Freshwater Pearl Mussel

Second Draft

Bundorragha Sub-Basin Management Plan

Photo courtesy of Evelyn Moorkens

Produced by NS 2, funded by DEHLG

March 2010

TABLE OF CONTENTS

GLOSSARY AND ABBREVIATIONS

AA:	Appropriate Assessment for Natura 2000 sites.
Acidification (artificial):	The rough canopies of mature evergreen forests are efficient scavengers of particulate and gaseous contaminants in polluted air. This results in a more acidic deposition under the forest canopies than in open land. Chemical processes at the roots of trees, evergreens in particular, further acidify the soil and soil water in forest catchments. When the forests are located on poorly buffered soils, these processes can lead to a significant acidification of the run-off water and consequent damage to associated streams and lakes.
ACP:	Agricultural Catchment Programme
Animal poaching:	Ground trampled or puddled by livestock resulting in exposed bare soil. Poaching can be widespread (i.e. whole field level) and/or localised in sensitive settings (e.g. along river banks, adjacent to feeding and drinking troughs and in water logged soils). Poaching represents a significant source of sediment loss to watercourses.
Animal trampling:	Direct damage to pearl mussels by livestock and/or machinery entering streams and rivers
Artificial water body:	A body of surface water created by human activity.
Biodiversity:	Word commonly used for biological diversity and defined as assemblage of living organisms from all habitats including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part.
CFB:	The Central Fisheries Board
Coastal waters:	That area of surface water on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters.
DAFF:	Department of Agriculture, Fisheries and Food.
DCENR:	Department of Communications, Energy and Natural Resources.
DEHLG:	Department of Environment, Heritage and Local Government.
DETE:	Department of Enterprise, Trade and Employment.
Diffuse sources (of pollution):	Non-point sources primarily associated with run-off and other discharges related to different land uses such as agriculture and forestry, from septic tanks associated with rural dwellings and from the land spreading of industrial, municipal and agricultural wastes.
EC:	European Commission
Ecological status:	An expression of the structure and functioning of aquatic ecosystems associated with surface waters. Such waters are classified as being of good ecological status when they meet the requirements of the Water Framework Directive.
Ecology:	The study of the relationships among organisms and between those organisms and their non-living environment.
Ecosystem:	A community of interdependent organisms together with the environment they inhabit and with which they interact; community and

	environment being distinct from adjacent communities and environments
EPA:	Environmental Protection Agency.
EU:	European Union
Eutrophic:	Having high primary productivity, the result of high nutrient content.
Eutrophication:	The process of enrichment of water by nutrients (principally phosphorus and nitrogen). The nutrients accelerate plant growth, disturbing the balance of aquatic plants and animals and affecting water quality.
Good status:	A collective term used to refer to the status achieved by a surface water body when both its ecological status and its chemical status are at least good or, for groundwater, when both its quantitative status and chemical status are at least good.
Groundwater:	All water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil. This zone is commonly referred to as an aquifer, which is a subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow a significant flow of groundwater or the abstraction of significant quantities of groundwater.
GSI:	Geological Survey of Ireland.
Heavily modified water body:	A water body that has been changed substantially in character as a result of physical alterations by human activity.
HSE:	Health Service Executive
Hydromorphology:	A study of the quantity and dynamics of water flow within a water body that has variations in its width, depth, structure and substrate of bed and riparian zone.
Inland surface waters:	All standing or flowing water on the surface of the land (such as reservoirs, lakes, rivers) on the landward side of the baseline from which the breadth of territorial waters is measured.
Invasive alien species:	Invasive alien species are non-native plants or animals that successfully establish themselves in aquatic and fringing habitats and damage natural flora and fauna.
Leachate:	The liquid containing dissolved and suspended contaminants that is formed as percolating water passes through potentially polluting materials. The term is generally associated with landfills.
Mitigation measures:	Measures to avoid, prevent, minimise, reduce or, as fully as possible, offset or compensate for any significant adverse effects on the environment, as a result of implementing a plan or programme.
NAP:	National Action Programme
NRFB:	Northern Regional Fisheries Board
NPWS:	National Parks and Wildlife Service.
On-site system:	Septic tank or other system for treating wastewater from unsewered properties.
Oligotrophic:	Water bodies that are poorly nourished or unproductive.
OPW:	The Office of Public Works

PRP	Pollution reduction programme
Programme of measures:	Those actions, defined in detail, which are required to achieve the environmental objectives of the Directive within a river basin district.
Protected area	Water protected by European legislation including drinking waters, shellfish waters, bathing waters, urban wastewater nutrient sensitive areas or sites designated as Special areas of Conservation or Special Protected Areas
Quantitative status:	An expression of the degree to which a body of groundwater is affected by direct and indirect abstractions. If this complies with Directive requirements the status is good.
River Basin District (RBD) & International River Basin District (IRBD):	Administrative area for coordinated water management, composed of multiple river basins (or catchments), with cross-border basins (i.e. those covering the territory of more than one Member State) assigned to an international RBD.
River basin:	The area of land from which all surface water run-off flows, through a sequence of streams, rivers and lakes into the sea at a single river mouth, estuary or delta.
SEA:	Strategic Environmental Assessment
Sedimentation:	The deposition by settling of a suspended material.
ShRFB:	Shannon Regional Fisheries Board
SNIFFER:	Scotland Northern Ireland Forum for Environmental Research.
Special Area of Conservation (SAC):	Site designated according to the Habitats Directive (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora).
Special Protection Area (SPA):	Area designated under the European Directive on the Conservation of Wild Birds.
SRFB:	Southern Regional Fisheries Board
Statutory Instrument (SI):	Any order, regulation, rule, scheme or bye-law made in exercise of a power conferred by statute.
Surface water:	Inland waters on the land surface (such as reservoirs, lakes, rivers, transitional waters, coastal waters) within a river basin.
SWAN:	Sustainable Water Network
SWRFB:	South Western Regional Fisheries Board
TCC:	Technical Conservation Committee
Transitional waters:	Bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their vicinity to coastal waters, but which are substantially influenced by freshwater flows.
Water body:	A coherent sub-unit in the river basin (district) to which the environmental objectives of the directive must apply. Hence, the main purpose of identifying “water bodies” is to enable the status to be accurately described and compared to environmental objectives
Water Framework Directive (WFD):	The Water Framework Directive is European legislation that promotes a new approach to water management through river basin planning. It covers inland surface waters, estuarine waters, coastal waters and groundwater.

WRFB:	Western Regional Fisheries Board
WMU:	Water Management Unit – geographical sub unit of a river basin district

GUIDE TO PLAN

This sub-basin management plan has been produced to act alongside the wider River Basin Management Plans (RBMPs) to provide a programme of measures required to improve the habitat of the freshwater pearl mussel so that it can attain favourable conservation status.

In Chapter 1, a background to the freshwater pearl mussel is described, its life history, ecology and conservation requirements outlined and the legal basis for the implementation of the sub-basin plans. The status of the species in Ireland is presented in Chapter 2.

The pressures identified within the Bundorragha Catchment are given in Chapter 3, and the status of the Bundorragha pearl mussel population, together with the monitoring carried out in the catchment is presented in Chapter 4. Chapter 5 summarises the monitoring requirements in fulfilment of the *Margaritifera* regulations 2009 on an ongoing basis.

Chapter 6 provides a list of measures following the format of the RBMPs. The measures listed in Tables 6.1 list measures to be taken across the wider RBD and detailed information in relation to these measures can be obtained from the RBMPs. A toolbox of pearl mussel additional measures have also been developed (Table 6.2) which can be applied throughout the catchment. Finally, the Summary Action Programme lists the site and catchment specific measures that are prioritised for the Bundorragha catchment over the timescale of this plan.

Chapter 7 is a summary action programme, and is presented as a succinct list of pressures and measures to be undertaken in the Bundorragha Catchment. This summary can be used on its own to gain a quick understanding of the key pressures and measures in the catchment, but the reader should refer back to the relevant chapter in the plan for greater detail.

1 INTRODUCTION TO THE FRESHWATER PEARL MUSSEL *MARGARITIFERA MARGARITIFERA*

1.1 BACKGROUND

The freshwater pearl mussel is a bivalve, which is a type of mollusc or snail with a body that is almost completely enclosed between a pair of shells. For most of its life it is a filter feeder, and large quantities of water are pumped through the animal's siphons and food particles are trapped and passed to the mussel's mouth. The adult pearl mussel burrows to two-thirds of its shell depth, and is almost sessile in nature, often not moving for 100 years.

There are two types of pearl mussels in Ireland, one called *Margaritifera margaritifera* and the other is the very rare *Margaritifera durrovensis*, which is only known from the Nore Catchment.

The pearl mussel *Margaritifera margaritifera* has attracted a lot of interest in recent years due to its interesting ecology, life cycle, ability to produce pearls and, most importantly, its decline which has left the species in danger of extinction.

As their name suggests, *Margaritifera* has the ability to occasionally produce pearls. However, there is currently no sustainable way to extract pearls (Moorkens 2004), and thus pearl fishing is illegal. This was not always the case, when pearl mussel populations were very abundant the pearl fishery was highly prized, and has been cited as the underlying reason for the invasion of Britain by the Romans (Johnston, 1850). When adult numbers were very high in certain rivers, pearls were an important cultural aspect of the river (Lucey 2005).

Populations of *Margaritifera margaritifera* are known from North America, northern, western and central Europe and Russia. The species is in very serious decline throughout its range and is listed in the IUCN red data book as endangered worldwide (Baillie & Groombridge 1996).

1.2 LIFE HISTORY

Pearl mussel ecology is complicated as individuals can grow to very large sizes for invertebrates (up to 145mm), building up thick calcareous shells, in most cases in rivers that have soft water with low levels of calcium. Their shell building is consequently very slow, and individuals live to over a hundred years of age (Comfort 1957).

Pearl mussels have separate male and female animals (Figure 1.1), which is unusual for molluscs, although there is no external difference between them. Reproduction occurs when sperm are released into the open water via the male's exhalant siphon, and are carried to the eggs via the female inhalant siphon (Figure 1.2) and fertilisation occurs in the brood chambers (Smith 1979; E. Ross 1988). These develop into the larval stage, called glochidia, which are temporarily brooded in the female gills from June each year, and are then released into the open water in high numbers in an event lasting one to two days between July and September, probably dictated by temperature in the river during development (Young & Williams 1984a; Bauer 1987, H. Ross 1992; Ziuganov *et al*. 1994; Moorkens 1996; Hastie & Young 2003). The numbers of glochidia being released have been found to vary between one individual and 28 million per individual female (Bauer, 1987: Young & Williams, 1984a; E. Ross, 1988).

A small percentage of the glochidia released to the river will be inhaled by passing salmonid fish (Bauer & Vogel, 1987), which act as the pearl mussels' temporary hosts. In a laboratory study, Young & Williams (1984b) found glochidia to be no longer viable after 24 hours. The same authors calculated that failure to find a host within 24 hours occurred 99.9996% of the time in the wild (Young & Williams, 1984a).

Glochidia are simple organisms with little more than a pair of shells, an adductor muscle to snap them shut, and a layer of cells which can absorb and digest nutrients (Ziuganov *et al,* 1994). The valves close on a filament of the salmonid gills, and nourishment is taken from this fish host until the glochidia are large and mature enough to exist independently (Nezlin *et al.* 1994; Ziuganov *et al.* 1994). During this time they increase to about six times their original length. In a field study, Young & Williams

(1984a) found a 95% loss of glochidia while attached to fish. A laboratory study showed losses of 88 to 95% (Young & Williams, 1984b).

Those glochidia that survive on the fish develop into young mussels. They fall off in early summer (normally June) and bury into gravel, remaining buried for about five years, until large enough to withstand the flow of open water, moving stone, and perhaps trout predation (Cranbrook 1976; Wells *et al.* 1983; Moorkens 1996). Young & Williams (1984a) estimated from field studies that only about 5% of young mussels falling off fish survive to reach three to six years of age in rivers capable of supporting recruitment.

The retention of a glochidial stage is unusual for a creature living in fast flowing water. Most freshwater molluscs have developed means of depositing eggs safely in gelatinous masses or attached to aquatic vegetation, but pearl mussels release free glochidia downstream, and rely on the salmonid host to keep the glochidia from flowing to the sea. In addition, the host attachment stage may act as a mechanism for dispersal of populations to new rivers, or upstream within a river (Purser 1988; Oliver *et al*. 1993).

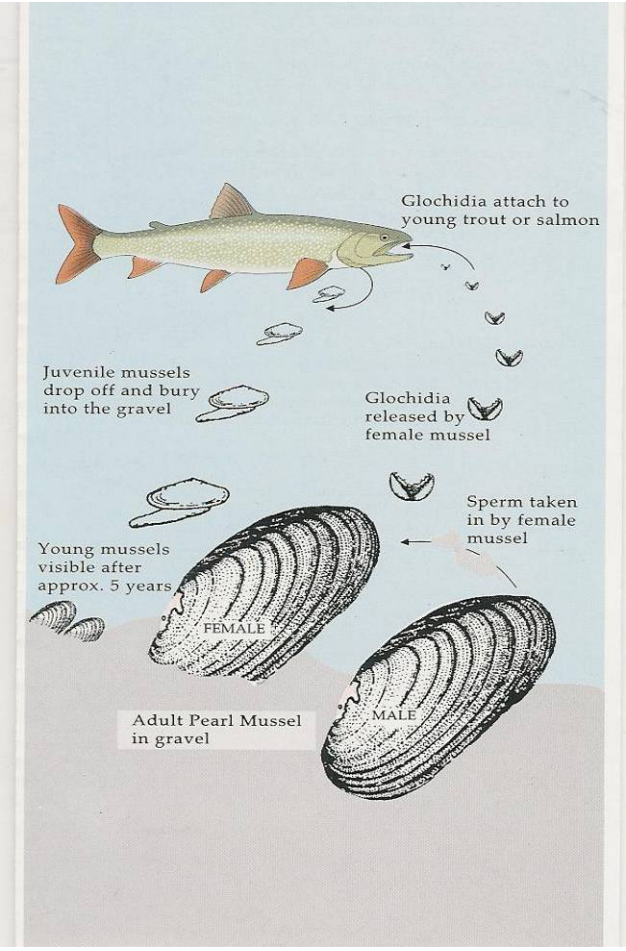


Figure 1.1: Life cycle of *Margaritifera* (from Moorkens, 1996)

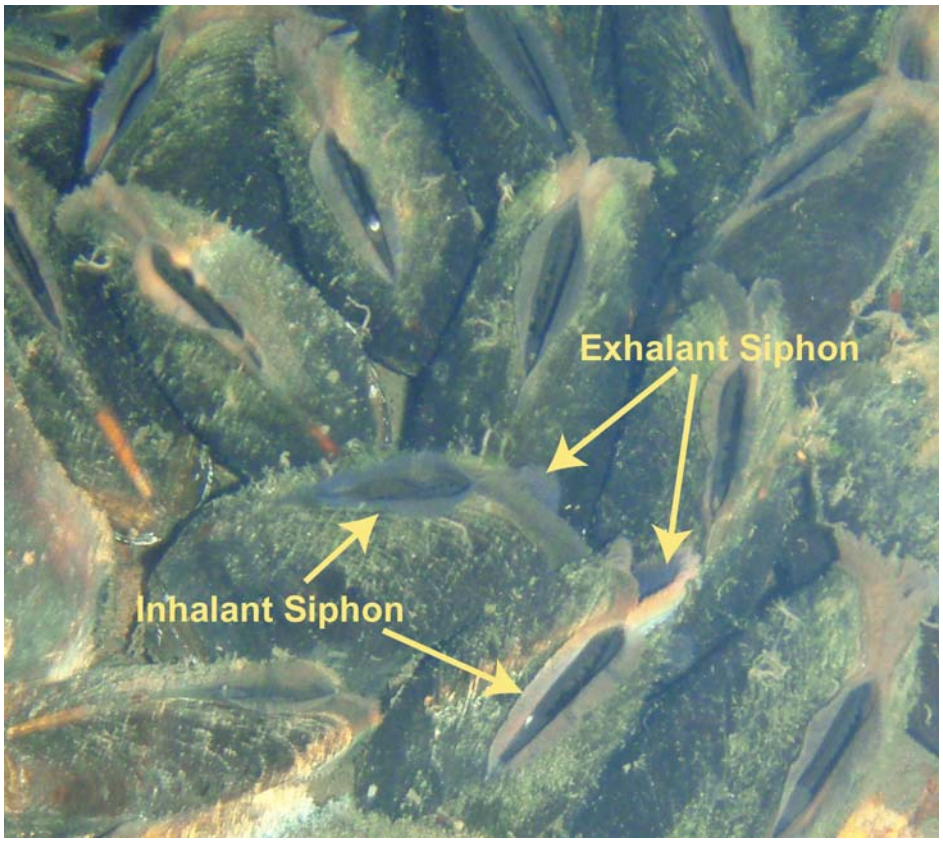


Figure 1.2: *Margaritifera* showing inhalant and exhalant siphons (Photo: Pete McCullough)

Fish hosts vary throughout the range of pearl mussels. In Europe, *M. margaritifera* has been shown to use native brown trout *S. trutta* L. and Atlantic salmon *Salmo salar* (Young & Williams, 1984a; Moorkens, 1996, 1999). Ziuganov & Nezlin (1988) have proposed that the relationship of pearl mussels and salmon is symbiotic. The fish provides the essential step in the mussels' life cycle, and mussels improve water quality by filtering water. Each mussel can filter up to 50 litres of water per day (Ziuganov & Nezlin 1988). In the Varzuga River in Russia, Ziuganov & Nezlin (1988) estimated that mussels filter 90% volume of the river in low water years.

