballyclovan as no juvenile salmon were captured upstream when surveyed in 1992.

Two barriers which were assessed as high risk barriers during field analysis have been reclassified as moderate risk post GIS analysis. Three other barriers on the Kings River have been classified as moderate risk following GIS analysis as two year classes were captured upstream in 2008. These include a weir at Drimeen on the main channel and a bridge located just upstream of Island bridge also located on the main channel.

The 1992 CFB electro-fishing survey revealed low densities of juvenile salmon at a number of sites on the Kings River. Sullivan (2007) suggests that only a small percentage of adult salmon manage to ascend the lowest weir, Bradleys weir. It is evident from the electro-fishing results that although some adult salmon are migrating upstream every year, the weirs on the lower reaches of the Kings River; Bradleys weir, Hutchinson's weir and Mullins weir are causing some impediment to salmon upstream migration.

Pococke River

Field assessment of barriers by SRFB staff classified sites in the lower reaches of the Pococke River as no risk. Using the rules based assessment, no juvenile salmon were recorded above one barrier in the lower reaches of the Pococke and this resulted in the barrier being re-classified as high risk. Examination of the barrier structure confirm that there is no physical obstruction to the upstream movement of fish and the absence of juvenile salmon upstream of this barrier may be related to poor habitat or water quality issues. Therefore this barrier is of no risk to salmon migration.

Arigna River
The SRFB field assessment classified a bridge apron at Clashacrow as a high risk barrier. In 2008 two year classes of juvenile salmon were captured. Under the GIS risk analysis the bridge has now been reclassified as moderate risk.

Nuenna River
Under the rules based GIS analysis four barriers on the main channel of the Nuenna have been classified as moderate risk due to the presence of only one year class of salmon at a site fished upstream. Three of these barriers are located in Freshford town and were assessed by the SRFB field analysis as no risk. The site surveyed upstream of all four barriers in 2008 recorded twenty two 2yr old juvenile salmon but no 1yr old fish. Not all of these barriers may be preventing the upstream passage of salmon and should be re-examined.

Lisdowney Stream
The Lisdowney stream is a small tributary just north of the Nuenna. The GIS risk assessment, identified a weir located on the lower reaches of the stream as the only impassable barrier on the entire Nore catchment. Removal of this barrier would allow salmon to access approximately 2587 m^{-1} of potential spawning grounds upstream.

Impassable barrier on Lisdowney

Erkina river/Goul

No barriers on the main channel of the Erkina were assessed by the GIS risk analysis as being moderate or high risk. Three barriers on the Goul tributary were assessed as moderate risk. The water diversion structure upstream of Aghmacart bridge which is used as a domestic and agricultural water supply (Sullivan 2007) was assessed as high risk by the field based analysis. This has now been reclassified as moderate risk under the rules based system as two year classes of juvenile salmon were captured upstream at two sites surveyed in 2006 & 2008. Two barriers located on the upper reaches of the Goul system have remained moderate risk barriers under GIS analysis as there is no juvenile information available upstream of these sites. The GIS risk analysis classified Loughman's weir as low risk.

Owenbeg River

The GIS analysis identified one high risk barrier and six moderate risk barriers on the Owenbeg River. The SRFB assessed Boleybeg Bridge North as a high risk barrier. It remained high risk under the GIS risk analysis as only one year class was found at an upstream site surveyed in 2008. All moderate risk barriers were assessed by the SRFB field analysis as low or no risk but were re-classified under the GIS analysis as moderate risk as there was only one year class present at the two sites surveyed upstream of these sites. As juvenile information is available at only two sites these barriers would need further investigation to distinguish which of the barriers, if any are causing the impediment to upstream migration.

While this risk assessment was undertaken for salmon, a similar exercise would need to be undertaken for other migratory fish species. After such an assessment, barriers could be prioritised with the greatest benefit to all fish species.

Barriers to Migration for other Fish Species

Eel

The distribution and abundance of eel from CFB/RFB electro-fishing surveys was analysed, fig 9. The high risk and impassable barriers to salmon are also shown. Data from five minute catchment wide electro-fishing surveys in 2008 are excluded as only riffle areas were fished. Electro-fishing data on eel was available for four high risk barriers for salmon. Only one site on the Dinan recorded the absence of eel. From fig 9, it is evident that eel penetration into some Nore tributaries is problematic as eel were absent from the Kileen trib of Dinan, and the upper Kings river. Eel were recorded on the upper reaches of the main channel. Highest abundance of eel was recorded in the lower reaches of the Nore and on the main channel up to and directly above Bretts weir. This would suggest that Thomastown weir, Mount Juliet weir, Bennetsbridge weir and Bretts weir are not major impediments to upstream eel migration. No further electro-fishing data is available on the main channel until below Castletown weir, where abundance was low.

The field based risk analysis undertaken in this study focused on salmon and a risk analysis is required specifically for eel.

EEL

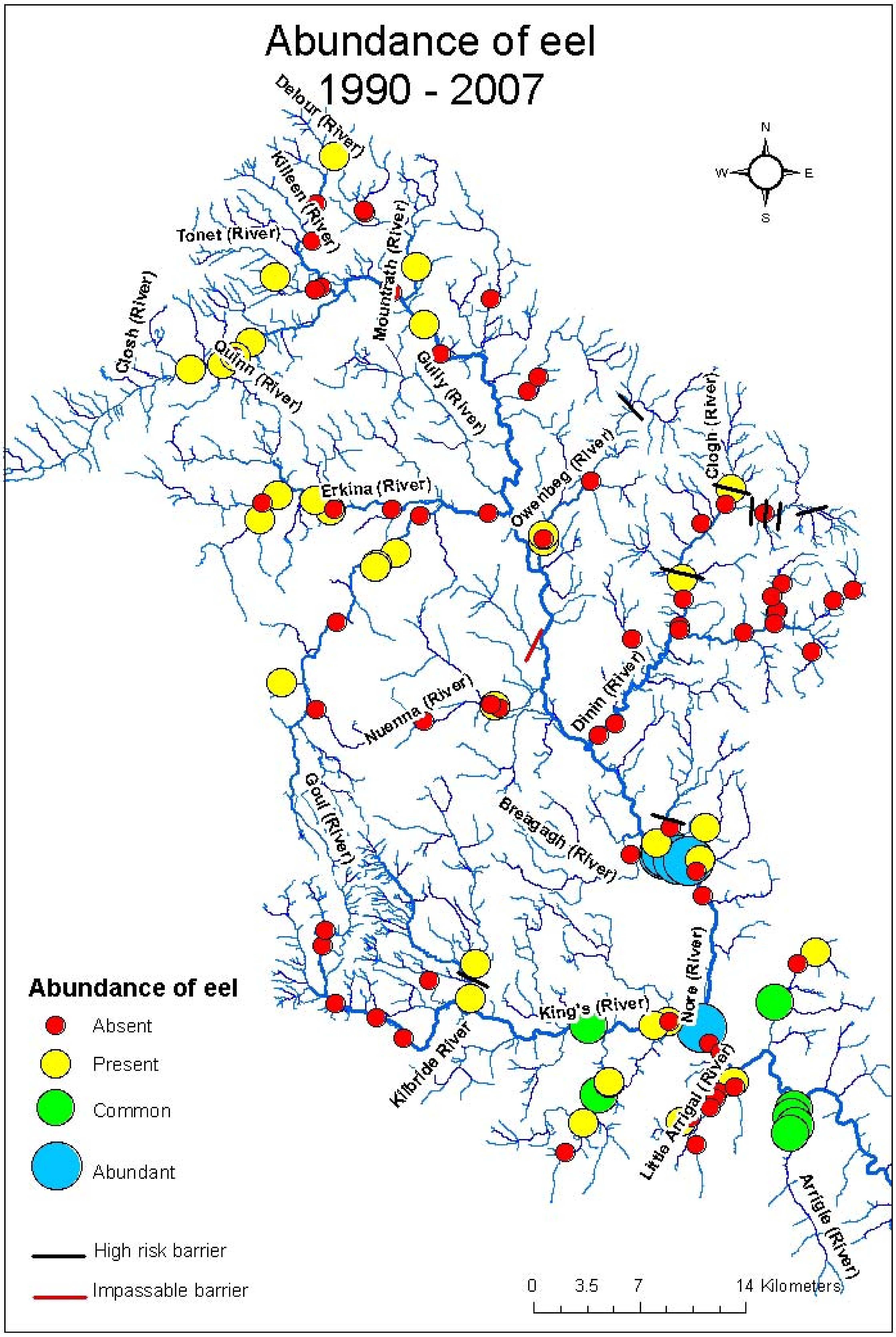

Fig 9. Abundance of eels in the Nore catchment

Sea Lamprey

The sea lamprey (*Petromyzon marinus* L.) is found in Ireland in its anadromous form, with young adult fish migrating to sea where they have a parasitic life style, attaching to and feeding on host fish. This parasitic phase may last approximately two years, with the fish growing to a length of 50 – 90 cm in length. Adult fish become sexually mature as they move from marine into estuarine waters and travel into rivers. They spawn in well-gravelled areas on bed material of similar size to that used by Atlantic salmon. Adult fish do not show a marked fidelity to natal waters (Bergstedt and Seelye 1995). The sea lamprey has the ability to penetrate long distances into fresh water and this ability can be constrained by barriers in the channel. Weirs and dams constructed for navigation, hydroelectric schemes and irrigation frequently serve to restrict sea lamprey upstream migration or eliminate it from the catchment (Beamish 1980, Assis 1990, Nicola *et al* 1996, Meyer and Brunken 1997).

Sea Lamprey

Distribution and quantity of spawning effort by adult sea lamprey in main stem of R. Nore SAC

The river Nore is a Special Area of Conservation under the EU Habitats Directive for sea lamprey. The initial SAC designation encompassed 48 km of main channel from the upper tidal limit upstream to Ballyragget, where an adult sea lamprey was captured by local anglers in 1967. This zone was surveyed in a downstream direction in each of three separate years – 2000, 2001 and 2004. On each occasion, no evidence of redd construction was noted until below the weirs at Bennetsbridge, a distance of 28 km from the upper tidal limit. Sea lamprey redds were found in localised clusters from here downstream to the tidal limit at Inistioge. The principal locations lay downstream of the weirs in Bennetsbridge and Thomastown and in an area at 5 – 10 km upstream of the tidal limit with no weirs or obstructions (Fig 10). Redds were much more numerous in 2001 than in 2000 although the same locations supported redds in both years.
The summer of 2004 was one marked by extended periods of low rainfall and, consequently, low flow in channels. No redds were recorded in the Nore in 2004 until the survey crossed down over the weir in Thomastown, the most downstream intact weir on the system. From here down to

Inistioge, a series of 52 redds was counted in 2004, many in locations where spawning had been previously recorded. This sector of the river had no obstructions to passage of sea lamprey.