Juvenile mussels spend their first five to ten years buried within the river bed substrate. Pearl mussels mature between seven and 15 years of age (Meyers & Milleman 1977; Smith 1978; Young & Williams 1984a), and can have a prolonged fertile period lasting into old age (Bauer 1987). Further details of the life cycle can be found in Moorkens (1999).

1.3 REASONS FOR THE DECLINE OF PEARL MUSSELS

1.3.1 Ecological reasons for decline

Some pearl mussel populations may have survived in parts of Ireland during glacial periods, but most probably established in Irish rivers shortly after the ice retreated. Large populations established where rivers were very clean and these are likely to have thrived for thousands of years. Early records of this species referred to very abundant populations, and it is only in the last 50 years that a major decline has been documented. It has been estimated that there was a decline of more than 90% in European populations during the 20th century (Bauer 1988), and the situation for the mussel continues to deteriorate (Araujo & Ramos, 2001).

The pearl mussel requires very high quality rivers with clean river beds and waters with very low levels of nutrients. In general, rivers and river bed habitat needs to be at "reference" level, i.e. near natural

conditions are required. Where river water quality has been depressed by inputs such as phosphates and nitrates, elevated BOD, or dangerous substances, such as metals or insecticides (particularly sheep dip), mussel numbers can rapidly decline.

The decline of pearl mussel populations in Ireland has mostly occurred from the continuous failure to produce new generations of mussels because of the loss of clean gravel beds, which have become infiltrated by fine sediment and/or over-grown by algae or macrophytes.

1.3.1.1 Decline in pearl mussel populations as a result of siltation and/or nutrient enrichment of juvenile habitat

Of particular importance in the decline of the pearl mussel has been the increase in sediment movement through rivers and its settlement onto the river bed. When this happens, formerly clean gravels become clogged with fine sediment. This prevents oxygen movement into the waters in the river bed (interstitial) that feed the juvenile mussels, and they quickly die. Each time siltation of gravels occurs, all juvenile mussels below five years of age are killed, and in rivers with chronic siltation problems, juvenile recruitment is rare and unsustainable. In these populations, lots of adult mussels may still be present, however when the older mussels die off they will not be replaced by a younger generation. If the habitat of the river bed is not restored, these populations will inevitably go extinct. The status of these populations is known as “functionally extinct”. The decline in interstitial water quality in silted gravels has been detailed by Buddensiek (1989) and by Buddensiek *et al*. (1993). Fine sediments in gravels were shown to increase mortality in juvenile mussels to 100% (Buddensiek, 2001). Fine sediment, once introduced to a pearl mussel river, can continue to cause very serious effects on a long term basis (Ellis 1936, Marking & Bills 1979, Naden *et al*. 2003, Araujo & Ramos 2001, Killeen *et al*. 1998).
As with siltation, nutrient enrichment can have serious and ongoing impacts on juvenile mussels. Increased inputs of dissolved nutrients to pearl mussel rivers tend to lead to filamentous algal growth, unless combined with siltation, where macrophyte growth can dominate. Macrophytes smother the juvenile habitat even further, and trap more sediment, exacerbating the problem in the long term. Filamentous algae can lead to the death of juvenile mussels, through blocking oxygen exchange with the sediment.

1.3.1.2 Adult pearl mussel deaths as a result of siltation and/or nutrient enrichment

Direct ingestion of silt by adult mussels can lead to rapid death. Turbidity, particularly from fine peat entering the water, causes adult mussels to clam up (they close their shells tightly and do not filter water through their siphons), a response that provides a protection against ingesting damaging fine particles. If the river water remains strongly turbid for a number of days, mussels can die from oxygen starvation, either from remaining clammed, or from ingesting contaminated water while stressed. During a time of year when water temperatures are high, oxygen depletion in the body occurs more rapidly, and mussels die more quickly. The evolutionarily primitive pearl mussel gills and the annual brooding of young in all four of the gills demand a continuous, high supply of oxygen. Even if the adult mussels survive an initial silt episode, food/oxygen deprivation from clamming will have caused them to become stressed, from which they will take a long time to recover. If during that recovery period, there are further incidents of mobilisation of silt, then the stressed mussels will be more susceptible to death than mussels in a cold river in unstressed conditions. Thus, they may continue to die over a period of several months. Higher temperatures throughout the summer further exacerbate this problem.

Silt also causes river changes, which in turn change the dynamics of the river into the future (Curran & Wilcock 2005, Colosimo & Wilcock 2005, Dietrich *et al*. 1989). Increases in fine material in the bed and suspended in the water column, and consequent changes in channel form, may affect mussels in many ways and at various stages in their life cycle. The fine sediment subsequently provides a medium for macrophyte growth, which makes the river bed habitat unsuitable for pearl mussels. One of the most essential requirements for pearl mussel conservation is the removal of the risk of any sediment reaching the river, as any one single incident has such long term ramifications.

Silt infiltration of river bed gravels can also have a negative effect on the essential species of fish that host the mussel glochidial stage (Levasseur *et al*. 2006).

Nutrient enrichment can also have serious and ongoing impacts on adult mussels. Filamentous algae can cause adults to become stressed, as a result of night time drops in oxygen. Even if filamentous algae are destroyed in a flood, adult mussels may not make a full recovery before the algae re-grow. Adult mussels may eventually die as a result of oxygen/food deprivation.

1.3.1.3 Declines in pearl mussel populations as a result of acidification

Acidification has been well documented as a threat to salmonid populations both internationally (e.g. Maitland *et al*. 1987, Henrikson *et al*. 1995, Lacroix, 1989) and in Ireland (Bowman & Bracken 1993, Allott *et al*. 1990, Kelly Quinn *et al*. 1997). Acidification has also been noted as a direct threat to pearl mussel from the first international IUCN red data book for invertebrates (Wells *et al*. 1983). Work carried out in Scandinavia has provided evidence for pearl mussel decline from acidification (Okland & Okland 1986, Eriksson *et al*. 1981, 1982, 1983; Henriksen *et al*. 1995, Raddum & Fjellheim 2004). A lowering of pH directly influences pearl mussels through a gradual destruction of their calcareous shell, and also their genital organs (causing infertility), and through problems with regulation of acid-base mantle fluid homeostasis (Vinogradov *et al*. 1987).

1.3.1.4 Declines in pearl mussel populations as a result of toxic pollution

Liming of land has a negative effect on pearl mussel populations, through direct toxic effects, and through increased growth rates leading to shortened life expectancy and, thus, loss of reproductive years (Bauer *et al*. 1991, Skinner *et al*. 2003). In some countries, however, acidification problems are so severe that liming is considered to have a more positive than negative effect (Henrikson *et al*. 1995). Water chemistry data from declining Irish pearl mussel rivers indicate high peaks of calcium and conductivity levels that are likely to have been caused by liming.

Other toxic products have resulted in deaths of pearl mussels. In one extreme case, a pearl mussel population became extinct as a result of toxic pollution. Pesticides such as sheep dip products are probably the most severe, but evidence from American surveys of glochidial stages of unionid mussels have demonstrated lethal effects from very low doses and environmentally relevant concentrations of chlorpyrifos and permithrin, the fungicides chlorothalonil, pyraclostrobin and propiconazole, and glyphosate. (Bringolf *et al.,* 2007a, b, c). Of particular concern are the severe deleterious effects of the latter substances in combination with surfactant blends, such as in commercial products like Monsanto Roundup. The end product including the surfactants can result in a much more toxic product than that of the individual ingredients

The Republic of Ireland is estimated to hold 46% of all the pearl mussels in the European Union, but only one of its populations is in favourable condition, none of the rest have sustainable juvenile recruitment. Recovery of a mussel population from unfavourable to favourable condition becomes more difficult when adult numbers are reduced, as the life history of the mussel relies on very large numbers of glochidia in the cleanest of waters to result in adequate juvenile survival. Thus, early detection of river management problems and fast remedial action is very important.

1.3.1.5 Issues that are unlikely to contribute to declines in pearl mussel populations

The essential interaction with salmonid fish hosts led to investigations into whether reductions in fish numbers contribute to pearl mussel decline (Geist *et al.* 2006). The research concluded declines in fish were not a contributory factor and that functional pearl mussel populations, i.e. those with high numbers of juveniles, had significantly lower densities and biomass of host fish than nonfunctional streams. Higher densities of host fish coincided with eutrophication, poor substratum quality and lack of pearl mussel recruitment.

Various studies have also investigated whether disease or parasite infestation may have contributed to the mussel's decline; these were reviewed with other factors affecting mortality by Bauer (2000). The conclusion drawn was that disease and parasite infection is a very rare occurrence in freshwater mussels, and an insignificant cause of mortality.

While climate change is noted as a possible future threat to the pearl mussel (Hastie *et al*., 2003), due to the potential increase of flood events, there is no evidence that it has contributed to the local or worldwide decline of the species. In predictive modelling, the freshwater pearl mussel is expected to show neither gains nor losses of potentially suitable climate space and to occur almost all over Britain and Ireland into the next 80 years (Berry *et al.,* 2007).

1.3.2 History of decline

The pearl mussel was historically widespread in Ireland. There appear to have been three periods over the last 150 years during which the mussel has faced very serious problems:

The first was after the Drainage (Ireland) Act of 1842, when many river catchments were modified and the land adjacent the rivers changed radically. Ongoing drainage schemes began the deterioration of many of the lowland rivers that are now some of the centres of our most intensive agriculture. Following this land intensification, approximately about 130 rivers retained mussels.

The second period of decline coincided with Ireland's entry into the EEC in 1973, and was associated with intensification of agricultural practices, and a marked increase in phosphorus and nitrogen loading to river catchments. Increases in sheep numbers following the introduction of EU headage payments resulted in overgrazing of hillsides above pearl mussel rivers, leading to loss of soil into the rivers below. The number of cattle drinking directly from pearl mussel rivers increased, causing trampling of the river bed and fouling of the water,water and erosion of the river bank around entry areas. When EU–led intensification began, the campaign to plant state forestry was well underway, with peat and peaty soils targeted for planting and phosphorus, crucially, being used during establishment, and often at intervals along the route to tree maturity and cropping. Industrial drainage and exploitation of peat has also intensified over the last 40 years. Clearing, draining and/or ploughing land for agriculture, peat exploitation and forestry activities releases silt, as the soil or peat washes into the river, and this is joined by silt caused by the decay of the filamentous algae that grows when nitrogen and phosphorus levels rise. The majority of Ireland's pearl mussel rivers last bred successfully in the 1970s. Some of these still retain a small population of adult mussels, but they typically range in age from 60 to over 100 years old, although some individuals as young as 30 are sometimes found.

We have entered the third phase of pearl mussel population decline. A number of factors are combining to provide a very serious threat to the remaining breeding populations. Three are of particular concern. Firstly, agricultural land that was not intensively managed historically has been repeatedly fertilised and is becoming saturated with phosphorus. Secondly, forestry units are now reaching maturity and, particularly in upland peat areas, have the potential on felling to release large quantities of phosphate into these rivers. Thirdly, the recent intensification of development, with associated land clearance, pressure on sewerage schemes and inappropriate locating of on-site systems for once-off housing near the rivers, is adding to the nutrient and sediment load. The third phase of damage to the pearl mussel habitat in these rivers has manifested itself since the Habitats Directive came into force and serious declines have occurred in some rivers following their designation as SACs, although some of the causes of the decline were in place before their designation.
The pearl mussel rivers in Ireland that are known to have recruited young recently are generally in remote areas, with short rivers and small catchments that have not historically been subject to intensive fertiliser inputs. They are typically areas of low human population density, with few urban areas, any habitation being located low down in the catchments. They are mainly below lakes, which provide an even, buffered source of water through the river. Many of the SAC rivers for *Margaritifera margaritifera* fall into this category.

1.4 WHAT IS A SUSTAINABLE POPULATION OF PEARL MUSSELS?

The target for a sustainable population is one that it is where reproduction and survival of sufficient numbers of young mussels to adulthood to sustain the population at current levels or previous levels (if known). Table 1.1 shows the mussel demographic criteria for the assessment of the conservation

status of pearl mussel populations, as set out in the draft European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations 2009.

Table 1.1 The targets for sustainable *Margaritifera margaritifera* population structure.

Criterion	Target to pass	Notes
Numbers of live adults	No recent decline	Based on comparative results from the most recent surveys
Numbers of dead shells	<1% of population and scattered distribution	1% considered to be indicative of natural losses.
Mussels shell length ≤65mm	At least 20% of population ≤65mm in length	Field survey of 0.5 X 0.5 m quadrats must be carried out in suitable habitat areas for juveniles
Mussels shell length ≤ 30mm	At least 5% of population ≤ 30mm in length	Field survey of 0.5 X 0.5m quadrats must be carried out in suitable habitat areas for juveniles

1.5 HABITAT ATTRIBUTES FOR SUSTAINABLE POPULATIONS OF PEARL MUSSELS

The habitat of *Margaritifera margaritifera* in Ireland is restricted to near natural, clean flowing waters, often downstream of ultra-oligotrophic lakes. A small number of records are from the lakes themselves.

The pearl mussel requires stable cobble and gravel substrate with very little fine material below pea-sized gravel. Adult mussels are two-thirds buried and juveniles up to five to ten years old are totally buried within the substrate. The lack of fine material in the river bed allows for free water exchange between the open river and the water within the substrate. The free exchange of water means that oxygen levels within the substrate do not fall below those of the open water. This is essential for juvenile recruitment, as this species requires continuous high oxygen levels.
The clean substrate must be free of inorganic silt, organic peat, and detritus, as these can all block oxygen exchange. Organic particles within the substrate can exacerbate the problem by consuming oxygen during the process of decomposition. The habitat must be free of filamentous algal growth and rooted macrophyte growth. Both block the free exchange of water between the river and the substrate and may also cause night time drops in oxygen at the water-sediment interface.

The open water must be of high quality with very low nutrient concentrations, in order to limit algal and macrophyte growth. Nutrient levels must be close to the reference levels for the river they inhabit. Phosphorus must never reach values that could allow for sustained, excessive filamentous algal growth.

The presence of sufficient salmonid fish to carry the larval glochidial stage of the pearl mussel life cycle is essential.

The conservation targets for sustainable mussel populations include maintenance of free water exchange between the river and the substrate and minimal coverage by algae and weed. The particular emphasis is on maintenance of recruitment i.e. the river bed structure required to breed the next generation.

Table 1.2 shows the sustainable pearl mussel habitat attributes, with ecological quality objectives for pearl mussel sites as set out in the draft European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations 2009.

The targets set out in these Regulations are interim targets that may be revised in line with the results of the monitoring programmes. These targets may be too stringent or not stringent enough – and will be reviewed following analysis of pearl mussel recruitment data with data for nearby diatoms, macroinvertebrates and other monitored elements.

Table 1.2 Ecological Quality Objectives for Freshwater Pearl Mussel Sites

Element	Objective	Notes
Macroinvertebrates	EQR ≥0.90	High status
Filamentous algae (Macroalgae)	Trace or Present (<5%)	Any filamentous algae should be wispy and ephemeral and never form mats
Phytobenthos (Microalgae)	EQR ≥0.93	High status
Macrophytes - rooted higher plants	Trace or Present (<5%)	Rooted macrophytes should be absent or rare within the mussel habitat.
Siltation	No artificially elevated levels of siltation	No plumes of silt when substratum is disturbed

1.6 LEGISLATION PROTECTING PEARL MUSSELS

1.6.1 Legal protection and red listing

The pearl mussel *Margaritifera margaritifera* (L., 1758) is protected under several tiers of national and international legislation:

- The Wildlife Act, 1976 and Wildlife (Amendment) Act, 2000 (The pearl mussel was given protected faunal species status under The Wildlife Act, 1976 (Protection of Wild Animals) Regulations, 1990, S.I. No. 112, 1990)
- The Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) as transposed by the European Communities (Natural Habitats) Regulations, S.I. 94/1997, as amended by S.I. 233/1998 and S.I. 378/2005. The pearl mussel is listed on Annex II and Annex V to the Directive,
- Bern Convention Appendix 3

The freshwater pearl mussel *Margaritifera margaritifera* (L., 1758) is also on the following red data lists:

- IUCN Red Data List as Endangered (IUCN, 1996)
- Red Data (Ireland) as Critically Endangered (Moorkens, 2006; Byrne *et al*., 2009)

The Republic of Ireland currently has stretches of 19 SACs designated for the pearl mussel covering 27 sub-basins. 26 of these sub-basins hold *Margaritifera margaritifera* and one, the River Nore, contains *M. durrovensis*.

Article 1 of the Habitats Directive states:

For the purpose of this Directive:

(a) conservation means a series of measures required to maintain or restore the natural habitats and the populations of species of wild fauna and flora at a favourable status as defined in (e) and (i);

(i) conservation status of a species means the sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations within the territory referred to in Article 2;

The conservation status will be taken as "favourable" when:

- *population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and*
- *the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and*
- *there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis;*

Article 6.1 of the Habitats Directive states:

For special areas of conservation, Member States shall establish the necessary conservation measures involving, if need be, appropriate management plans specifically designed for the sites or integrated into other development plans, and appropriate statutory, administrative or contractual measures which correspond to the ecological requirements of the natural habitat types in Annex I and the species in Annex II present on the sites.

Article 6.2 of the Habitats Directive states:

Member States shall take appropriate steps to avoid, in the special areas of conservation, the deterioration of natural habitats and the habitats of species as well as disturbance of the species for which the areas have been designated, in so far as such disturbance could be significant in relation to the objectives of this Directive.

1.6.2 How legal protection can be implemented

Under Article 6 of the Habitats Directive as mentioned above Member States must show the steps taken to achieve the Directives objectives as well as avoiding deterioration in those natural habitats and habitats of species. To achieve these requirements, in Ireland the European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations 2009 (S.I. No. 296) have been established and require:

a) Specific objectives and targets, in accordance with Regulation 2 and the Fourth Schedule, and deadlines for their achievement;
b) The investigation of sources of pressures leading to the unfavourable conservation status of the pearl mussel;
c) The establishment of a programme, including a timeframe, for the reduction of pressures giving rise to unfavourable conservation status. The programme shall include pressure reduction targets and deadlines, either in relation to individual pollutants or to particular sectors or activities or both, to be implemented within the sub-basin, or parts of the sub-basin as appropriate;
d) A detailed programme of monitoring to be implemented within the sub-basin, or parts of the sub-basin as appropriate, in order to evaluate the effectiveness of measures and progress made towards restoring favourable conservation status.

In addition to this, the Water Framework Directive (WFD) requires that a programme of measures (POMs) is established in order to achieve its environmental objectives. The EU WFD (2000/60/EC), which came into force on 22 December 2000, is the most important piece of European water legislation. It aims to promote common approaches, standards and measures for water management on a systematic and comparable basis throughout the European Union. It establishes a new,

integrated approach to the protection, improvement and sustainable use of Europe's rivers, lakes, transitional waters (estuaries), coastal waters and groundwaters.

The WFD POMs include "basic measures" which include those measures required to implement Community legislation for the protection of water including measures specified under 11 named Directives, one of which is the Habitats Directive. The programme of measures will be established by the 22 of March 2010 and must be made operational by 22 December 2012 at the latest.

Consequently, the sub-basin plans and environmental objectives established for those pearl mussel populations designated under the Habitats Directive are also afforded protection under the Water Framework Directive's river basin programme of measures. They form part of the basic measures and the objectives for these protected areas must be achieved.

2 STATUS OF THE FRESHWATER PEARL MUSSEL *MARGARITIFERA MARGARITIFERA* IN IRELAND

2.1 IRELAND IN CONTEXT WITHIN THE EU

In the EU, most countries' pearl mussel populations are considered to be completely extinct (e.g. Poland), almost extinct (e.g. DenmarkLuxembourg) or have small senescent populations which, in the absence of major river habitat recovery, will become extinct by the end of the lives of the current generation (e.g. Austria, Latvia, Luxembourg, Belgium) (Araujo & Ramos, 2001; Geist, 2005). A few countries have populations with some juvenile recruitment (Scotland, Finland, Sweden), but recruitment in most cases is found to be inadequate to replace existing adults. The 2007 Habitats Directive Article 17 reports classified the pearl mussel as in unfavourable-bad conservation status in all EU regions (http://biodiversity.eionet.europa.eu/article17/).

2.2 STATUS OF POPULATIONS IN THE REPUBLIC OF IRELAND

Pearl mussels are widespread in Ireland, particularly in the South West, West and North West of the country. Populations range from very small relict examples with a few remaining elderly mussels that have not successfully recruited for 50 years, to some of the largest populations of pearl mussels in the world. There are 96 populations of pearl mussels in the Republic of Ireland, some of which include two or more rivers in close enough proximity to make them one single population (Moorkens *et al*. 2007). A total of 27 populations have been designated within 19 SAC areas for *Margaritifera margaritifera* (Figure 2.1, Table 2.1).

Only one of the 96 populations in the country is considered to be in favourable conservation status, as in the other populations reproduction and juvenile survival is not matching adult mortality rates and numbers are declining annually.

Many of the non-designated rivers contain very small populations of 5,000 or less, and although some of these are still internationally important compared with the remaining populations of other countries, the most important Irish populations, and the ones of most international concern are those with populations between 500,000 and 3,000,000. These are populations within catchments that were near pristine up until very recent times, but have declined within the lifetime of their designation as SACs, although much of the decline may have been the result of activities occurring before designation.

Recent declines have been due to a number of issues, which have combined to lower the quality of the river water and river bed habitat. The purpose of this sub-basin management plan is to address the catchment-wide issues that are contributing to this decline and to develop a strategy for implementing measures that will bring the catchment and thus the population back to favourable condition.

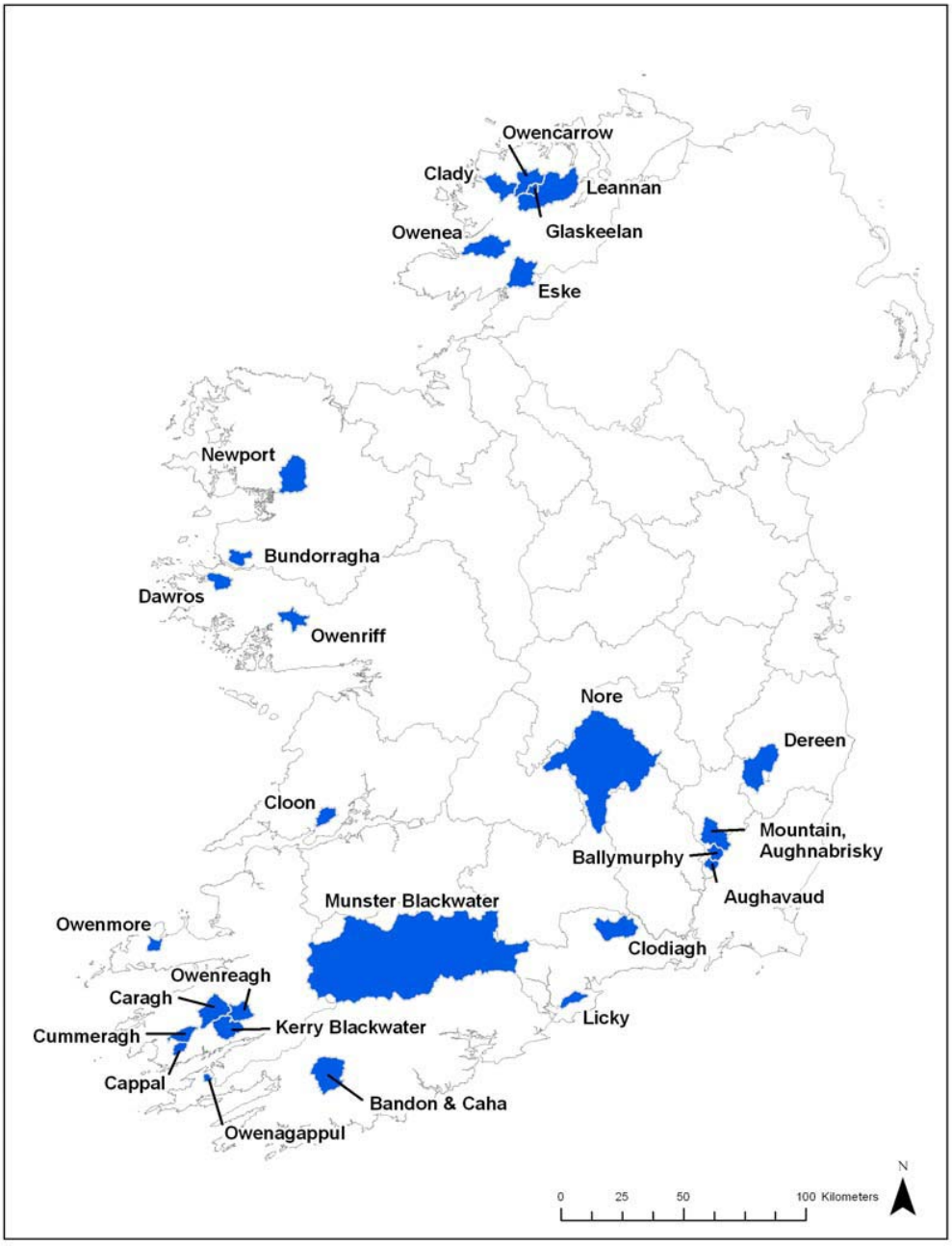


Figure 2.1 Map of the catchments of the specified pearl mussel populations.

Table 2.1 List of the 27 sub-basin catchments designated as SACs for freshwater pearl mussel populations.

	Freshwater pearl mussel population[1]	SAC Site Code	SAC Site Name	Rivers and lakes containing *Margaritifera* (list not exhaustive)	Associated RBD
1	Bandon	002171	Bandon River cSAC	Bandon & Caha	South Western RBD
2	Aughavaud (Barrow)	002162	River Barrow and River Nore cSAC	Aughavaud	South Eastern RBD
3	Ballymurphy (Barrow)	002162	River Barrow and River Nore cSAC	Ballymurphy	South Eastern RBD
4	Mountain (Barrow)	002162	River Barrow and River Nore cSAC	Mountain, Aughnabrisky	South Eastern RBD
5	Bundorragha	001932	Mweelrea/ Shreefry/ Erriff Complex cSAC	Bundorragha	Western RBD
6	Caragh	000365	Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment cSAC	Caragh, Owenroe, Meelagh, Caraghbeg, Glashawee, Lough Beg Stream, Lough Acoose, Cloon Lough	South Western RBD
7	Clady	000140	Fawnboy Bog/ Lough Nacung cSAC	Clady	North Western IRBD
8	Owenriff (Corrib)	000297	Lough Corrib cSAC	Owenriff, Glengawbeg	Western RBD
9	Currane	000365	Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment cSAC	Capall, Cummeragh	South Western RBD
10	Dawros	002031	The Twelve Bens/ Garraun Complex cSAC	Dawros	Western RBD
11	Eske	000163	Lough Eske and Ardnamona Wood cSAC	Eske	North Western IRBD
12	Kerry Blackwater	002173 & 000365	Blackwater River (Kerry) cSAC & Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment cSAC	Blackwater, Kealduff, Derreendarragh	South Western RBD
13	Gearhameen (Laune)	000365	Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment cSAC	Gearhameen & Owenreagh	South Western RBD
14	Glaskeelan (Leannan)	002047	Cloghernagore Bog and Glenveagh National Park cSAC	Glaskeelan	North Western IRBD
15	Leannan	002176	Leannan River cSAC	Leannan	North Western IRBD

[1] Population named after river of highest stream-order that contains mussels

	Freshwater pearl mussel population[1]	SAC Site Code	SAC Site Name	Rivers and lakes containing *Margaritifera* (list not exhaustive)	Associated RBD
16	Allow (Munster Blackwater)	002170	Blackwater River (Cork/Waterford) cSAC	Allow	South Western IRBD
17	Licky	002170	Blackwater River (Cork/Waterford) cSAC	Licky	South Western RBD
18	Munster Blackwater	002170	Blackwater River (Cork/Waterford) cSAC	Munster Blackwater (main channel)	South Western RBD
19	Newport	002144	Newport River cSAC	Newport	Western RBD
20	Nore	002162	River Barrow and River Nore cSAC	Nore	South Eastern RBD
21	Owencarrow	002047	Cloghernagore Bog and Glenveagh National Park cSAC	Owencarrow	North Western IRBD
22	Owenea	000197	West of Ardara/Maas Road cSAC	Owenea	North Western IRBD
23	Owenmore	000375	Mount Brandon cSAC	Owenmore	Shannon IRBD
24	Ownagappul	001879	Glanmore Bog cSAC	Ownagappul & Barrees	South Western RBD
25	Cloon (Shannon Estuary)	002165	Lower River Shannon cSAC	Cloon	Shannon IRBD
26	Derreen (Slaney)	000781	Slaney River Valley cSAC	Derreen	South Eastern RBD
27	Clodiagh (Suir)	002137	Lower River Suir cSAC	Clodiagh	South Eastern RBD

3 IDENTIFICATION OF KEY PRESSURES AFFECTING THE STATUS OF THE FRESHWATER PEARL MUSSEL *MARGARITIFERA MARGARITIFERA* IN THE BUNDORRAGHA CATCHMENT

3.1 Introduction

The Bundorragha River emerges from Fin Lough, but the catchment includes a series of other interconnecting lakes in a valley between the Mweel Rea Mountains and the Sheeffry Hills. These lakes consist of the larger Doo Lough, with Glencullin Lough and Lough Cunne further upstream. Between Doo Lough and Fin Lough the river is called the Owengarr. Below Fin Lough the Bundorragha flows directly south for just over two kilometres into Killary Harbour.
The main river channel has little adjacent agriculture or housing, but it has a large adventure centre with significant numbers of temporary residents just downstream of the outflow from Fin Lough, and a smaller hotel (Delphi Lodge) to the North of Fin Lough. The Delphi Lodge operates the angling fishery on the river, and they operate a small hatchery for salmonid restocking purposes.

There are a series of steep cascade tributaries entering the Bundorragha River from the east, all rising on Ben Gorm. Another series of tributaries, that are not as steeply sloped, enter from the west from the slopes of the Mweel Rea Mountains. Of these, the Owennagloch and Sruhaundoo flow through coniferous plantation. The Glenummera Rivers flows from the east along the Valley between the Sheeffry Hills and Ben Gorm, also through considerable coniferous plantation. Another series of cascades enter Doo Lough from the east from the Sheeffry Hills, and from the Mweel Rea Mountains in the west.

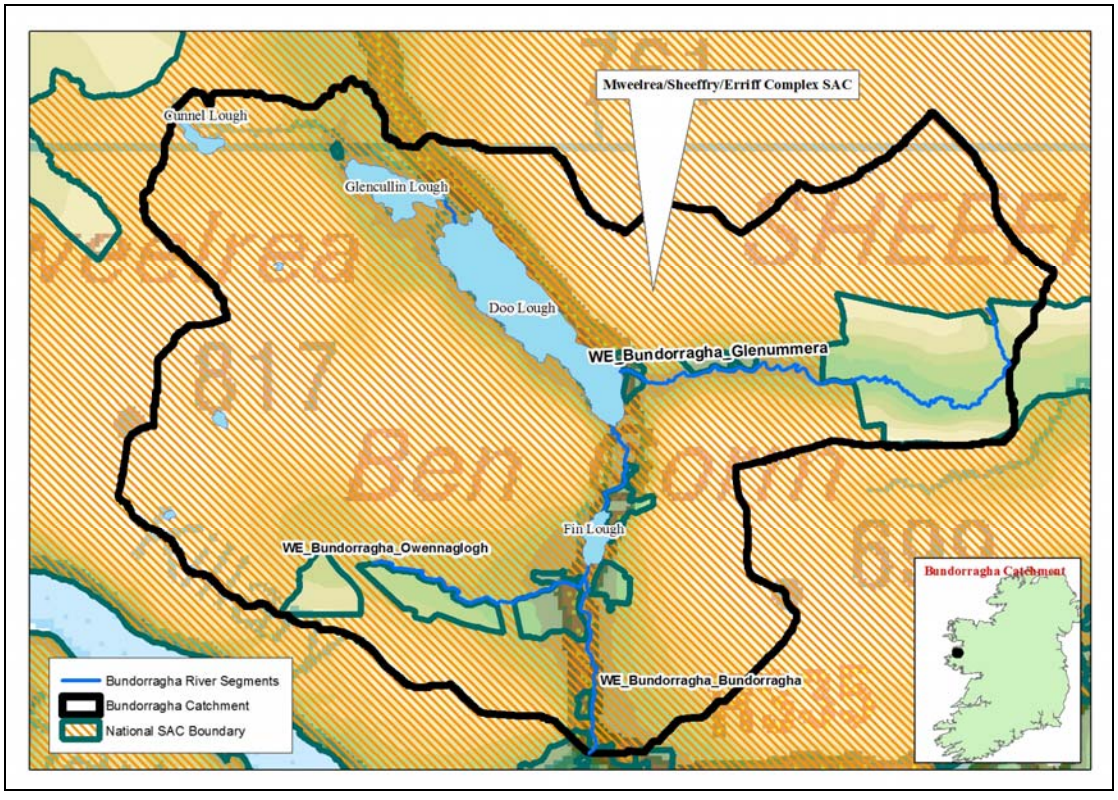


Figure 3.1 Overview of Bundorragha catcment indicating the extent covered by SAC

Based on the Corine land cover data, which is obtained from aerial imagery http://www.eea.europa.eu/publications/COR0-landcover, the most common Corine land use type within the Bundorragha catchment is peat bogs (54.77%). Natural grassland also accounts for 22.27% followed by bare rock (14.76%). The various other minor land use types are shown in Figure 3.2.CORINE level 6 data were utilized in the sub-basin management plans Due to the coarseness of the data and the age of the data however, they were used with caution. As a result, aerial photography was also used where available, and catchment walkovers and pressure assessments have been carried out as part of the field work which was undertaken through the NS2 project in 2009. Both the aerial photography and the catchment walkovers will provide more accurate information on land cover and pressures. Higher resolution maps of agricultural land-use, including livestock density, fertiliser use, slurry spread grounds and application rates are required in order to assist the prioritisation and accurate identification of measures.