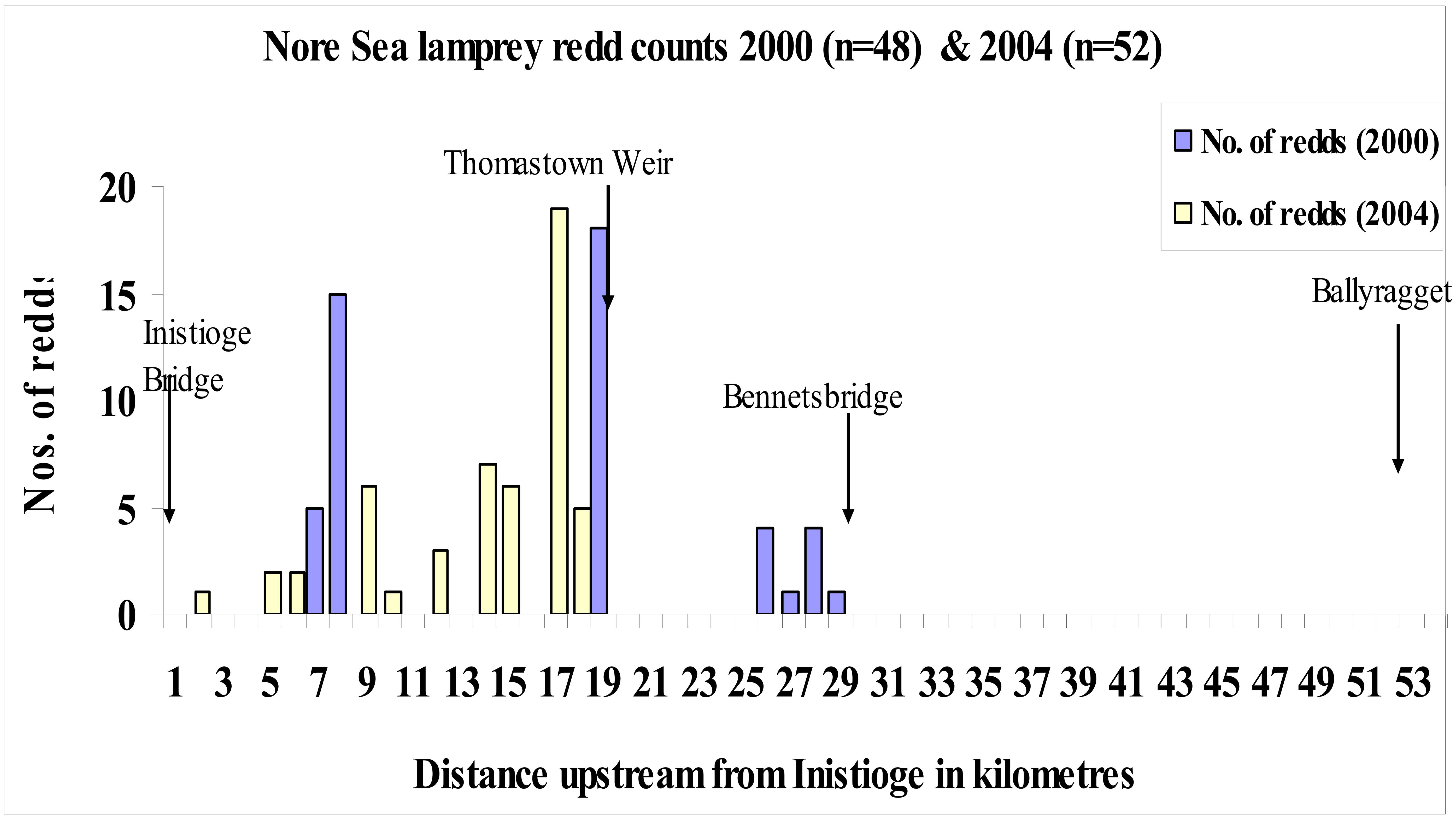

Fig 10. River Nore, Location of Sea Lamprey redds.

Distribution and status of juvenile sea lamprey populations in R. Nore main stem and tributaries
Sampling of juvenile lamprey was undertaken in a series of years in the period 2002 – 2008. Surveys in 2002 and 2003 related to the Kilkenny City Flood Relief Scheme, being constructed by the Office of Public Works. Spot fishing was undertaken in 2003 in the main stem of the R. Nore and in tributaries upstream of Kilkenny.

Study of 2003: Sampling focussed on areas upstream of the engineering works in Kilkenny as suspended solids issues prevented electric fishing. Sea lamprey juveniles were detected in a number of sites on the main stem R. Nore upstream of Kilkenny as well as sites downstream.

Study of 2004: Quantitative depletion sampling was undertaken in September 2004 on the main stem of the R. Nore (10 sites) and on two tributaries – the R. Erkina (7 sites) and the R. Dinin (9 sites). Sea lamprey juveniles were captured on the main stem 67 km upstream of the tidal limit and 22 km upstream of the original SAC boundary. The sea lamprey component varied from 5.4% to 20 % of the total juvenile lamprey population captured in any 1 m^2.
The density of juvenile sea lamprey ranged from zero, at two sites, to 6 / m^2. No juvenile sea lamprey were recorded in the nine enclosures surveyed on the R. Dinin, entering at *circa* 36 km upstream of the tidal limit, despite the presence of suitable spawning habitat and absence of barriers to passage, at least in lower reaches.

Three of the seven sites on the R. Erkina, entering at 54 km, had zero sea lamprey juveniles. Minimum density values of 1 fish/m^2 were recorded at three of the remainder and one site contained 7 fish/m^2.

Length frequency data for the combined Nore main channel sea lamprey juveniles indicated a majority of fish in the 8 -15 cm size range and was indicative of up to three age classes. No young-of-the-year was recorded. The data from the R. Erkina was dominated by material from a single site at Durrow Bridge, near the confluence with the R. Nore. A single fish of 2 cm was taken here along with individuals in the range 4 – 10 cm. The Erkina data also indicated the presence of up to three year classes. No juvenile sea lamprey were recorded on the King's river,

Study of 2005: In 2005 quantitative sampling (1m^2 technique of Harvey and Cowx 2003) was undertaken in two locations within Kilkenny city, in the context of lamprey recovery after completion of the flood relief scheme. A series of replicates was surveyed in newly-created habitat and in adjoining undisturbed habitat at both locations. Sea lamprey juveniles were encountered in both areas. These ranged in size from 60 – 140 mm with two modal peaks. These findings suggest no recent spawning (in previous two years). Of the 36 enclosures examined, sea lamprey were present in 20, primarily in undisturbed areas of channel. Sea lamprey density values were low, with a mean value of 1.36 fish/ m^2, compared to total juvenile density which had a mean value of 12.1 fish/ m^2.

Study of 2008: This was a whole-catchment study, designed to complement that of 2004 and focussing on those channels not examined in 2004. In excess of 100 individual locations were examined for surveying status of juvenile lamprey. A large portion of this total was considered unsuitable for survey for the target organisms. Electric fishing was undertaken on the remainder of sites. Juvenile river/brook lamprey density and population structure data was compiled for these sites. No juvenile sea lamprey was recorded at any of the survey sites.

Summary data over all years studied

No juvenile sea lamprey were recorded in the King's River, Little Arrigle, Arrigle and Nuenna tributaries. Juvenile sea lamprey were only recorded in the Erkina and Nore main channel. The Nore catchment data point to a highly variable degree of penetration, in different years, into the freshwater system by adult sea lamprey. This mirrors the findings of King and Linnane (2004) in respect of the R. Slaney and R. Munster Blackwater.