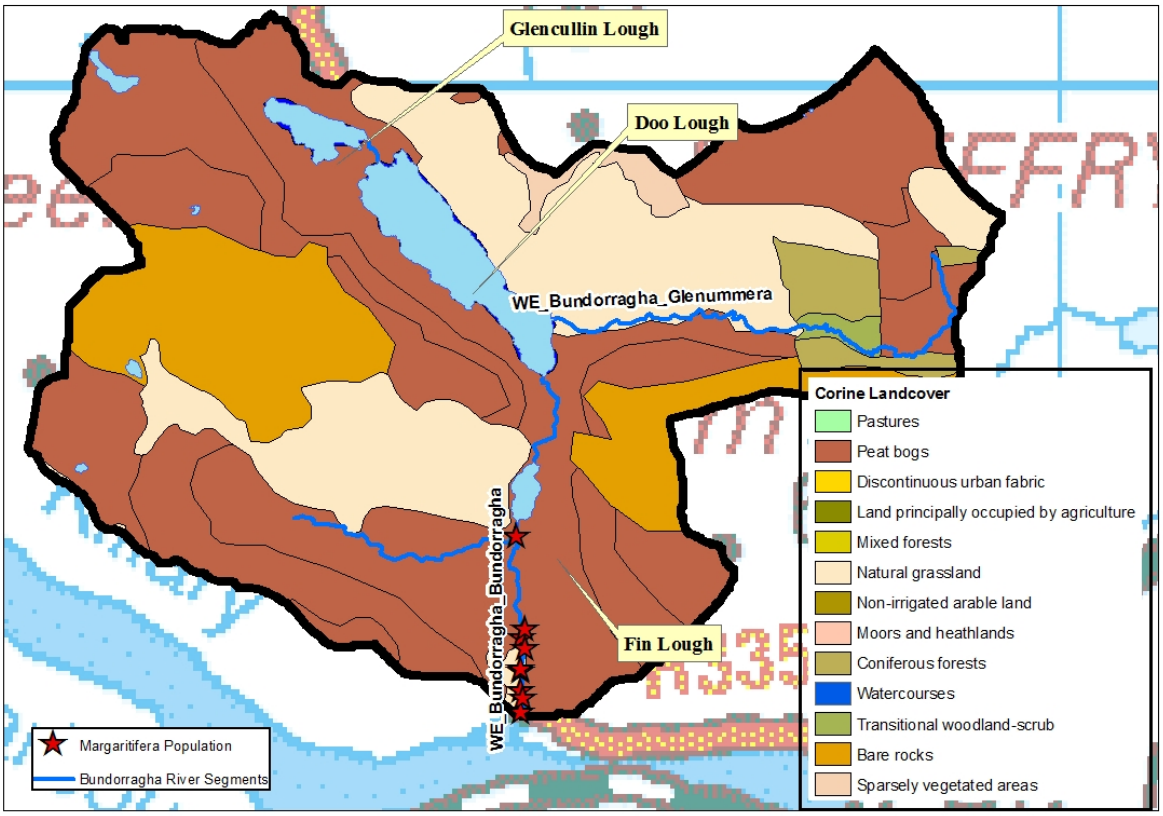


Figure 3.2 Corine Landcover within Bundorragha catchment

While the Bundorragha is currently at favourable conservation status, in the recent past this was not the case. The main causes of the former unfavourable conservation status and the pressures still acting on the population are described below. The key improvements needed for the Bundorragha Catchment are to restore juvenile habitats to appropriate condition by simultaneously reducing nutrient and silt inputs to the river.

The order in which the pressures are described follows that in the Western River Basin Plan with which this plan is associated. It does not reflect the magnitude of the pressures or the risks they pose to the favourable conservation status of the pearl mussel populations in the Bundorragha catchment.

Table 6.2 contains a toolbox of measures, a selection of which will be implemented at those sites where investigations and risk assessment have shown that specific pressures need to be remediated to restore pearl mussel to favourable conservation status. Chapter 6 contains a summary of the measures which will require implementation within the catchment by the

statutory authority. The Summary Action Programme contains the site specific measures which will be implemented on a prioritized basis as indicated by the overview map. Throughout 2008 and 2009, a series of field investigations and risk assessments were conducted in order to verify the pressures identified in the Draft Freshwater Pearl Mussel Plans together with locating further pressures within the Bundorragha catchment. Field investigations covering biological surveys (pearl mussels, fish, invertebrates and plants), as well as physico-chemical, morphological and siltation surveys were carried out. Further details in relation to the results of these field surveys can be obtained from Chapter 4 and the monitoring methods report can also be downloaded from

(http://www.wfdireland.ie/docs/5_FreshwaterPearlMusselPlans/Monitoring%20Manual/).

Prior to implementation, all measures will be assessed for their effectiveness and potential negative impacts on mussels or other species or habitats of high conservation value. The measures will also be subject to a cost benefit analysis to ensure that the most cost-effective measures are used to solve particular problems.

Every six years, under Article 17 of the Habitat's Directive, each member state must report to the EU on the status of each habitat and species protected under Annex I and Annex II of the Habitat's Directive. The Bundorragha population of the freshwater pearl mussel was reported in 2007 to be in unfavourable conservation status. In 2013, the next set of Article 17 reports will be sent to the EU. This will need to include an update on the size and status of the Bundorragha population, the measures that are in place and the improvements or deteriorations (as applicable) to the river bed at mussel habitat (such as silt, filamentous green algae and macrophytes). It is therefore urgent that measures are undertaken as soon as possible, and data on their implementation returned in a timely manner to NPWS to assist Article 17 reporting.

3.2 Hydrological and Morphological Pressures

Morphological and Hydrological (termed hydromorphological) pressures within catchments generally have the key impact of increasing sediment load to the river, and erosion and deposition processes within the river itself. This has a critical effect on pearl mussel survival.

3.2.1 Morphological Pressures

Desk based investigations using national GIS pressure datasets, such as the OPW drainage schemes and the National over-grazing GIS layers developed by the Central Fisheries Board (CFB), helped us to initially identify, locate and target the areas where pressures exist. By using detailed aerial imagery we were further able to refine these assessments and identify more localised issues. Through identification of these pressures using the desk-based approach we were then able to focus our field-work element within these areas. This enabled us to verify and ground-truth the pressures and to focus the application of measures.

Where impact is confirmed, the Code of Practice for Morphology Pressures which is included in River Basin Management Plans shall be referred to (Shannon IRBD Freshwater Morphology Programmes of Measures and Standards Study, Review of Best Practice Measures, 2008), as well as any relevant future guidance produced by DEHLG. These measures encompass the concepts of reducing the pressure itself, and remediation where necessary.

Desk Based Assessments

Table 3.1 shows the national GIS pressure datasets that were used in the assessment of pearl mussel catchments from a morphological perspective.

Table 3.1 National GIS Based Pressure Datasets for Morphology

Pressure	National GIS Pressure Dataset	Present in Bundorragha Catchment
Channelisation	OPW Drainage Scheme	No
	OPW Drainage District	No
Barriers To Migration	Barriers to Migration (located using expert judgement by CFB but not yet qualified using fish data)	No
Overgrazing	National dataset developed by CFB using expert judgement	Yes
	Damaged areas depicted by Commonage Framework Plans through the Rural Environmental Schemes and Programmes (REPS 3) in 1999	Yes

Overgrazing

The impacts on the aquatic environment, caused by overgrazing of lands are increased flashiness and sediment load to rivers, which in turn cause:

- Loss of riparian zone due to overgrazing
- Excessive bank erosion
- Sediment deposition in watercourses
- Over-widening of channel / braided channels

As indicated by **Table 3.1**, overgrazing is a pressure that has been identified through the Commonage Framework Plans. These have led to de-stocking proposals implemented by DAFF. Further de-stocking has taken place in certain areas of the country through NPWS farm plans and modifications to REPS. **Figure 3.3** illustrates the spatial extent of commonage areas and indicates the level of damage based on the Commonage Frameworks Plans through the Rural Environmental Schemes and Programmes (REPS 3, 1999) and catchment walkover risk assessments. While this information is dated it provides us with an indicative of the level of damage which these catchments have undergone in the past.

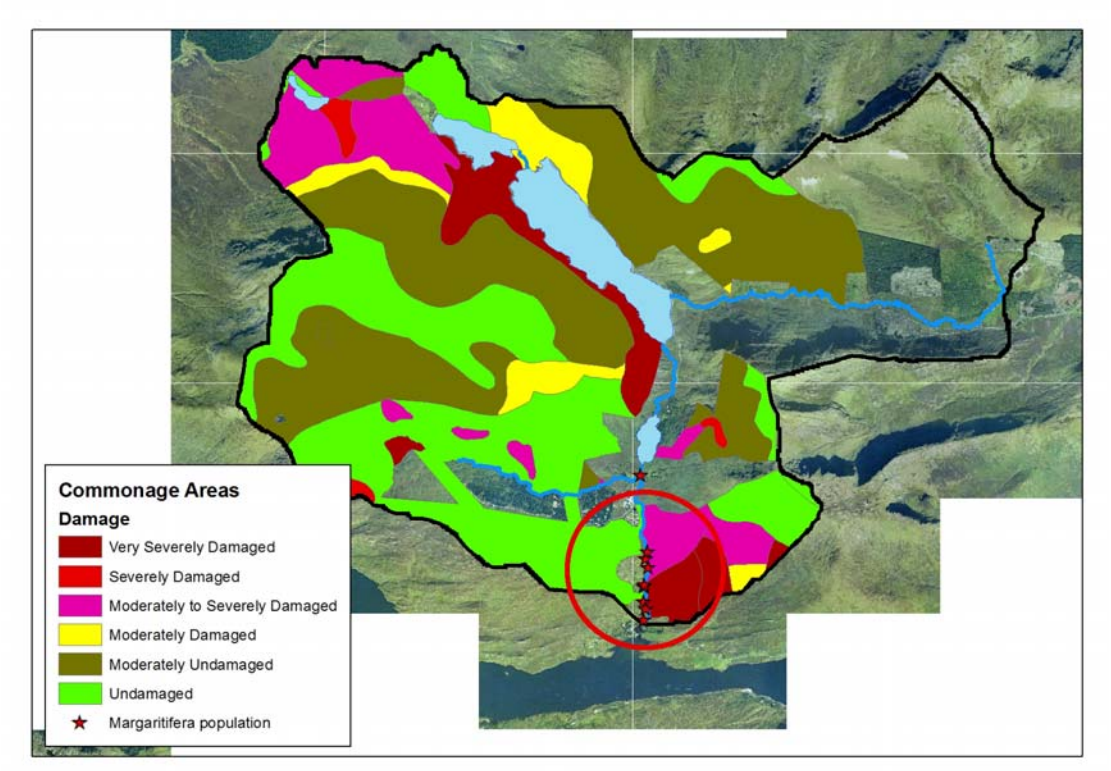


Figure 3.3 Areas of Commonage and Associated Damage

Figure 3.3 indicates that:

- 3398ha of the Bundorragha catchment area is Commonage land. This is 70% of the overall catchment area
- 288ha of the Commonage land is severely damaged or worse
- 359ha of the Commonage land is moderately to severely damaged
- 19% of all Commonage Land within the catchment is damaged
- Of particular concern is the extent of overgrazing of land adjacent to the Pearl Mussel populations as circled on **Figure 3.3**.This is an area of 194ha, of which all land is moderately damaged or worse, and several tributaries can transport silt to the main river.

Plate 3.1 & 3.2 were taken as part of the catchment walkover risk assessments. Figure 3.4 provides an indication of the overgrazing on peat soils and animal access to the river channel in the vicinity of the pearl mussel populations. **Figure 3.5** was taken above Gelncullin Lough where severely to moderately damaged areas have been recorded in the past as outlined in **Figure 3.3.**

Plate 3.1 Animal trampling/poaching along the Bundorragha River

Plate 3.2 Upstream of Glencullin Lough

Although the information contained in the commonage dataset is quite old at this stage field surveys through the NS2 project have confirmed that overgrazing by sheep together with excessive trampling and animal poaching along the river banks is an issue. While some of the recovery within this catchment and the achievement of favourable conservation status can be attributed to the decrease in stocking levels continued adherence with a de-stocking plan for the catchment is required. The continued implementation of the commonage framework plans is key to maintaining the favourable condition of the Freshwater Pearl Mussel population. This includes plan references – MA-15-A2, MA-15-B2, MA-15-F2, MA-15-K1, MA-15-L1, MA-15-U1, and MA-4-A.

Maintaining Good Agricultural and Environmental Condition by minimising soil erosion caused by overgrazing and in particular, abiding by cross compliance that requires sustainable grazing in designated areas will also assist in maintaining the favourable condition of this catchment.

Landslides and slippages

Investigations within the Bundorragha catchment indicate evidence of recent and former landslides at several locations. A relatively recent landslide occurred in the upper reach of the Glenummera and is reported to be still releasing silt particularly after periods of heavy rainfall. In addition, there is also a report of a landslide in the Owennaglogh tributary in 2009. These occurrences and the whole issue of landslide risk in the catchment need to be further investigated because of the potentially catastrophic impacts on the pearl mussel population

Dissolved Organic Carbon (DOC)

Further investigation is required into the potential impacts of increased dissolved organic carbon (DOC) on pearl mussel habitats. DOC may support biofilms of heterotrophs that, similar to the impact of macroalgae, could prevent the free exchange of oxygenated water between the water column and the substratum and result in the deposition of significant quantities of detritus on the river bed. Increases in DOC concentrations in surface waters have been reported across eastern North America and northern and central Europe in recent times (Evans et al., 2005; Monteith et al., 2007). The global increases in DOC have been linked to climate change, deposition chemistry (particularly acid deposition) and changes in land use. It has also been suggested that extensive conifer afforestation may exert some influence on DOC generation through increased litter production and mineralisation; and that this effect may be more significant following felling (Evans et al., 2005). It is considered that one of the most likely mechanisms for increased DOC in Irish surface waters is increased decomposition of peat as a result of drainage for agriculture, forestry and peat extraction. Draining peat also increases water movement through the soil and, thereby, may increase the rate of DOC loss to surface water. The effect of peat drainage on DOC concentrations in surface waters warrants significant further research.

3.2.2 Agriculture

Agricultural practices that contribute to increases in nutrient or silt to the river can be damaging to pearl mussels. Any practice that leads to exposure of bare ground can increase the fine sediment and nutrient load to the river. The cumulative effects of such practices can have very severe impacts on mussels.

Liming of land has a negative effect on pearl mussel populations, through direct toxic effects, and through increased growth rates leading to shortened life expectancy and, thus, loss of reproductive years (Bauer *et al*. 1991, Skinner *et al*. 2003). In some countries, acidification problems are so severe that liming is considered to have a more positive than negative effect (Henrikson *et al*. 1995). However, water chemistry data from declining Irish pearl mussel rivers indicate high peaks of calcium and conductivity levels that are likely to have been caused by liming.

Pearl mussels continued to thrive until recent years in catchments with very extensive agricultural practices. The intensification of agriculture, particularly with slurry and artificial fertilisers has led to cumulative effects that have had very severe consequences for pearl mussel reproductive success.

Toxic products have also resulted in the deaths of adult and juvenile mussel losses and, in one extreme case, the loss of an entire pearl mussel population. Pesticides such as sheep dip products are probably the most severe, but evidence from American surveys of glochidial stages of Unionid mussels have demonstrated lethal effects from very low doses and environmentally relevant concentrations of chlorpyrifos and permithrin, the fungicides chlorothalonil, pyraclostrobin and propiconazole, and glyphosate (Bringolf *et al.,* 2007a, b, c). Of particular concern are the severe deleterious effects of the latter substances in combination with surfactant blends, such as in commercial products like Monsanto Roundup. The end product including the surfactants can result in a much more toxic product than that of the individual ingredients.

Five active sheep dipping units have been recorded within the Bundorragha catchment as indicated in **Figure 3.6.** Three of these are operated by single farmers with the remaining two units used by five to six commonage shareholders.

Figure 3.4 and **3.5** indicate the soil types and livestock densities within the Bundorragha Catchment.

The Bundorrogha catchment comprises peaty podsolic type soils, natural grasslands and bare rock with some blanket peat type soils (**Figure 3.4**). Soils have been grouped in accordance with their organic matter content based on the IFS soils map (commonly referred to as the Teagasc/EPA soil map layer). Soils which are high in organic matter have low phosphorus retention properties. An analysis of the mapping indicates that the catchment is generally dominated by peaty gleys and peaty podsols with brown earths and podzolic soils located in the tributary river areas of the Glenummera and the Owennaglogh rivers. Very low livestock unit density is indicated by the national livestock unit density data provided by Teagasc (**Figure 3.5**), with densities ranging between 0.058 to 0.28 lu/hectare over most of the catchment and ranging up to 0.6 in some small areas, additionally soil P levels are low indicating nutrient loss from agriculture soils is not generally a significant land use pressure in the catchment.

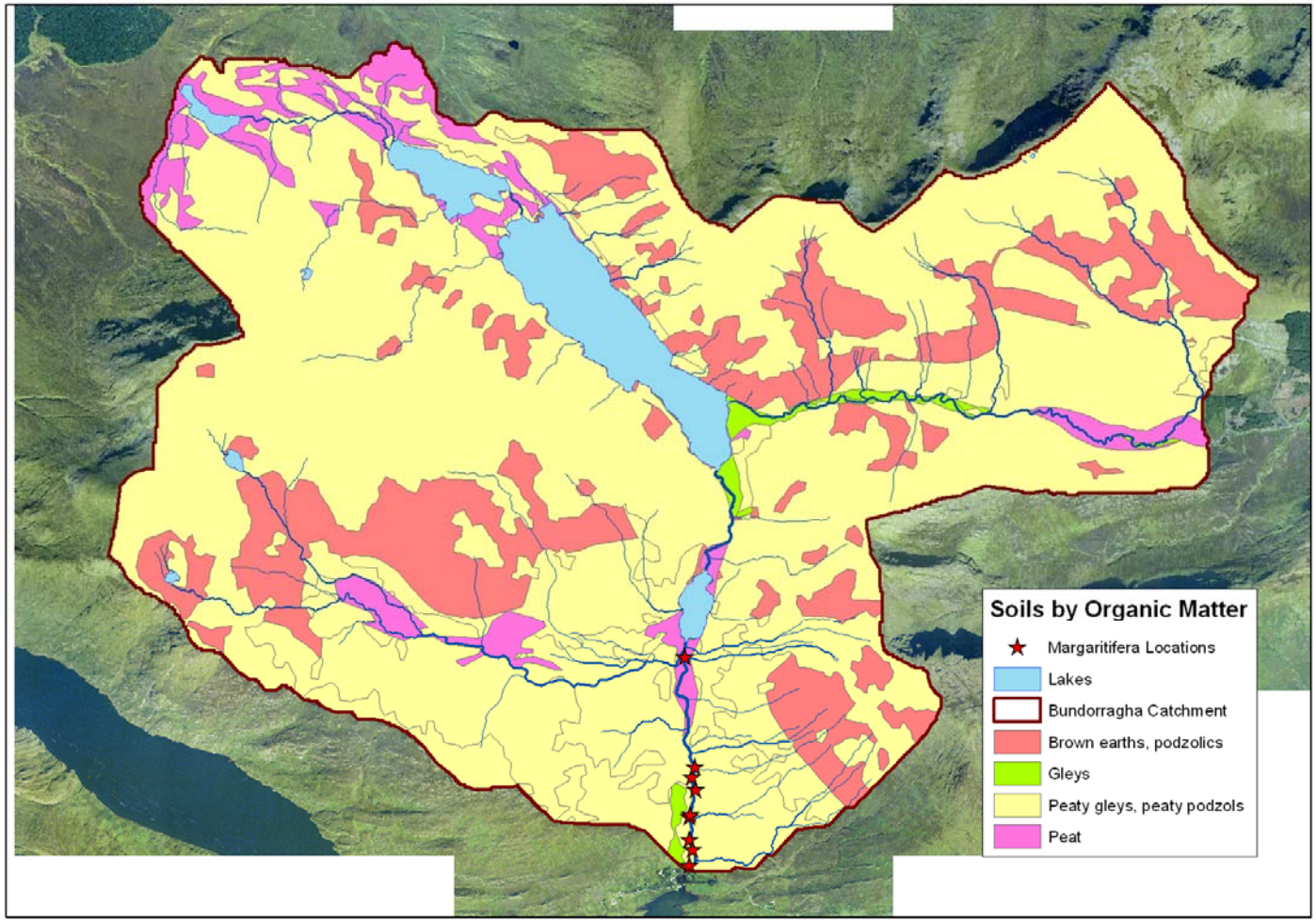


Figure 3.4 Bundorragha soil organic matter content

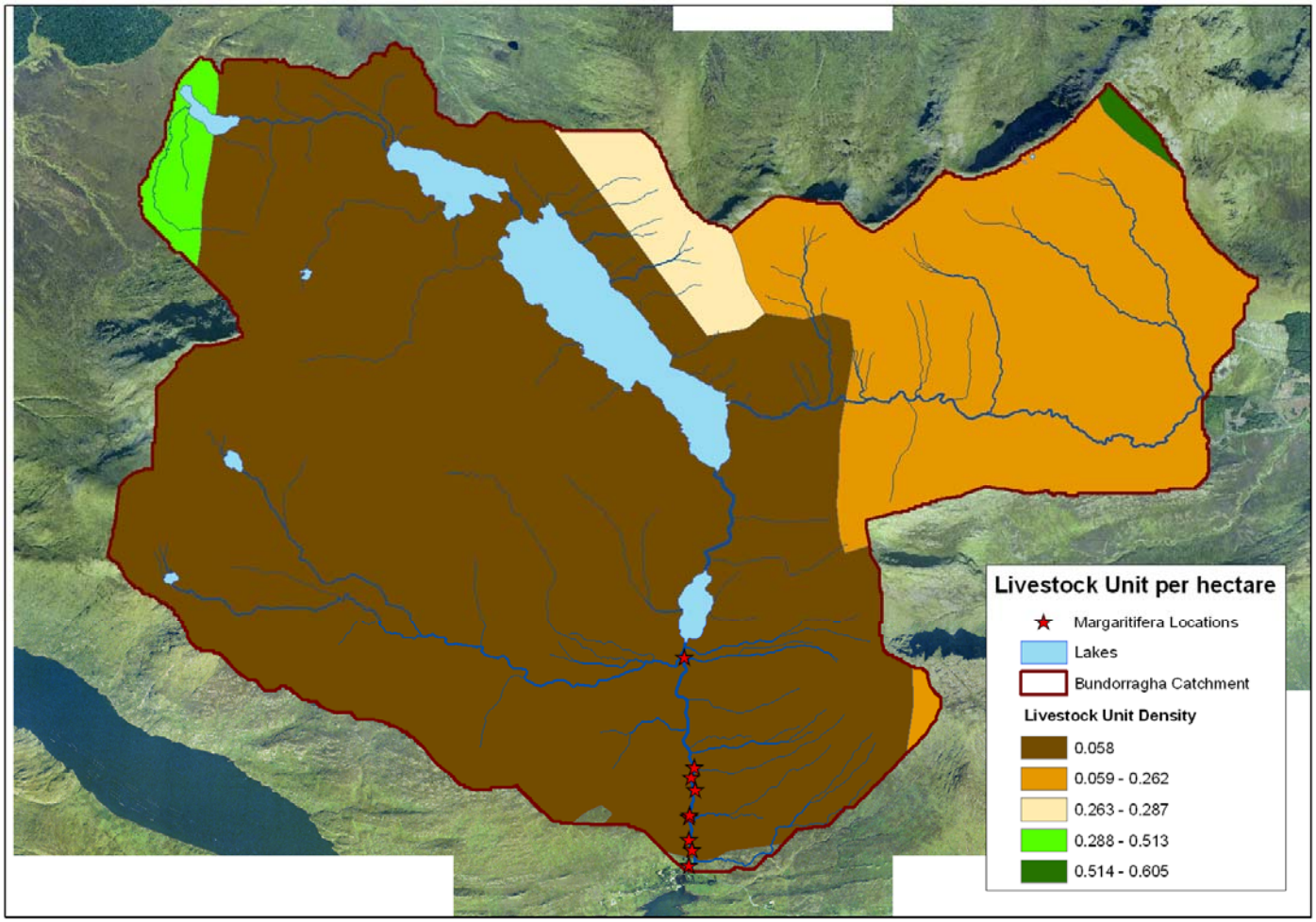


Figure 3.5 Bundorragha livestock unit density map

The livestock unit density map was provided by the Department of Agriculture to the River Basin District Projects to facilitate preparation of the RBD characterisation reports. It is based on the CSO data from 2002 and provides the average LU densities averaged on a DED basis. Whilst this data set is eight years old it provides a general guide to the level of livestock unit density in each sub basin catchment rather than absolute values on a field by field basis.

3.2.3 Catchment Walkover Risk Assessments

As outlined above, the best use was made of all available datasets such as the pressure source data collated by the River Basin District Projects for the Article V Characterisation and Programme of Measures Studies to allow the NS2 project team to assess the catchment through the combined availability of aerial imagery and digitised pressure information. Where gaps in this data existed together with areas that required ground truthing such as physical barriers to migration, catchment walkover risk assessments were focussed throughout the 2009 field survey season.

The catchment walkover risk assessment covers eight main categories or pressures which are subsequently sub-divided into the various sources as outlined below:

Source of Erosion	Bank erosion	**Barriers to Migration**	Culverts
	Land clearance		Bridge aprons
	In river clearance		Weirs
	Arable ploughing		Stone weirs
	Animal trampling		Other sources
	Fords	**Field Drainage**	Ditch managed
	Channel manipulation		Ditch unmanaged
	Hard bank protection measures		Drainage on high slope
	Other sources		Drainage on low slope
Diffuse Nutrient	Arable		Land drainage (perforated pipes)
	Grazing		Other sources
	Improved grassland	**Outfalls**	Industrial discharges
	Silage		Storm drains
	Forestry		Culvert outfalls
	Housing		Other sources
	Industry and associated works	**Abstractions**	Small
	Other sources		Large
Diffuse Silt	Arable	**Current Riparian Zone**	Fencing
	Grazing		Buffer
	Over-grazing		Tree line at bank
	Improved grassland (Re-seeding)		Tree line buffer
	Forest		Plantation with no buffer
	Silage		Urbanisation
	Industry		Flood protection
	Construction stages		Marshy land
	Housing		Landuse at bank
	Infilling		Other sources
	Peat cutting		
	Quarries		
	Other sources		

Each source is identified if present and an overall risk assessment for each pressure assigned from high to medium to low over the survey length. All eight pressures are combined to give an overall risk assessment to the catchment based on the “one out all out principle”.

A total of six sites were surveyed in the Bundorragha sub-basin catchment, with a risk assessment carried out at five of these sites (one stopping points). **Figure 3.6** outlines the location of some of the point source pressures in addition to the High to Low Risk Assessments from the Catchment Walkover Risk Assessments. Three high risk sites were recorded out of the five that were assessed. The remaining two sites were recorded as medium risk, meaning no low risk sites were recorded within this catchment. **Figure 3.7** outlines the percentage of sites classified at high and medium risk together with the stopping point in the catchment.

The most common high risk categories identified were from the five sites which were risk assessed were as follows:

- Diffuse Silt – at 67% of high risk sites,
- Barriers to Migration –at 33% of high risk sites

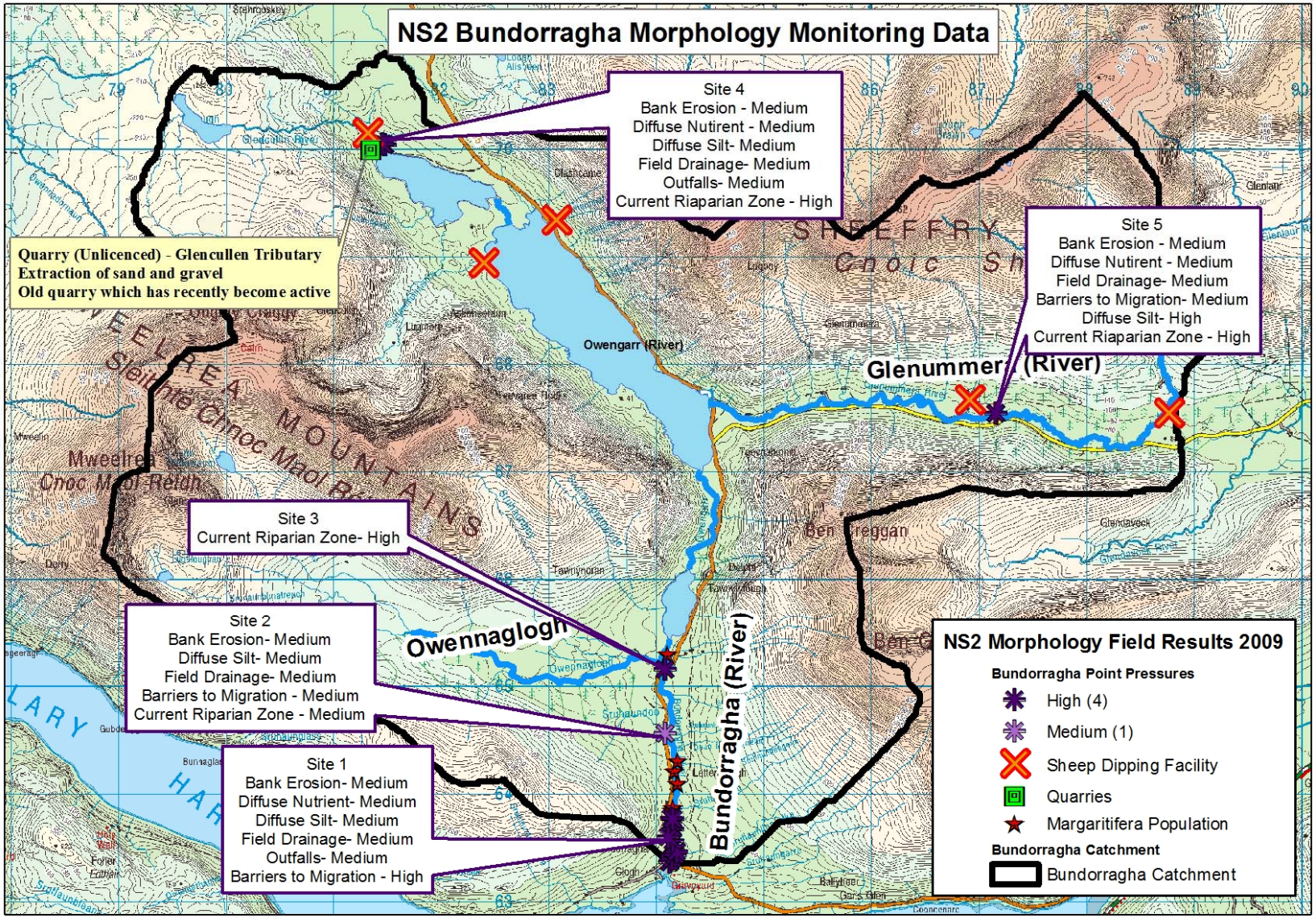
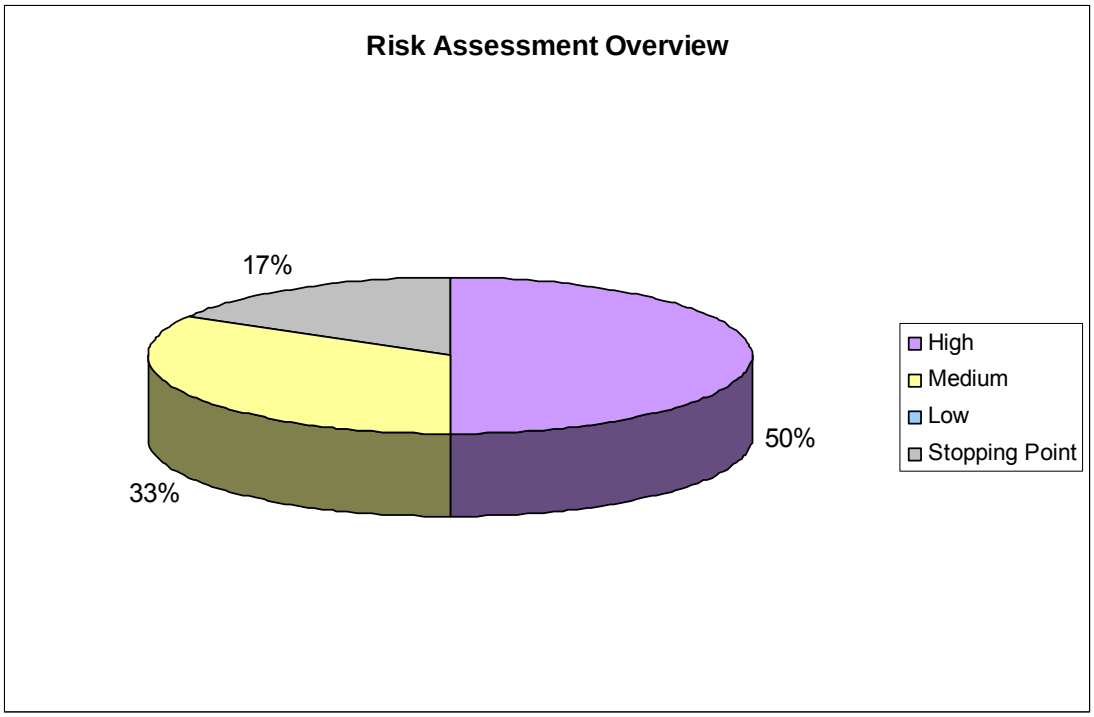


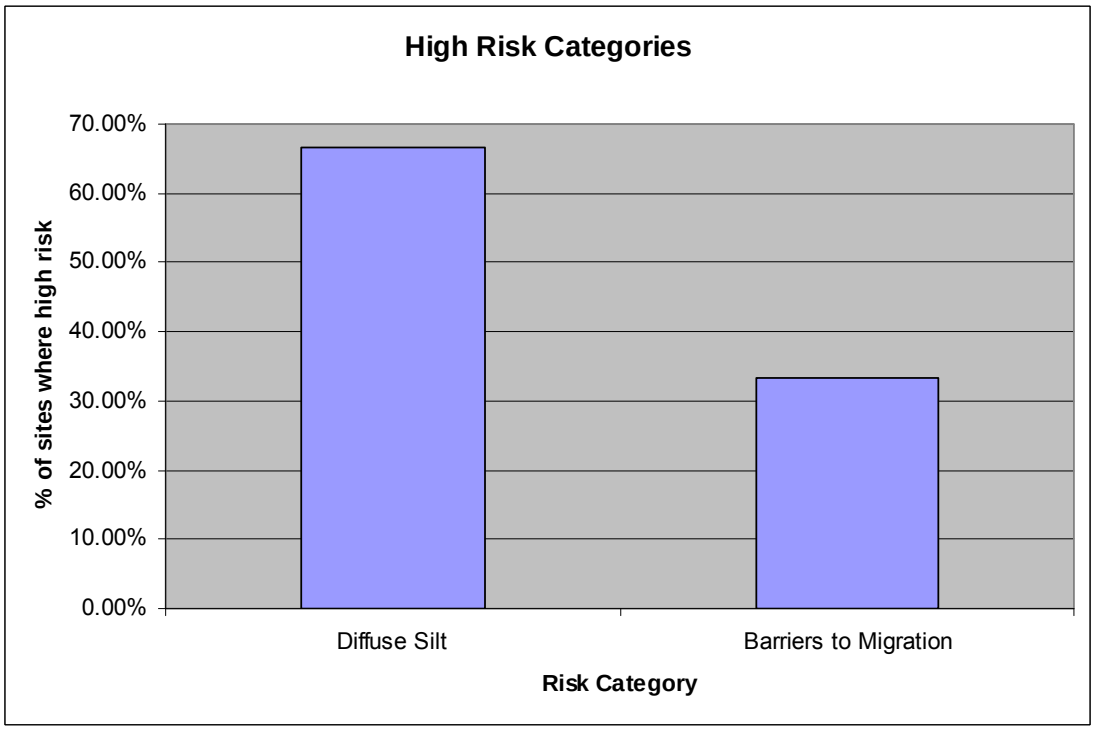
Figure 3.6 Location of Catchment Walkover Risk Assessments and point source pressures

Figure 3.7 Risk Assessment Overview



The break-down of high risk categories leading to a high risk site are shown below, as can be seen diffuse silt and barriers to migration were the only high risk categories recorded:

Figure 3.8 Break-down of High Risk categories



The most common source of diffuse silt is grazing which caused a high risk classification at two sites, the remaining high risk sources of diffuse silt are shown in **Figure 3.9** below

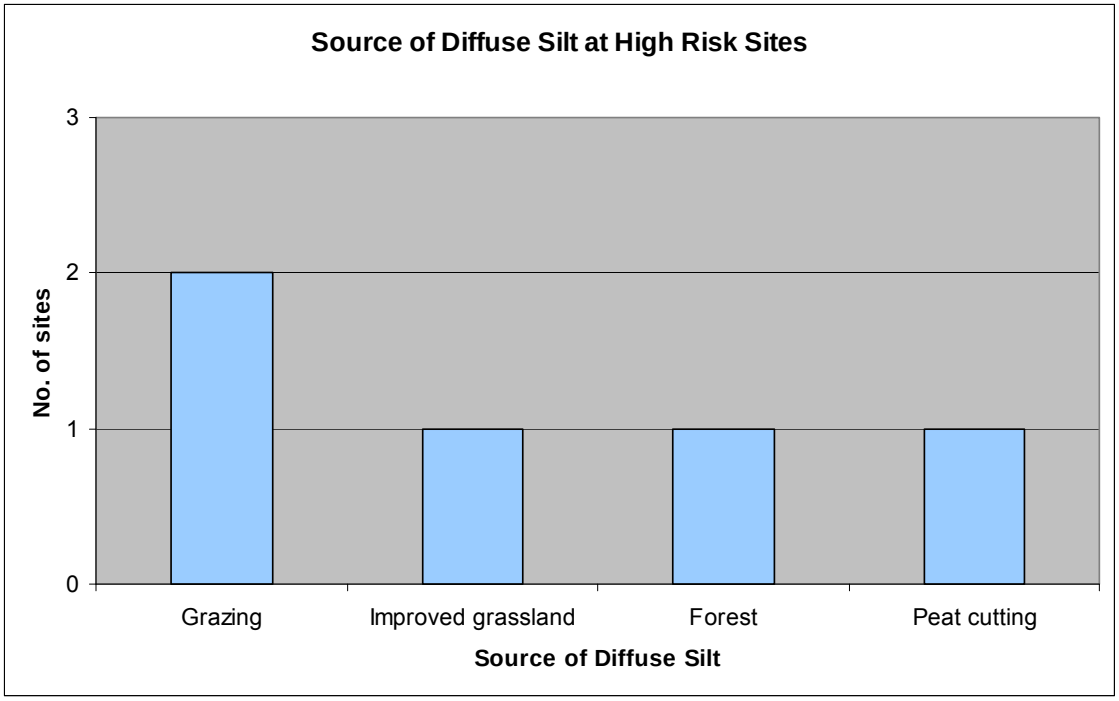


Figure 3.9 Sources of Diffuse Silt at High Risk Sites

3.2.4 Direct Morphological Pressures

Aerial Imagery is currently available for the Bundorragha Catchment. This imagery enables closer inspection of the catchment and the identification of more direct morphology pressures, which are not detected by national datasets.

The following sections describe the morphology pressures observed using the Aerial Imagery and verified by field investigations.

Structures within the River

Figure 3.10 highlights several structures within the river. From the aerial imagery these structures appeared to be weirs, bridges or culverted crossings. Following our field investigations throughout 2009 these structures were verified as Fishery weirs.

Figure 3.10 Series of Fishery Weirs along the Bundorragha Rvier which contains Pearl Mussel Populations

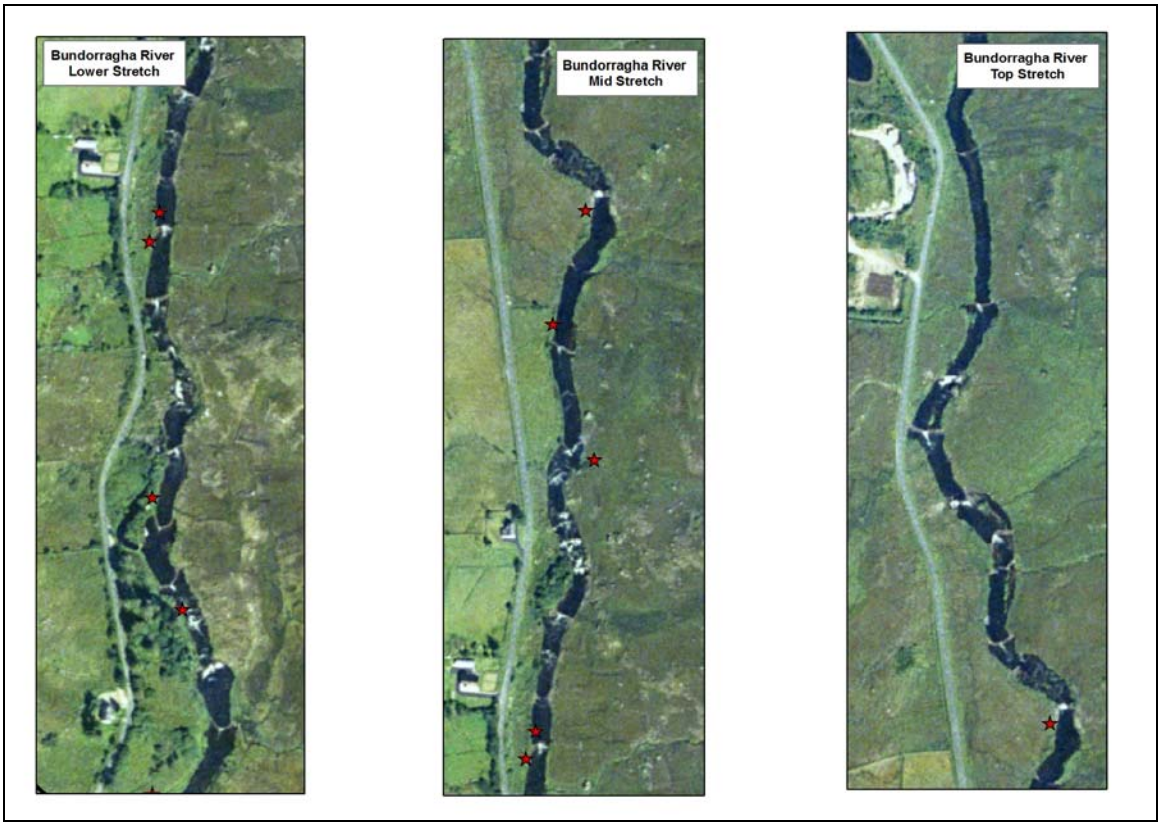


Plate 3.3 indicates some of the weirs which were surveyed as part of the morphological investigations and the catchment walkover risk assessments.

Following field investigations these structures were confirmed as artificial stone fishery weirs which have been built along this stretch over the past number of years. Several V-notch stones weirs were recorded along the survey stretch which was found to alter the flow of the channel and have lead to the build up of silt within the pools which have been created as a result. Generally weirs are constructed at least seven channel widths in distance apart except in high gradients, the weirs found on the Bundorragha were separated at equal distances

which verifies their use as fishery weirs. The river has nineteen named pools, some of which were created by the building of these stone weirs in the 1860s. Delphi Fishery is a private fishery which consists of the Bundorragha River, and two large lakes draining the Delphi Valley – Finlough and Doolough.

Short term impacts during construction of these in stream structures include increased siltation. Longer term damage to mussel habitat can be caused by erosion and ponding below the structures due to scour.

Regulation of Future Engineering Activities

The River Basin Management Plans outline all of the required (or basic) measures currently in place in Ireland (Table 6.1 of this report). These measures are required by law and apply to all waters. Many required measures are under existing EU Directives, but the WFD stipulates extra required measures which must also be implemented. '*Control on physical modifications to surface waters'* is one of these extra required measures. The RBMP Programmes of Measures for Morphology recognised the need for a prior authorisation or registration based system to manage future engineering activities near rivers and lakes (Shannon IRBD 2008, Freshwater Morphology POMS Study, Final Report).

National technical studies on the impact of physical modifications on fresh and marine waters (www.wfdireland.ie/docs) identified apparent gaps in existing authorisation systems. A Ministerial decision on the need for new regulations creating a registration and authorisation system is required.

These controls will account for the assessment requirements of the Habitats Directive within the decision making process. If permission is granted, stringent binding rules or conditions will be attached to the license, in accordance with the Freshwater Morphology Code of Practice and Protected Areas requirements. The potential for impeding fish migration will also be a key factor in impact assessment.

A Freshwater Morphology Web Based tool has been developed which is driven by a Morphology Database. This tool supports decision making in authorisation systems by assessing pressure extent and risk to water body status. Damage to mussel populations, in combination with other impacts both during construction and operation will be considered in the assessment. Currently this web based tool is held and operated by the EPA. If an authorisation process is rolled out Local Authorities should be given access to this tool. Therefore structures within rivers may be subject to controls in future.

3.3 Abstractions

Water abstraction from rivers can cause low flows, which can be directly damaging through drying out of existing or potential mussel habitat, or through temperature increases, silt deposition or nutrient concentration. Water abstraction from managed lakes can cause low flows in the river downstream.

The River Basin Management Plans state that where abstraction pressures are identified within a water body as posing a risk, this risk must be confirmed by a process of investigation. This involves determination of instream flow needs for rivers through computer modelling, which will enable review or setting of compensation flow requirements and selection of the appropriate measures on a site-specific basis.

In the context of pearl mussel catchments, this enables a focussed application of measures where abstraction pressures are specifically problematic to the pearl mussel populations.

A national register of abstractions has been compiled and up-dated in March 2009 to identify areas at risk by the Eastern River Basin District Project (ERBD). The up-dated register is improved over versions used to perform the Article V Initial Characterisation in 2005. Most public and group water schemes have been identified and included, but it is unlikely that all industrial, miscellaneous small private abstraction schemes (e.g. schools, hospitals or farms) are captured in the updated register. It also does not include domestic wells

As far as possible the NS2 project undertook a programme of investigation through their catchment walkover risk assessments to locate and identify any of these small scale abstractions which may pose a threat to the pearl mussel or its habitat.

The ERBD used this register to assign a risk classification to each river waterbody which contains the abstractions as follows:

Risk Category	Risk Classification	Net-abstraction-to-Q95 Flow*
2b	Not at risk	<5%
2a	Probably not at risk	5-10%
1b	Probably at risk	10-40%
1a	At risk	>40%

** In a few cases, the compensation flow may be substituted or added to the Q95 flow*

This national register indicates an abstraction at the upstream end of the Bundorragha catchment. However, the risk assessment undertaken by the ERBD places this in the "not at risk" category.
Further information in relation to ERBD Programme of Measures study together with a detailed report on the methodologies used is available to download from www.wfdireland.ie

3.4 Diffuse Pressures

3.4.1 Forestry

The National Summary Characterisation Report identified forestry as a potential significant pressure which should be addressed in the Water Framework Directive River Basin Management Plans and Programme of Measures (www.wfdireland.ie). The National Forestry Inventory indicates that the total forest area in Ireland now stands at 10% of the total land area, of which 57% is in public ownership and 43% in private ownership. Conifers comprise 74% of the total stock. An estimated 43% of the total stocked forest estate is on peat soils. A typical forest lifecycle for conifer plantations is 40 years and between 60 to 100 years for most broadleaves.

The establishment and management of forests generally involves ground preparation, drainage, thinning, roading, harvesting, replanting and associated management practices which are a major potential significant source of both silt and/or nutrients losses to watercourses. These can result in significant risks to pearl mussel populations if avoidance and effective mitigation measures are not adopted. Afforestation occasionally involves the use of herbicide, particularly in regard to broadleaf establishment. Fertilisation of forests either at planting or possibly at thicket stage can lead to release of nutrients into the watercourse. Fertilisation is generally a requirement for nutrient poor soils such as peat soils. Brash left on site during and following harvesting operations can also release nutrients through decomposition, a process which can continue for a significant number of years. Where an extensive drainage network has been established this can increase surface water run-off rates resulting in increased erosion risks. The more frequent harvesting of conifer crops will, all other things being equal, result in increased risks to water quality.

Prior to 1990, forests were established with extensive drainage networks draining directly to surface water courses and lakes, and without the benefit of buffer strips. Subsequent afforestation and restocking of clearfelled sites has involved a range of water protection measures, including buffer strips. These measures have been further augmented by those listed in *Forestry and Freshwater Pearl Mussel Requirements* which came into effect in 2008.

Recent research in Ireland carried out by the Western RBD in relation to forestry and acidification (www.wfdireland.ie) has linked coniferous forest cover on peat soils overlying igneous/metamorphic rock (Granites) and sedimentary rock (Old Red Sandstones) to acidification impacts. Impacts are also observed with coniferous forest stands on podsolic/lithosolic soils on granite and to a lesser extent on sedimentary rocks. The main known impacts on pearl mussels from conifer forests to date have been the result of increased sedimentation and eutrophication rather than acidification. Forest stands planted on peaty soil types pose the greatest threat in terms of sedimentation and nutrient loss.

Despite the fact that the conifer forests in the Bundorragha cover only 6% of the catchment and are located up to 5.0 km from the nearest FPM population they can represent significant risks of silt losses to watercourses during forestry operations. This is mainly due to the combination of high rainfall, steep slopes and erodible peaty podsol soils, which increase erosion risks and decrease the potential for silt trapping once it enters watercourses. Nutrients from fertiliser application and brash could also pose a significant risk to loss to watercourses, especially on steep slopes and peaty soils. In these circumstances all appropriate avoidance and mitigation measures must be put in place to protect the Bundorragha pearl mussel population, which is the only pearl mussel population in favourable conservation status in Ireland. Such measures may include initiatives to remove or restructure forests in pearl mussel catchments.

Forest stands in the Bundorragha Catchment are located in two pockets, in the upper part of the Glenummera river, which flows into Doo Lough and to the west on the Owennaglogh River a tributary of the Bundorragha river (**Figure 3.11 & Figure 3.12).** Nearly 70% of Glenummera forest property, which was originally planted prior to Forest Service Guidelines in the early 1950s with Sitka Spruce (*Picea sitchensis*) with some lodgepole pine (*Pinus contorta*), Japanese larch (*Larix kaempferi*), including small areas of broadleaves has been clearfelled in recent years. The felled areas have been restocked to include both open space and 25 m buffers along tributaries identified on a 6" OS map and 10-15 m buffers on the remaining watercourses. The remaining trees in the property are now due to be felled. This site with its very steep slopes, high density of natural drains, thin peaty podsolic soils which are highly erodible and high rainfall, make it very difficult to control silt run-off once it is mobilised by soil disturbance. The latest harvesting operations conducted in 2009 was planned and implemented in accordance with the *Forestry and Freshwater Pearl Mussel Requirements*. This included a range of mitigation measures, such as the use of brash mats and bridging structures to minimise ground disturbance and the installation of numerous silt traps to remove silt from flowing water. Despite these measures and considerable care in their implementation, localised soil disturbance and significant overland flows of water (under high rainfall conditions) occurred, resulting in the transportation of silt towards the Glenummera river, some 450 m below the harvest site. While silt was not observed flowing directly into the river, there is a strong possibility that some did. It is therefore necessary to further develop and refine the deployment of avoidance and mitigation and monitoring measures to ensure that potential risks to pearl mussels arising with forestry operations on such difficult sites do not occur in future.

Plate 3.4 Forest track with damaged brash mat and significant flows of surface water.