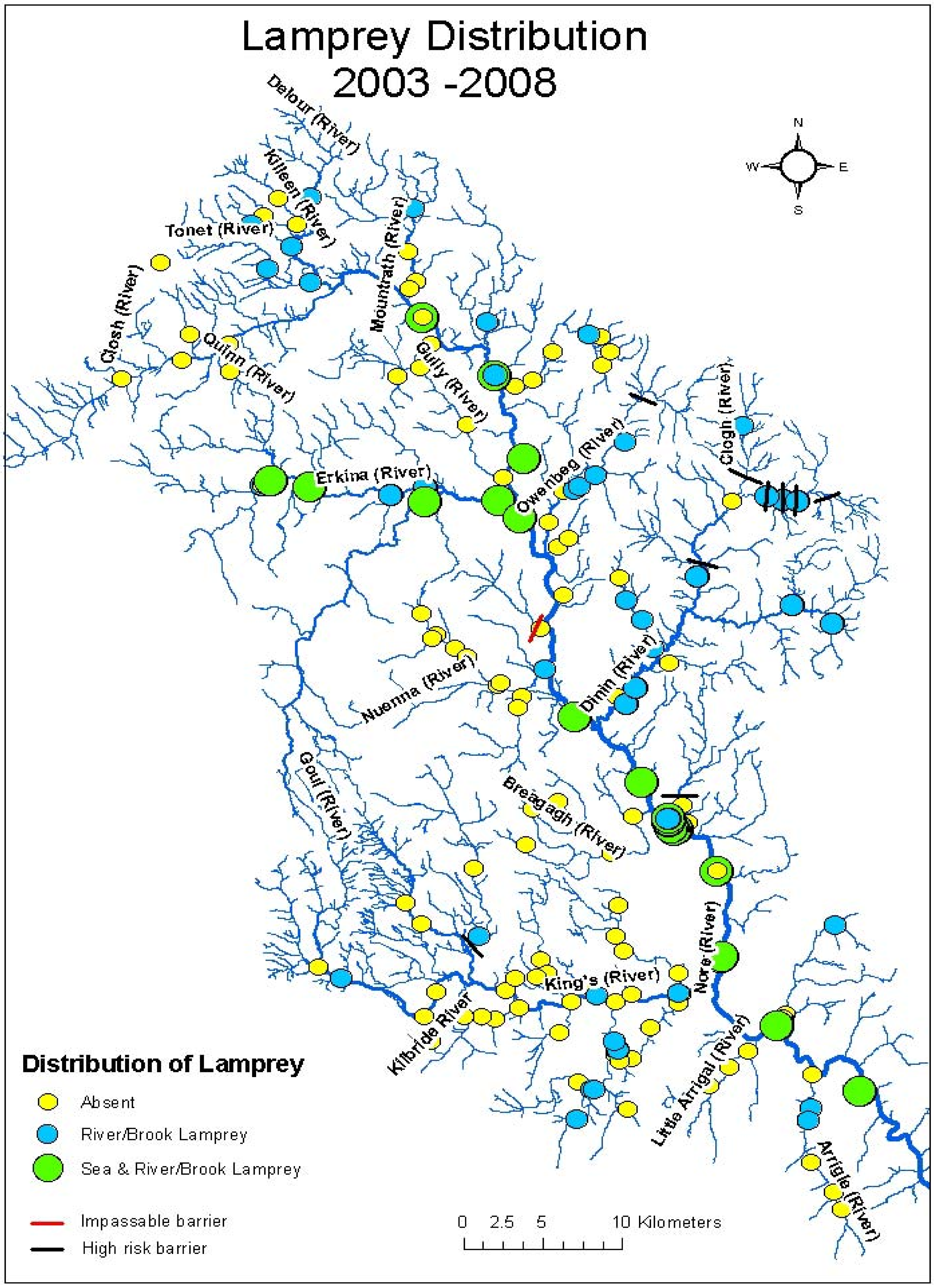

Fig.10 Distribution of sea lamprey in the Nore catchment

Adult Sea Lamprey and Spawning

The association of redd clusters with locations downstream of weirs is paralleled in other studies (Beamish 1980; Stier and Kynard 1986 a and b; Almeida et al 2002). It is considered that the timing of upriver migration by spawning sea lamprey may inhibit a more widespread and successful spawning effort. Unlike river lamprey that migrate in seasons of, potentially, elevated flow, sea lamprey movements into Irish rivers occur in May, and can be as late as August, at a time when flow conditions are likely to be falling or low. This does not facilitate sea lamprey passage through weirs.

In the Irish channels examined, including the R. Nore, the areas downstream of weirs served as locations of alluvial accumulation, easily excavated and with a flow of oxygenated water. Ducasse and Leprince (1980) identified these downstream areas as being particularly important for sea lamprey spawning in the Garonne rivers. Similar features occurred on a large scale in each of the channels studied here in areas well downstream of weirs but these were not necessarily used by sea lamprey. Indeed the degree of underuse, or non-use, of potential spawning areas in Irish channels examined points to systems well below carrying capacity for this species. The extent of such unused areas may suggest that sea lamprey are drawn upwards into the river system and spawn at the downstream side of weirs out of necessity, being unable to travel further upstream.

Status and Distribution of Juveniles

Gardiner et al (1995) reported a mean density of 0.54 fish/ m^2 for sites in which *Petromyzon* was recorded (range 0.2 – 3.9 fish/ m^2). Gardiner et al (1995) also reported that *Petromyzon* densities in their sites were much lower than those of river/brook ammocoetes, as found in the present study. The incomplete population structure shown in the CFB studies referred to here was also mirrored by Gardiner et al (1995). Subsequent work in Scotland (APEM 2004 a and b) recorded such low numbers of *Petromyzon* ammocoetes that no determination could be made on population structure. While these findings can be argued as being a statistical defect due to small sample, the very gaps point to the presence of small numbers of fish. It is considered that this is due to low levels of spawning in any year as well as intermittent spawning among years rather than to any differential survival of sea lamprey juveniles relative to river or brook lamprey juveniles. An alternative view is that sea lamprey ammocoete abundance was higher in areas where sea lamprey nests were observed (Dempson and Porter 1993; Almeida and Quintella 2002).

A caveat must be entered here in regard to identification of juvenile sea lamprey. The CFB studies reported here (2002 – 2005) used the most recent identification guide compiled by Gardiner (2003) for discriminating juvenile sea lamprey. Subsequent work by O' Connor (2006) found what appeared to be significant numbers of large juvenile sea lamprey in upper reaches of the Boyne catchment, a system with many large weirs in its lower reaches. A counting of myomeres confirmed that these were, indeed, river/brook juveniles, despite the pigment pattern suggesting a sea lamprey conformity. Applying this reservation to the sea lamprey data compiled pre-2006 may suggest some degree of over-enumeration of sea lamprey. If this were the case then the status of sea lamprey would be diminished relative to that reported here for juveniles.

It is apparent from the findings here that the identification of spawning sites is important in conservation terms, particularly where these sites are in regular annual use. Enumeration also provides some key to production of juveniles. Further monitoring and data collection in regard to both juveniles and adults is required in Ireland. In addition, the Irish experience must be compared with that of other EU member states to assess relative status. This may inform a more widely pertinent set of status guidelines and may also identify if additional conservation measures are required. These could include modification, removal or circumvention of barriers to improve upstream escapement (Nicola et al 1996, Travade et al 1996, Renaud 1997). Such approaches are particularly pertinent and cost-effective in cases where such barriers or weirs may be subject to modification in the course of civil engineering projects.