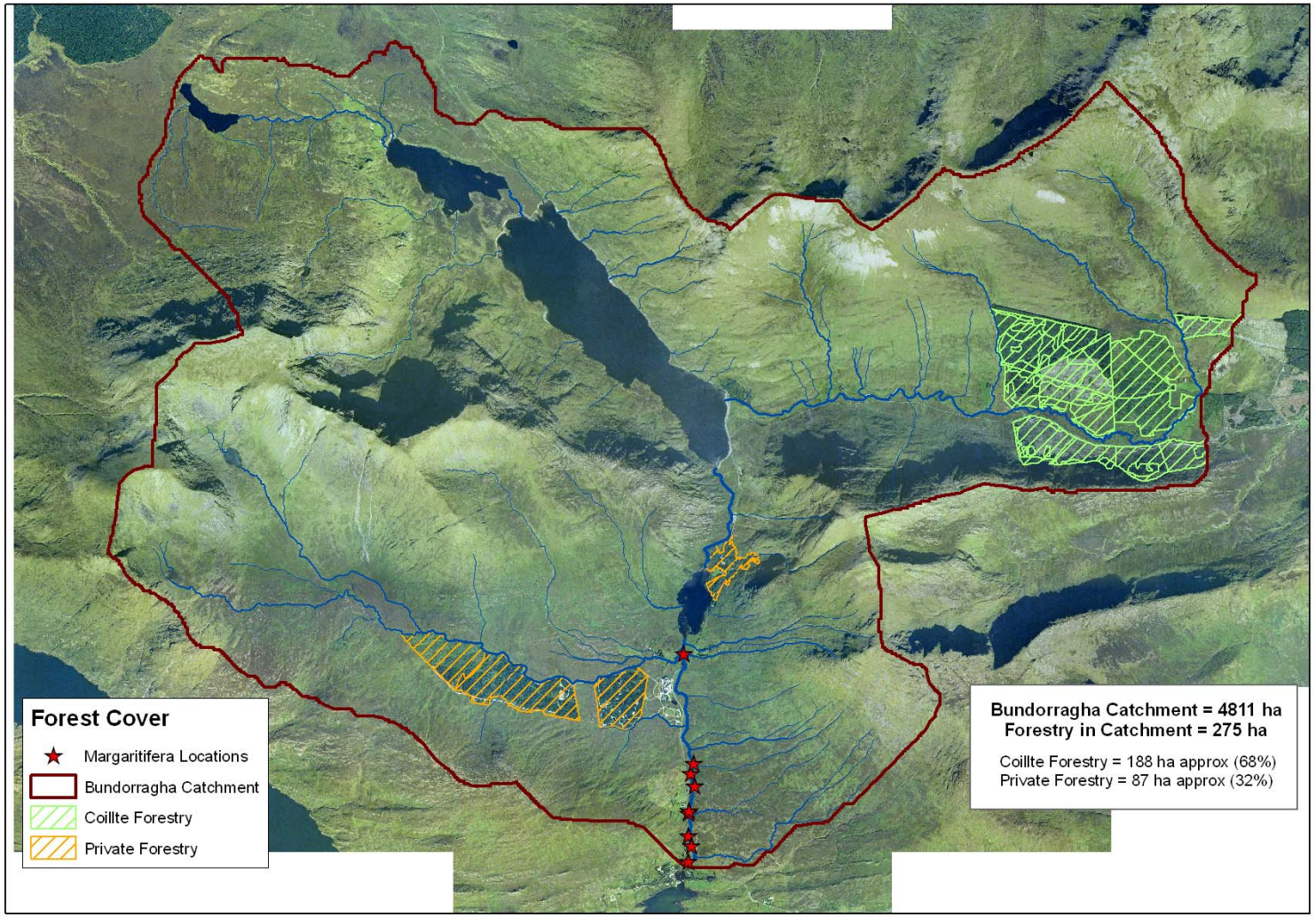


Figure 3.11 Bundorragha Forestry by Ownership

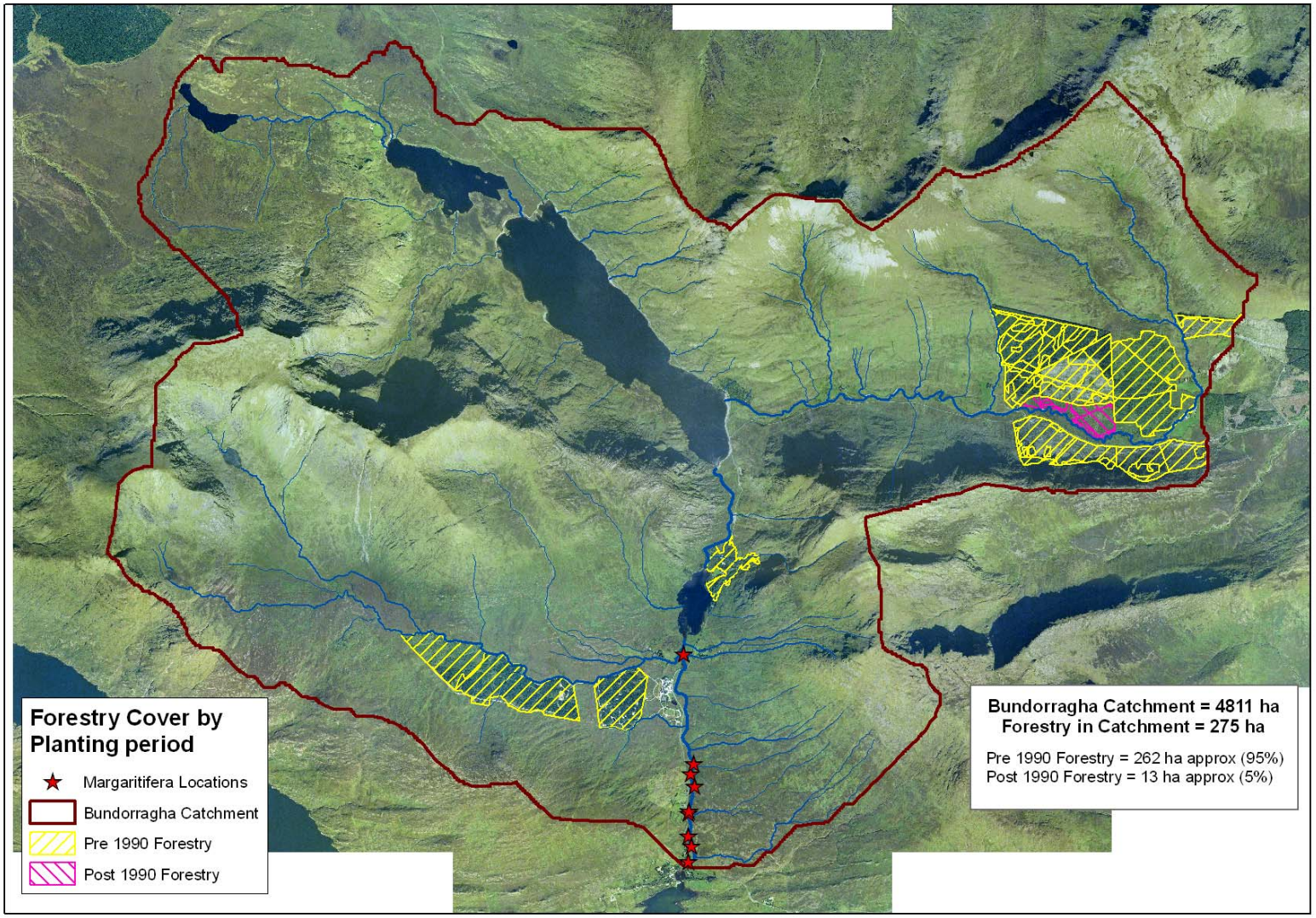


Figure 3.12 Bundorragha Forestry by planting period

Main pressures from forestry in the Bundorragha catchment

The main pressures identified from forest stands in the Bundorragha catchment are

- Sediment loss: Forestry operations, such as drainage, roading and harvesting (clearfell), can give rise to significant loss of sediment particularly on steeply sloping sites with highly erodible soil types.

- Nutrient enrichment from brash decay post felling: Brash decay post clearfelling can release nutrients, both N and P. While some may be retained by the exposed mineral soils the high rainfall and steep slopes increase the risk of significant losses until the site is fully vegetated.

- Nutrient enrichment from fertilisation: Fertilisation of forests on steeply sloping or peaty soil presents significant risk of nutrient loss to receiving waters.

- Pesticide use. Both insecticides and herbicides can be used at afforestation and replanting stages for coniferous forestry. Insecticides, such as cypermethrin, are used at reestablishment stage (replanting) on post-clearfelled sites to limit attack of the pine weevil (*Hylobius abietus*) a devastating pest of young conifer stands. If used a potential exists for losses of insecticide to the aquatic environment.

The above pressures have the potential to impact on the pearl mussel population in the Bundorragha catchment. The risk is increased where direct connectivity of the forest drainage network to the receiving water course exists, where vegetated buffer strips are lacking, and where nutrient and sediment loss from harvesting operations can occur. The Minister for Agriculture, Fisheries and Food is responsible for ensuring that any forestry activity, operation, plan or project (either individually or in combination) likely to have a significant effect on a European Site within the catchment designated for the protection of the freshwater pearl mussel species and/or it's habitat, and that requires his concurrence, consent or approval, is subject to the an Appropriate Assessment for Natura 2000 site. This assessment process will take account of the Forestry and Freshwater Pearl Mussel Requirements together with any revisions and further information provided by appropriate authorities.

3.4.2 On-Site Wastewater Treatment Systems

On-site wastewater treatment systems and other small effluent systems can be significant sources of nutrients to rivers. Losses from such systems typically behave as diffuse nutrient sources, however, more serious leaks and inappropriate systems can cause point source pollution damage.

Two fundamental questions need to be considered for effective treatment of single house effluent discharged through on-site wastewater treatment systems, such septic tanks with percolation areas and proprietary systems.

- Will the effluent be afforded adequate treatment by the system?
- Will the final effluent be able to get away?

A simplified pathway risk map (**Figure 3.13)** of the Bundorrogha catchment has been prepared to assess the potential impact from on-site wastewater treatment systems. These are based on the WFD National Programmes of Measures and Standards study on On-site Wastewater Treatment Systems. The risk maps take into consideration the aquifer type, vulnerability and subsoil permeability in assessing the pathway risk. Locations of on-site wastewater treatment systems have been derived from the An Post GeoDirectory. In total 15 on-site systems are located within the catchment 14 at extreme risk potential and 1 at very high risk potential setting as indicated in **Figure 3.13.** 22 of these systems are domestic on-site systems while the remaining two service large and seasonally variable numbers of visitors (Delphi Mountain Resort and Spa, and Delphi Lodge). These two premises are considered the highest current risk to the pearl mussel population given their location and the risk potential. (Please refer to Section 3.4 for further details)

Given the wet soil type overlying poorly productive aquifers, together with the locations of the on-site systems, the risk analysis indicates that there will be very high to extreme pathway risk from most onsite systems within the catchment, in terms of pathogens and phosphorous load to surface waters. However the numbers of OSWTS are very low and are unlikely to cause a significant impact. This is also borne out by the risk mapping of areas of likelihood of inadequate percolation. It should be borne in mind that these are generalised maps providing an overall indication of likely risk and specific localised conditions need to be taken into account in assessing each on site system. However, it highlights the need to undertake some surveys of on-site systems in the catchment where there is a high likelihood of risk to surface waters, particularly from phosphorus.

The European Court of Justice has ruled against Ireland in relation to on-site wastewater treatment systems (ref. Case C-188/08). The Court found that by failing to adopt the necessary legislation to comply with Articles 4 and 8 of Council Directive 75/442/EEC as regards domestic waste waters disposed of in the countryside through septic tanks and other individual waste water treatment systems, Ireland has failed to fulfil its obligations under that directive. To address the ruling, the Department of the Environment, Heritage and Local Government will be bringing forward legislation in the first half of 2010. It is intended that the legislation will provide for the setting of standards for the performance and operation of all septic tanks and similar on-site wastewater treatment systems. The legislation will also provide for the monitoring and inspection of the performance of such treatment systems and will set out the responsibilities of households served by those systems (including requirements to carry out remedial actions where necessary). In order to ensure prompt compliance with the Court ruling, it is intended that this legislation will be in place by Q3 2010.

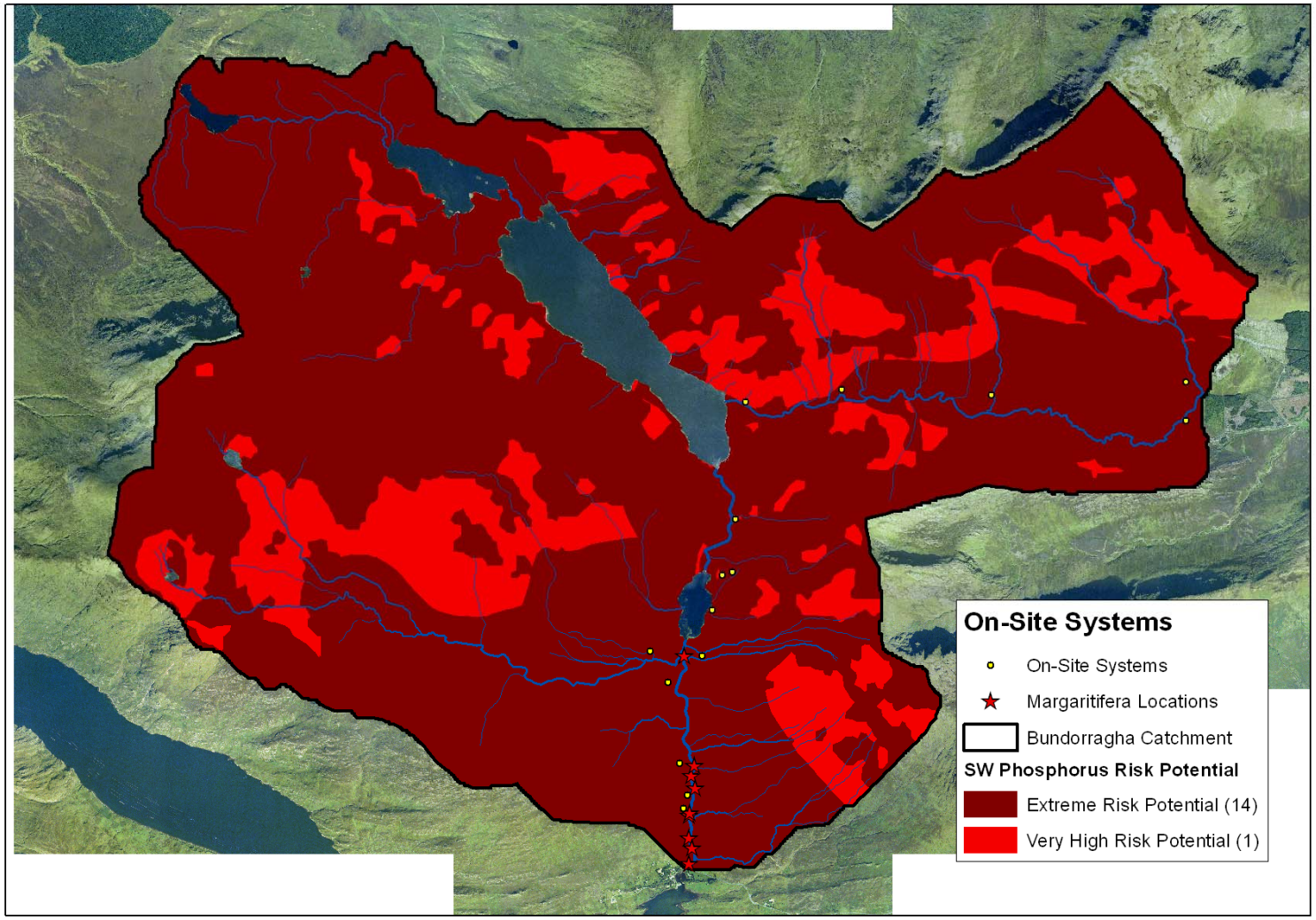


Figure 3.13 Surface water phosphorous pathway risk map showing location of onsite wastewater treatment systems.

3.5 Point Source Pressures

Point Discharges

Point sources discharging nutrients, such as wastewater treatment plants, can contribute very significant nutrient and organic loads to rivers.Quarry dust and effluent can cause problems with silt pollution and, in some cases, lime pollution. Landfills and landfill leachate can be sources of surface and groundwater contamination that can find pathways to the river. Storm water drainage can be a source of silt and pollutants.

Quarries

The Bundorragha catchment contains one quarry which is unlicensed and has recently become active extracting sand and gravel just upstream of Glencullin Lough it's location within the catchment is indicated in **Figure 3.14**

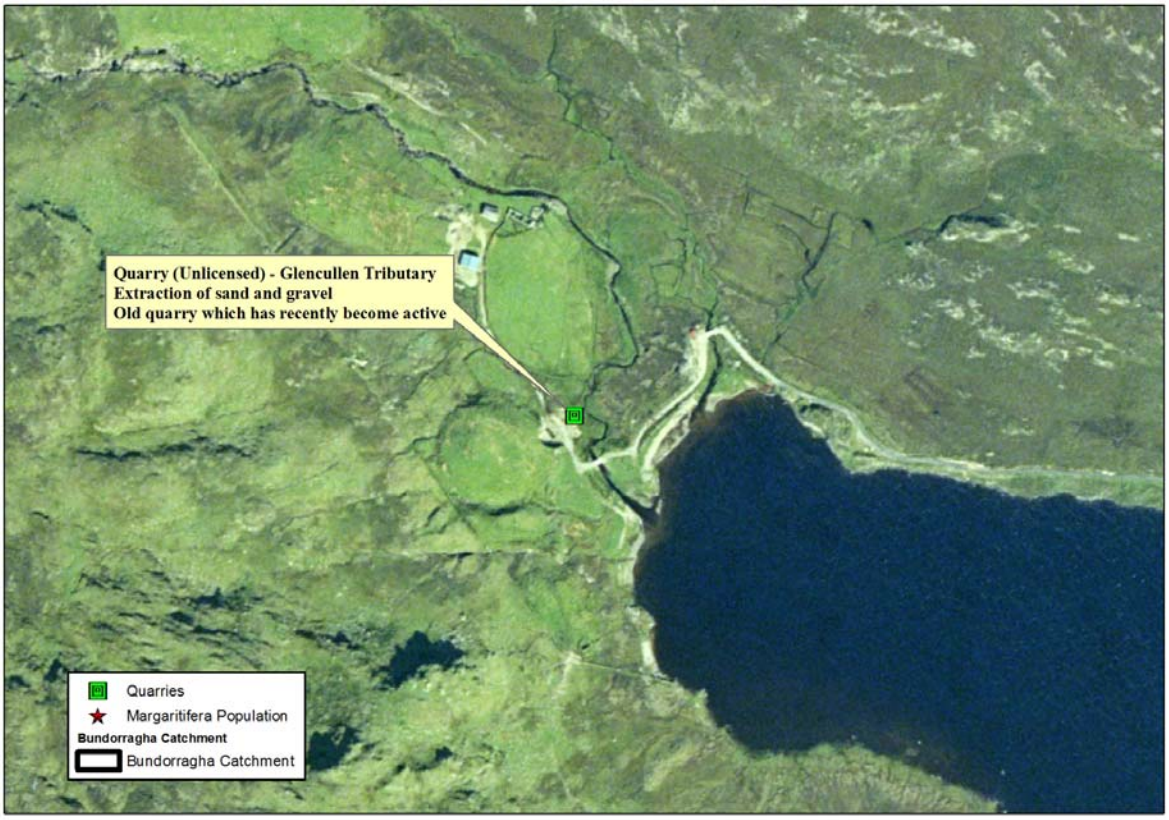


Figure 3.14 Location of Quarry within Bundorragha Catchment

The pressures outlined above all have the ability to negatively affect the status of the freshwater pearl mussel. In some cases, a single pressure alone may be enough to cause a kill or ongoing chronic effects, but in most cases it is the combination of the negative effects of a number of pressures that are acting together to leave the freshwater pearl mussel habitat in unfavourable condition. It is unlikely that the effect of every diffuse source of pollution can be totally removed. Therefore, it is not possible

to choose a subset of pressures to act on; steps must be taken to reduce every pressure, until the cumulative effect of all the reductions is a sustainable habitat for the freshwater pearl mussel and all the other species that it protects thanks to its umbrella and keystone status in its habitat. This is the essence of the precautionary principle under which the Habitats Directive must be implemented.