River Lamprey

At the juvenile stage, it is not possible to distinguish brook- and river lamprey (Gardiner 2003). Even at the transformer stage, the separation on dental features is not possible until *circa* December. As adults, the two taxa are easily distinguished on size. Adult river lamprey in Ireland entering estuaries in autumn commonly measure 27 – 35 cm in length whereas adult brook lamprey may be little more than half this length.

River Lamprey

River lamprey are anadromous, descending as young adults into estuaries and the open sea. Following a parasitic growth phase, mature adults return to freshwater and ascend rivers to spawn. They can enter estuaries and freshwater from at least August onward (W. Roche, unpublished data) in the year prior to spawning. Thus they are ascending rivers at a time when flows may be high – elevated and this may facilitate their passage over some barriers. Thus they have been captured in late autumn in the R. Slaney upstream of Clohamon Weir, the first major barrier to fish passage on this channel (King and Linnane 2004) and in the R. Liffey above the Islandbridge Weir (J. King unpublished data). The information available on the degree of anadromy of river lamprey is anecdotal, in large part, and no systematic information is available on the nature and size of barriers they can ascend and/or the flow conditions needed to accommodate such barriers.

What would be most important to discern for river lamprey would be their spawning locations as, once known, these sites could be subject to particular conservation measures. To achieve this, spawning fish would require to be observed in the acts of redd excavation, as per salmon and trout, or of actual spawning. This could be achieved via a telemetry programme, where ascending adults could be intercepted in estuarine waters and tagged with individual radio transmitters. These could then be followed upriver during the autumn-winter period and traced to specific spawning locations. This has been successfully undertaken in one system in the UK and represents a method to identify barriers than can, and cannot, be surmounted by this taxon.

Adult River lamprey have been captured in netting surveys in spring at Inistioge, at the top of the tidal reach of the R. Nore. Adults have not been recorded throughout the Nore system, simply because of their migration time and the low likelihood of their being encountered in surveys during winter-spring. Due to the problems of differentiating juvenile river and brook lamprey it is not possible to make comment on the degree of anadromy of river lamprey into the Nore system.

Brook Lamprey

As stated above, it is not possible at the juvenile stage to distinguish brook- and river lamprey (Gardiner 2003). Even at the transformer stage, the separation on dental features is not possible until *circa* December. As adults, the two taxa are easily distinguished by size. Adult river lamprey in Ireland entering estuaries in autumn commonly measure 27 – 35 cm in length whereas adult brook lamprey may be little more than 12 – 14 cm in length.

Brook lamprey adult from R. Nore system

Brook lamprey are not anadromous and their migration may involve relatively short journeys for adults to upstream areas with suitable spawning gravels. Above impassable barriers, Maitland (1980) has reported that the brook lamprey is the only lamprey species to be found, in these islands. Given their small size, brook lamprey may be impeded by substantially smaller barriers than those impeding river- or sea lamprey. Concrete sills and aprons around bridges may be placed in such a manner as to create hydraulic breaks or jumps. Even the smallest such discontinuity may impede brook lamprey adult migration. Thus, the presence of barriers may lead to genetically-isolated populations of brook lamprey.

Shad

The National Parks and Wildlife Service (NPWS) implements the Habitats Directive in Ireland and designated four river corridor segments for the Twaite shad – Rivers Slaney, Barrow-Nore, Suir and Munster Blackwater. As is the case in the U.K. (Hillman, 2002) no designations have been made in regard to the Allis shad as there are no known spawning sites for this species in the state. Both Allis and Twaite shad were collected and examined from the four Irish riverine SACs in the period 2000 – 2005 and from Waterford Harbour, the estuarine area formed by the convergence of the R. Barrow and R. Suir estuaries (King and Roche 2008).

Twaite shad records were most numerous from the R. Barrow, due to angler catches taken in May at the spawning area at St. Mullins, 32 km up the estuary from the confluence with the R. Suir estuary. Allis shad were taken in all four SAC estuaries in very low numbers. Almost all material was taken as commercial salmon by catch. The majority of these were taken in the shared tidal waters downstream of the Barrow-Suir confluence, either by salmon drift nets in June-July or by bottom-fishing gill nets in autumn-winter, set for marine species. A single fish, in prime spawning condition, was taken by angling in the R. Barrow in May 1998. Two fish were taken by angling, in 2003 and 2005, on the R. Munster Blackwater 25 km into freshwater above the tidal limit.

Unspeciated shad have been recorded in most seasons in the tidal R.Nore by commercial snap-net fishermen. A large Allis shad, in excess of 50 cm, was also captured here within the last five years. While anglers visit the adjoining St. Mullins site at the head of the tidal R. Barrow annually in May, for Twaite shad angling, there are no official records of Twaite shad coming to the top of the tidal R. Nore. The occurrence and/or extent of adult Twaite shad ascending the tidal R. Nore, to Inistioge at least, would require to be ascertained by survey means.

Shad have a pronounced capacity to travel up estuaries and deep into freshwater to spawning grounds (Aprahamian, 1981; Manyukas, 1989). This is particularly so with Allis shad. Such capacity is obviously facilitated, in part, in the R. Munster Blackwater and Slaney SACs but is impeded on the R. Barrow by navigation weirs and locks at the upper tidal limit. In the R. Suir SAC, Twaite shad have traditionally spawned up to the tidal limit above Carrick-on-Suir. They appear to be impeded from further upstream movement by an area of steep bed slope with stony, shallow bed type. A similar bed slope regime occurs at Inistioge on the R. Nore at the top of the tide.

SHAD

Improved passage facilities in major Irish SAC channels could permit a spatial, and hence genetic, separation of Allis and Twaite shad in the same catchment. It would be imperative that the upstream channel provide suitable spawning habitat including extensive areas of fast-flowing shallows over cobble and gravel as well as pool areas and backwaters (Maitland & Hatton-Ellis 2003). Such terrain is present in the R. Nore upstream of Inistioge, through the Brownsbarn area and up to Thomastown. The addressing of such obstructions may be required under both Water Framework Directive and Habitats Directive. Such measures would provide 'infrastructural support' for the shad species but could only be beneficial to shad conservation if shad were available to penetrate these new areas in sufficient numbers to find mates and engage in successful spawning.

A priority on the R. Nore would be to determine the degree of penetration and use by spawning Twaite and/or Allis shad of the upper tidal waters to Inistioge. Identification of spawning location(s) here would inform on the status of high gradient shallows and any possible role these may have in impeding shad movement further into riverine freshwater. It must be stated, however, that removal of natural obstructions, if these shallows prove to be, is not considered appropriate under either the Habitats Directive or the WFD.

Table 9. Multi-Fish Species Risk Assessment

River	Trib/Location	Salmon	Eel	Sea Lamprey Juveniles	Sea lamprey Redds	River Lamprey	Shad	Field based risk assessment	Spawning Channel u/s of u/s barriers(m^{-1})	Length of Ponding (m^{-1}) (O'Sullivan)
MC	Inistiogue	√	√	√	√	√	x	**No risk**		
MC	Thomastown*	√	√	√	√	√		No risk		1500*
MC	Mount Juliet	√	√	√	√	√		Low risk		700
MC	Bennetsbridge	√	√	√	x	√		No risk		2000
MC	Bretts	√	√	√	x	√		No risk		700
MC	Ballyraggert	√	√	√	x	√		No risk		500
MC	Castletown	√	√	x	/	√		No risk		1500
Arrigle	Ballyduff	√	√	x	/	√		Low risk		0
Little Arrigle	Goatsbridge weir	√	√	x	/	x		Moderate		500
Little Arrigle	Derrynahinch bridge	x	x	x	/	/		No risk	362	
Kings river	Bradleys Weir	√	√	x	/	√		High		500
Kings river	Hutchinson weir	√	√	x	/	√		Moderate		200
Kings river	Mullins weir	√	√	x	/	√		Moderate		200
Kings river (Munster trib)	Bridge at Ballyclovan	x	√	x	/	√		High	4168	
Kings river	Weir near drimeen	√	√	x	/	√		High		
Kings river	Br u/s of Island Br	√x	x	x	/	√		High		
Kings river	Willford Br	/	x	x	/	x		Moderate		
Pococke	Garrincree Br	x	/	/	/	/		No risk	1470	
Dinin	Douglas	/	/	x	/	x		Moderate		
Dinin	Gloisha	√x	/	x	/	√		No risk		
Dinin	Drumgoole weir	√	√	x	/	√		Moderate		0
Dinin	Metal bridge	√	x	x	/	√		High		0
Dinin	New Coan Bridge	√	x	x	/	/		High		0
Dinin	Castlecomber bridge	√	√	x	/	√		High		0
Dinin	Castlecomber weir	√x	√	x	/	√		Moderate	2173	1000+
Dinin	Massford bridge	√x	√	x	/	√		Moderate		0
Dinin (Killeen)	Clooneen Br.	√x	x	x	/	√		Low		
Dinin	Doonane bridge	√x	x	x	/	√		High	726	0
Dinin	Ormonde Bridge	x	x	x	/	√		High	901	0
Dinin	Killeen Br.	x	x	x	/	√		No risk	3265	

Dinin	**Mayo Br**	x	x	x	/	x		No risk	617	
Dinin	**Monavea river**	x	x	x	/	x		Moderate		
Dinin	**Clogh bridge**	√x	√	x	/	√		High	2195	0

River	**Trib/Location**	**Salmon**	**Eel**	**Sea Lamprey Juveniles**	**Sea lamprey Redds**	**River Lamprey**	**Shad**	**Field risk assessment**	**Spawning Channel u/s of u/s barriers(m^{-1})**	**Length of Ponding m^{-1} (O'Sullivan)**
Arigna	**Clashacrow Br**	√	/	/	/	/		High		
Nuenna	**New Br.**	√x	/	x	/	x		No risk		
Nuenna	**Freshford (BR1)**	√x	/	x	/	x		No risk		
Nuenna	**Freshford (BR2)**	√x	/	x	/	x		No risk		
Nuenna	**Ballyguider Br**	√x	/	x	/	x		Low		
Lisdowney stream	**Weir**	x	/	/	/	/		Impassable	2587	
Owenbeg	**Cloghoge Br**	√x	/	x	/	√		Low		
Owenbeg	**Castlecoole Br**	√x	/	x	/	√		Low		
Owenbeg	**Dysart wooden Br.**	√x	/	/	/	/		Low		
Owenbeg	**Bolybeg Br**	√x	/	/	/	/		Low		
Owenbeg	**Bolybeg Br. North**	√x	/	/	/	/		High	772	
Owenbeg	**Graiguenesmuttan Br**	√x	/	/	/	/		No risk		
Owenbeg	**Cross r.d nr chapel cross roads**	√x	/	/	/	/		Low		
Goul	**Loughmans weir**	√	√	√	/	√		Moderate		500
Goul	**Irrigation Dam Aghmacart**	√	√	/	/	/		High		500
Goul	**BR 1**	/	/	/	/	/		Moderate		
Goul	**BR 2**	/	/	/	/	/		Moderate		
Delour	**The Basin**	√	√	x	/	√		High	17,214	1,500

*Thomastown weir has suffered a partia collapse in 2008.

	GIS risk analysis
(cyan)	**No risk**
(green)	**Low risk**
(orange)	**Moderate risk**
(red)	**High risk**

Multi-Species Approach to Risk Analysis

Table 9 lists 51 of the more serious barriers on the Nore catchment. Those highlighted in blue represent those rivers that were assessed as no risk to salmon migration post GIS analysis. Those in green were assessed as low risk, orange assessed as moderate risk and red assessed as high risk. In the columns titled Salmon, Eel, Sea lamprey, Sea lamprey redds, River lamprey & Shad, (x) denotes the absence of the species upstream of a barrier and (√) identifies their presence. A (/) is placed in a cell where no information is available. In the column titled salmon, (√x) denotes the presence of one year class upstream of a barrier.

Main channel

The first five barriers in the table are all located on the main channel. They include Inistogue, Thomastown, Mount Juliet, Bennetsbridge weir, Bretts weir, Ballyraggert and Castletown. They were all assessed as no risk to salmon migration by GIS analysis as two year classes of salmon were captured upstream of all five. Salmon, eel and river lamprey were recorded upstream of all five barriers. Sea lamprey redds were recorded between Inistogue to Mount Juliet but were absent upstream of Bennestbridge, Bretts weir and Ballraggert weir. Sea lamprey juveniles were found upstream of all weirs except Castletown. An area of steep bed slope at Inistogue is preventing shad from ascending upstream to potential spawning grounds located between Inistogue and Thomastown.

Arrigle

Ballyduff weir was assessed as no risk by the GIS analysis. Salmon, river lamprey and eel were recorded upstream. Sea lamprey were absent from the Arrigle.

Little Arrigle

Salmon and eel were recorded upstream of Goatsbridge weir but were absent upstream of Derrynahinch bridge which was assessed as a high risk weir to salmon migration by the GIS risk analysis. There is approximately 362 m^{-1} of potential salmon spawning grounds upstream of Derrynahinch Bridge. Sea lamprey and river lamprey were absent upstream of Goatsbridge weir which is located on the lower reaches of the Arrigle. This was assessed as low risk to salmon migration by the GIS analysis but may be impeding sea and river lamprey migration.

Kings river

No sea lamprey were recorded on the Kings river which would indicate that the weirs Bradlys, Hutchinsons and Mullins weir located on the lower reaches of the Kings river are impeding upstream migration. Juvenile salmon were scattered throughout the Kings river but were absent upstream of one of the bridges at Ballyclovan bridge and only one year class was recorded upstream of the bridge upstream of Island bridge. There is approximately 4168m^{-1} of potential salmon spawning grounds upstream of Ballyclovan bridge. Eel were found throughout the catchment except for the upper reaches of the Kings River. No eel were located upstream of the bridge upstream of Island bridge or upstream of Willford bridge. River lamprey were recorded upstream of six of the seven barriers listed in the table. They were absent upstream of Willford Bridge.

Dinin river

The GIS analysis identified a large number of high and moderate risk barriers to salmon migration on the Dinin catchment. Two year classes of juvenile salmon were recorded on the main Dinin channel up as far Castlecomber weir. Only one year class was recorded upstream of Castlecomber weir, Cloonane bridge, Massford bridge and Doonane bridge. No salmon were recorded any further upstream than downstream of Ormonde bridge. There is approximately 4783m^{-1} of potential spawning ground available to salmon u/s of Ormonde, Killeen and Mayo Bridge. No sea lamprey were recorded on the Dinin catchment which suggests that Drumgoole weir on the lower reaches of the Dinin may be preventing their upstream migration. River lamprey were recorded throughout the catchment but were absent upstream of Mayo bridge and Monavea bridge. Eel were recorded upstream of Drumgoole weir, Castlecomber bridge, Castlecomber weir and Clogh bridge. Eel were absent from the Killeen tributary and they were also absent upstream of the metal bridge and Coan bridge.

Mayo Br

Nuenna

Four moderate risk barriers to salmon migration were identified by the GIS analysis on the Nuenna. Only one year class of salmon was recorded on the Nuenna. No sea lamprey or river lamprey were recorded and there is no information available for eels.

Owenbeg river

The GIS analysis identified one high risk barrier and six moderate risk barriers to salmon migration on the upper reaches of the Owenbeg. River lamprey were present upstream of Cloghoge bridge & Castlecoole bridge but sea lamprey were absent. There was no information for either species further upstream. There was no information available for eel in the Owenbeg catchment.

Goul

Salmon, eel, River and sea lamprey were recorded upstream of Loughmains weir on the lower reaches of the Goul. Eel & salmon were also present upstream of the irrigation damn at Aghmacart bridge. There was no information available for sea lamprey or River lamprey upstream of this barrier.

Delour

Salmon, eel and river lamprey were recorded upstream of the basin on the lower reaches of the Delour. There is approximately $17{,}214m^{-1}$ of potential spawning grounds upstream of the basin. While the Basin weir is categorised as a moderate risk barrier (table 8), the quantity of spawning channel upstream (approximately $17{,}214m^{-1}$) would prioritise this weir for modification. No sea lamprey were recorded on the Delour which supports the need to improve fish passage at the Basin weir.

Multi-Species Approach

The GIS risk analysis identified high & moderate risk barriers (table 7 & 8). Table 9 adopts a multi-species approach without using GIS analysis. A combination of barriers identified from a salmon perspective (table 7 & 8) and by a multi-species approach by presence & absent above barriers (table 9) provides a list of priority barriers for attention.

General Approach: The strategy of step-wise removal or modification of artificial barriers in an upstream direction is one that would provide optimal conservation value for the relevant species. Where barriers are of sufficient severity, this strategy would benefit all fish species. In the case of the R. Nore catchment, the weir at Thomastown, demonstrated to be a factor for sea lamprey penetration, would be the first structure requiring such management. The recent collapse of part of this weir may now allow fish to surmount this weir with greater ease. It may be the case that subsequent barriers may lie in the lower reaches of major tributaries. Thus a large barrier in the lower reaches of the Kings River may be functioning as an obstruction to fish passage and access through this would facilitate fish moving extensively throughout this sub-catchment. As commented on by King and Roche (2008), river engineering works at any other barrier site, even if not in sequence upstream, may provide opportunities to tackle a fish-passage problem. The installation of the rock ramp on the R. Nore in Kilkenny city at Lacken Weir is a case in point. This weir was largely replaced in the course of the Kilkenny city flood relief scheme and the new design proved problematic in respect of Atlantic salmon. A re-design involved removal of one side of the new structure and construction of a rock ramp with a design to accommodate 'the lowest common denominator' in fish passage terms.

Discussion

The approach set out in this report is based on a number of assumptions which require further discussion. The development of a salmon spawning GIS layer is critical to assessing the risk of barriers to restricting upstream salmon movement in the present study. The quality of the field data making up the spawning layer is critical to this assessment. It is likely to be more difficult to obtain accurate data on large rivers systems. Therefore re-classification of barriers as no risk due to the absence of spawning gravel upstream may need further assessment.

In the case of salmon, the risk categorisation of barriers based on the presence of spawning gravel upstream of barriers is technically correct. If there is no potential for salmon spawning upstream of an impassable barrier, then that barrier does not pose a risk to preventing salmon spawning upstream. However there may be a loss of juvenile productivity as juvenile salmon spawned downstream of a barrier may utilise rearing habitat upstream if assess was available. Sullivan (2007) comments that in assessing the impact of barriers to migration rarely are the temporal and partial effects on juveniles taken into account. Juveniles may be prevented from moving up and down catchments to find refuge from elevated water temperatures, critical reductions in stream discharge, etc. Juvenile salmon are known to migrate upstream from main stems into smaller tributaries where competition for food is less (Barnhart, 1991). A further risk category may therefore need to be introduced which can be linked to the amount of juvenile habitat available upstream.

The present study uses the presence or absence of salmon fry and parr as an index of passability of barriers. It is recognised that it would be more appropriate to use the relative abundance of juvenile salmon above and below barriers on the same channel sections to provide a better assessment of the degree to which barriers are restricting upstream salmon movement. The species and lifestage passability approach taken by Sullivan (2007) may be appropriate here.

An issue not addressed in this study is of barriers acting to delay upstream fish movement. While a barrier or series of barriers may not act to prevent salmon or lamprey ascending, barriers may delay upstream movement. This may have implications for salmon angling upstream or delay multi-sea winter salmon from reaching headwaters, cause stress etc. This may be dependent on time of year, for example lamprey spawn in summer and may be prevented from moving upstream to spawn in low summer flows. A delay in migration may result in risk of predation, stress and the onset of disease. Fish jumping at barriers and being physically injured, loss of eggs, etc also needs to be considered. While any particular barrier may not act to prevent upstream fish movement, the cumulative effect of barriers also needs to be considered.

The Nore catchment is undrained and likely to be fairly typical in respect of barrier density for Irish rivers generally. Catchments where arterial drainage works were carried out in the past typically had many old weirs and other obstructions removed for flood relief purposes and consequently have fewer barriers to fish migration. Salmon stocks are now being managed on a river by river basis and there is an increased need for provision of new fish counters for stock assessment. It is important that any new weirs constructed for fish counters or other weirs for water abstraction, flow measurement etc. be designed to have adequate provision to allow the upstream and downstream passage of all life stages of all migratory fish species over a broad range of river flow.

Conclusion

The methodology set out in this report describes field assessment of barriers to initially categorise the risk of restricting upstream fish movement. It uses a rules based system to systematically classify barriers and carries out a GIS analysis to provide a revised risk assessment. Obstructions are mapped systematically and a step wise approach to risk assessment is undertaken. This allows assessment of the gain in channel length or spawning area to be assessed. Once a priority list of barriers has been drawn up, consideration can be given to the nature of the obstruction, cost of rectification and benefit by fish species.

The primary aim of this risk based approach should be the restoration of the fisheries resource after knowledge based assessment. This may allow better planning of infra-structure and minimise the impact on the fisheries resource. While the current approach was primarily based on Atlantic salmon, a similar risk assessment should be undertaken for all migratory fish species. The risk assessment procedure for any migratory fish species can be summarised as follows;

Suggested Mechanism for Assessment of the Risk of in-River Barriers to Fish Migration.

1. Undertake field survey of all potential barriers and classify the risk of preventing upstream migration for each fish species

2. Ground truth this field assessment by electro-fishing and determine the relative abundance of fish species relative to other catchment sites

3. Map the potential for spawning throughout the catchment. Further mapping of productive nursery habitat is also desirable

4. Map the physical catchment chrematistics (i.e. gradient, stream order, geology) relative to the target species

5. Map the quality of the habitat in terms of water quality, habitat quality, habitat use, (afforestation, lakes, Special Areas of Conservation, etc)

6. Undertake risk analysis by species based on the criteria set out (i.e. presence of spawning potential, gradient, etc)

7. Re-classify barriers for each species based on the results of the risk analysis

8. Determine the potential gains (length of channel, quantity of wetted area, quantity of prime habitat) of achieving fish passage

9. Undertake a cost/ benefit analysis after prioritising barriers for remedial works

10. Undertake an analysis of the priority barriers based on a multi-species approach to achieve maximum benefit

11. Prepare list of priority candidate barriers for remedial works

It is recognised that such an approach may not be possible under all circumstances as this will be limited by time and resources. In such circumstances the main barriers to fish migration on main channel stems and tributaries could be identified and remedial action directed at these initially.

Project Personnel

The following personnel contributed to the production of this report,

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Appendix 1 Field Survey Sheet for Barrier Classification

SRFB DEVELOPMENT SURVEY OF OBSTRUCTIONS TO FREE MOVEMENT OF FISH

River System: Barrow **B** Nore **N** Suir **S** Blackwater (Munster) **BW** Other **0**	B	N ✓		S		BW		0
River Tributary Name (from 1:50,000 OS on site)	TRIB OF LITTLE ARRIGLE		Location GPS Reference (on site)		IS 5h2h6 ITm 35712			
River Tributary Name (from GIS 6 Inch at HQ)			Location: GIS Reference (at HQ)					
Townland(s) (from GIS at HQ)	BALLYKULE							
Nature of Obstruction: Bridge Apron **BA:** Weir **W:** Rock/Bedrock **R/B:** Culvert **C:** Ford **F:** Hydro Scheme **HS:** Bridge no Apron **BNA:** Other **0**	**BA** ✓	**W**	**RB**	**C**	**F**	**HS**	**BNA**	**0**
Material Type: Mass Concrete MC: Masonry (ie Stone) M: Rock/Bedrock R/B: Ford Material FM: Timber T: Natural Bed Material NBM: Other 0	**MC**	**M** ✓	**R/B**	**FM**	**T**	**NBM**	0	
River Channel Width (Metres) just d/s of Obstruction	2½	River Channel Width (Metres) just u/s Obstruction		2m				
Total Height of Obstruction / Fish Jump (Metres)	¼m.	Total Horizontal Length of Obstruction (Metres)		2½m.				
No. of Vertical Steps	1	No. of Horizontal Lengths		1				
Is Fish Pass Provided	YES	NO ✓	DENIL			POOL	OTHER	
Can Fish Readily Pass	Not at All	At Low Flow	At Moderate Flow ✓			At High Flow		
Is water diverted through(1)Head Race	YES	NO	(2) Tail Race			YES	NO	
If water diverted, are screens present	Headrace	Yes	No	Interbar Space(cm)		Tailrace cm	Yes	No
RISK of fish prevented to Pass	**No Risk**	**Low Risk**	**Moderate**		**High** ✓		**Impossible**	
Any Other Relevant Details	Road Bdge - Apron & Adjoining Walls in bad shape							

Details of Persons Met / Status		Alleged Ownership Details / Supplied By		
Photograph No'S	430			
River Conditions	Low Flow ✓	Moderate Flow		Flood Flow
Surveyed By:	[illegible signature]	Date	7/4/07	

1. To Facilitate photocopying, complete form in Black, not in Blue
2. 2Attach a B&W photocopy of 1:50,000 OS with the location of the obstruction clearly marked

compass informatics

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