Waste Water Treatment Plants

Delphi Mountain Resort and Spa discharges under licence to groundwater approximately 650-700 m from the Bundorragha River and approximately 200 m from its tributary, the Sruhaundoo. The effluent treatment system is a Packaged Membrane Bioreactor (MBR) system. The discharge is pumped to a sand polishing filter and the discharge from the sand polishing filter is percolated via a series of radial percolation trenches designed by Bord Na Mona. Inspection of the discharge point in 2006 by NPWS (See Plate 3.5 – 3.9 for photographs from this visit), gave rise to concerns that the effluent was not discharging to ground, but rather resurfacing a short distance downslope.

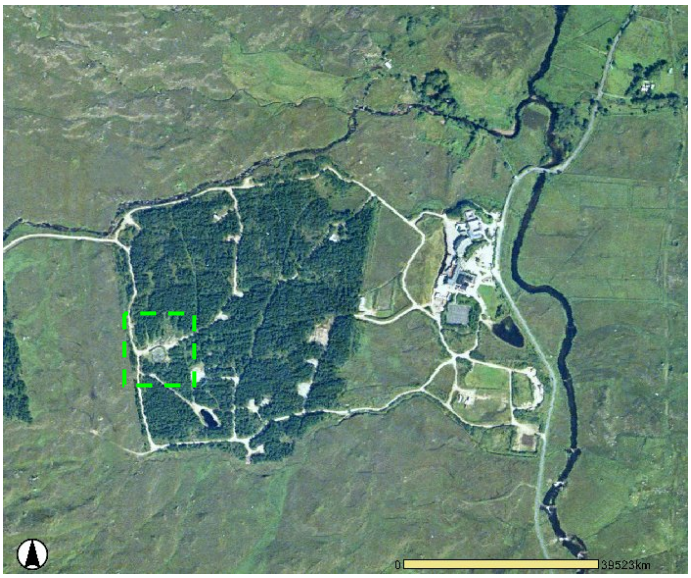


Figure 3.15 Aerial Photograph (2000) of Delphi centre site, showing location of percolation area.

Plate 3.5 Peat puraflow filter bed. The pipes should be covered to prevent the effluent being washed away with surface run-off during heavy rain. *Photo by Dr Julie Fossitt*

Plate 3.6 Juncus (rushes) surrounding the peat filter, indicating waterlogged conditions *Photo by Dr JulieFossitt*

Plate 3.7 Rock outcropping and wet heath vegetation. *Photo by Dr Julie Fossitt*.

Plate 3.8 Exposed soil and subsoil adjacent percolation area. *Photo by Dr Julie Fossitt*.

Plate 3.9 Iron precipitate in drain at construction site. *Photo by Dr Julie Fossitt*

Following a joint inspection of the polishing filter and its surrounds by Mayo County Council and NPWS, the Discharge Licence shall, if judged necessary, be reviewed. Such a review shall include a detailed hydrogeological assessment to investigate if the effluent can discharge fully to ground and if there is sufficient thickness of unsaturated mineral soil beneath the polishing filter to adequately treat the effluent, for the life-time of the resort and spa.

The above pressures have the potential to impact on the pearl mussel population in the Bunndorrogha catchment. The risk is increased where direct connectivity of the forest drainage network to the receiving water course exists, where vegetated buffer strips are lacking, and where nutrient and sediment loss from harvesting operations can occur. The Minister for Agriculture, Fisheries and Food is responsible for ensuring that any forestry activity, operation, plan or project (either individually or in combination) likely to have a significant effect on a European Site within the catchment designated for the protection of the freshwater pearl mussel species and/or it's habitat, and that requires his concurrence, consent or approval, is subject to the An Appropriate Assessment for Natura 2000 sites. (HDA) process. This assessment process will take account of the Forestry and Freshwater Pearl Mussel Requirements together with any revisions and further information provided by appropriate authorities.

4 STATUS OF THE FRESHWATER PEARL MUSSEL AND MONITORING IN THE BUNDORRAGHA CATCHMENT

4.1 CURRENT STATUS OF THE FRESHWATER PEARL MUSSEL

Shells from the Bundorragha River collected by R.J. Welch in 1898 are in the Dublin Museum collection, and the population has been mentioned in the literature since 1925 (Jackson, 1925).

Ross (1988) surveyed five rivers in south Mayo during the 1980's. Estimates of mussel density varied from river to river, from rare through occasional to common but were noted as abundant from both the Newport and Bundorragha Rivers.

Ross (1984) measured 249 mussels from the Bundorragha River. There was an absence of very young mussels with the majority of shells measuring from 35 to 135 mm in length, but with some as small as 25 mm and as large as 160 mm. These results suggests that the mussel population in the Bundorragha was in better status than the Newport at this time, and Ross estimated that individuals under five years of age were present, along with almost every age class up to old age.

Moorkens (1995, 1996) surveyed the Bundorragha River in the early 1990s to 1995. Mussels were abundant for the entire 2 km from the road bridge below Fin Lough to the road bridge above Killary Harbour. Juveniles of 6 mm upwards were present, suggesting juvenile survival of three consecutive years prior to that particular survey, although the distribution of juvenile mussels was not assessed. There was no evidence of filamentous algae in three summer visits between 1990 and 1995. During these surveys it was noted that mussels were abundant across the width of the channel, and the banks were open with very few trees along the length of the river. The most recent information on the mussel population of the Bundorragha comes from a full monitoring survey undertaken by Moorkens (2005) on behalf of NPWS.

The pearl mussel survey in 2005 found mussels to be absent in Fin Lough and above, occasional (less than 20 per 100m) in the stretch below the road bridge, becoming frequent to common (20 – 250 per 100m), and then abundant (over 250 per 100m) down to the road bridge above Killary Harbour, below which mussels were occasional (Moorkens 2005).

Survey work to update information on the Bundorragha River was carried out by Moorkens & Killeen (2009) and consisted of:

1) Total counts in previous standard repeat areas
2) Redox potential measurements, as a proxy for the loss of oxygen with depth of sediment
3) Measurements of mussel lengths for size profile

1) Total counts in previous standard repeat areas

Baseline monitoring in 2005 included standard defined areas that could be repeatedly surveyed for mussels by counting from a marked place that would not interfere with the mussels. Two of these areas were surveyed in 2009 and compared with baseline counts made in 2005. The results are shown in **Table 4.1**.

Table 4.1 Standard Count 2 and Count 3 repeat (see Moorkens, 2005)

Section	Total No. of mussels		Comments
	2009	2005	
Count 2	a) 78 b) 125 c) 36 d) 54 Total 293	a) 100 b) 84 c) 25 d) 25 Total 234	The number of mussels counted in 2009 were 125% that of 2005. This is likely to be due to some shifting of locations of the adult population, but there is no evidence of any decline.
Count 3	20 along boulder, 29 above boulder including 13 tucked under bank	49 in total including 13 tucked under bank	The numbers and locations of the mussels in standard area 3 are unchanged since 2005.

The results of the standard count survey was to conclude that there are no unnatural recent declines in adult numbers.

2) Redox potential measurements, as a proxy for the loss of oxygen with depth of sediment

A total of 28 redox potential measurements were made in the location of mussel beds in the Bundorragha River. The loss of redox potential at 5cm ranged from 11% to 23%, with the average loss being 16% (**Figure 4.1**). An average loss of less than 20% is considered to be necessary for juvenile survival (Geist & Auerswald, 2007).

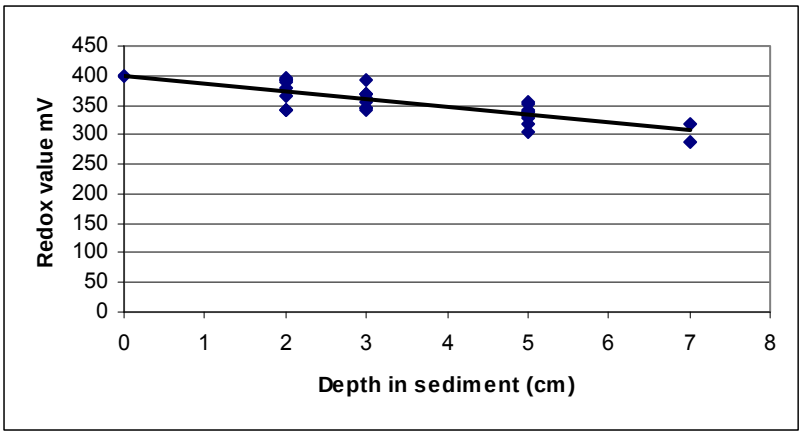


Figure 4.1. Trend in loss of redox potential with depth of river bed substrate.

3) Measurements of mussel lengths for size profile

A total of 147 individuals were measured from 2 quadrats. The percentage of individuals in each size class is shown in **Figure 4.2**.

The size class percentages from Ross (1984) and Moorkens (2005) are shown with the 2009 data in **Figure 4.3**.

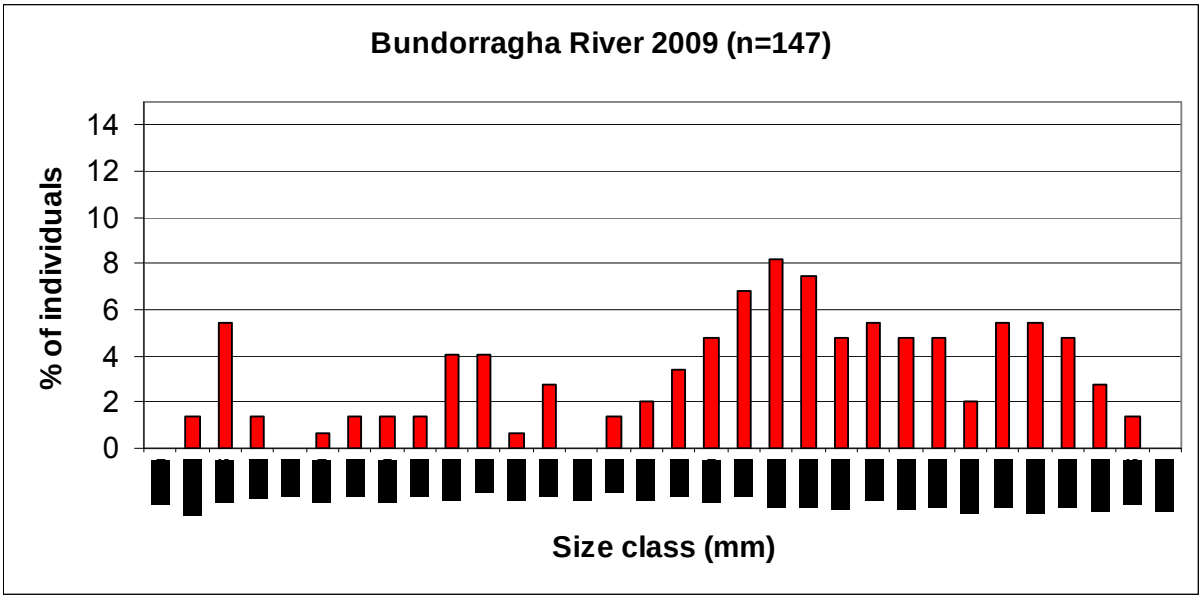


Figure 4.2 Size profile from the River Bundorragha 2009.

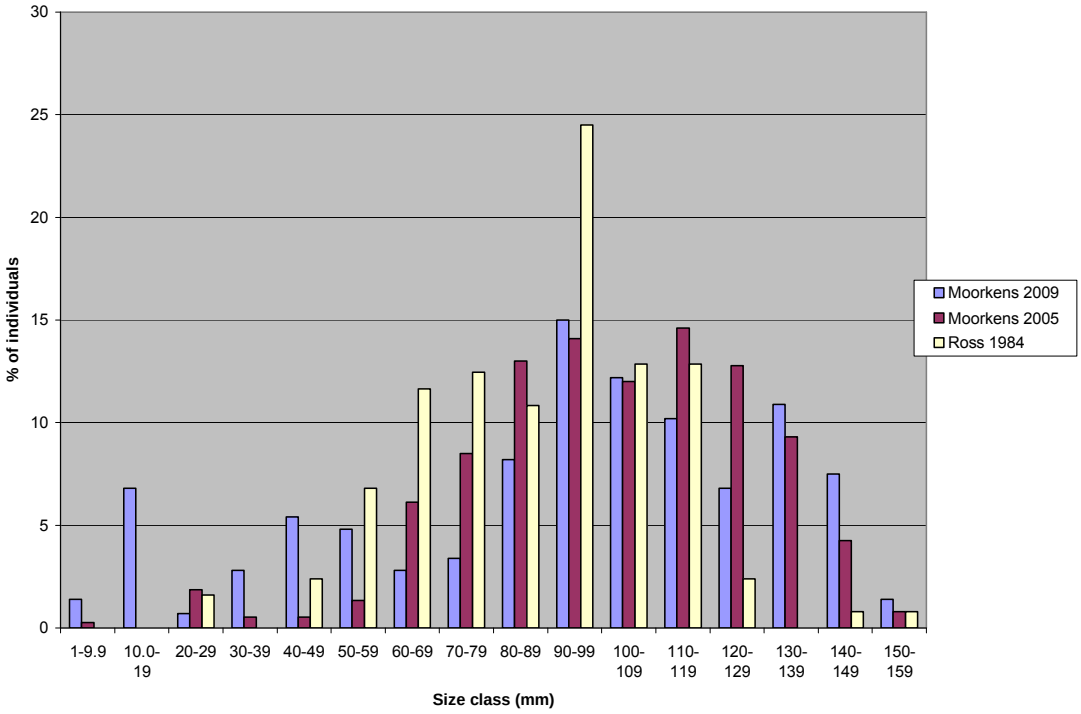


Figure 4.3. Size profile from the River Bundorragha 1984, 2005, 2009.

In addition to direct survey of mussels, an electrofishing exercise was undertaken to assess whether fish bearing glochidia were present in the river. Two sites on the Bundorragha were surveyed on 18th May 2009 (Paul Johnston Associates, 2009). In the first site, 6 trout and 12 salmon were caught, and none were found to be encysted with glochidia. This site is upstream of the main mussel population. At the second site, 7 trout and 7 salmon were counted, and 5 salmon and no trout were found to be encysted with glochidia. Thus salmon rather than trout are acting as hosts to the Bundorragha mussel population, and some of these were found to have very high numbers of encysted glochidia. This second site was at the downstream end of the population.

The parameters required for the European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations 2009 were all fulfilled, with a marked improvement in numbers of very young mussels (under 6 years of age). This is the age when the young mussels remain buried within the gravel interstices. This habitat has suffered in recent times from excessive siltation, which leads to loss of oxygen exchange to the juvenile mussels from the open water above. While a comprehensive monitoring of the entire population was not possible in the scope of the sub-basin plan project, the results are indicative that this population as a whole is recovering well.

Figure 4.4 shows the numbers of individual mussels that are predicted to occur in the Bundorragha over time if conditions are maintained as favourably as they are now. This shows that a healthy very large population can be sustained in spite of some years in the past where recruitment was below optimum levels.

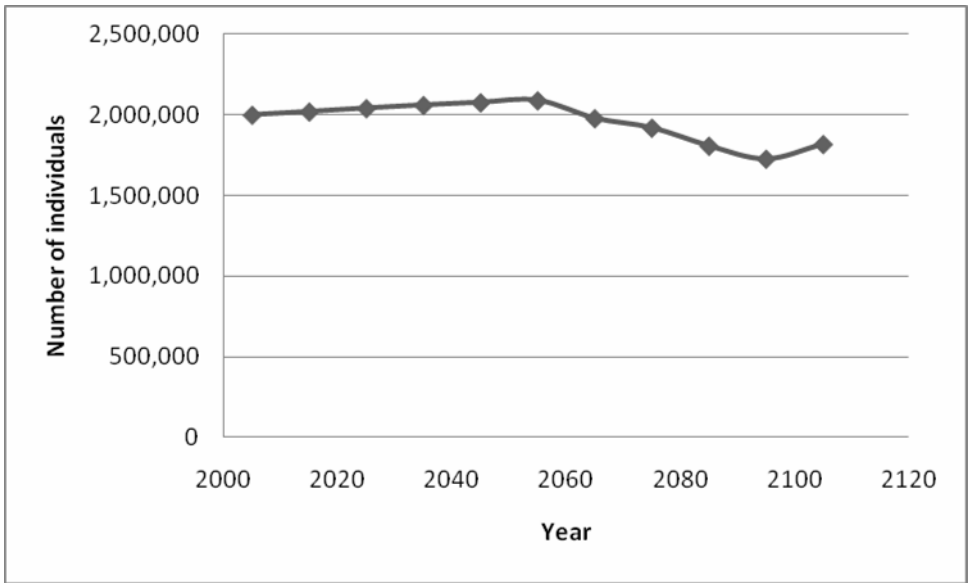


Figure 4.4: Predicted numbers of mussels over time in the Bundorragha River

The improvement from the past siltation is considered to be mainly a consequence of de-stocking of grazing animals as part of the implementation of the Commonage Framework Plan. The recovery of vegetation in the catchment is in stark contrast to the bare peat that was a feature of parts of the catchment in the recent past.

Improved salmon and sea trout numbers have been noted in 2009, probably due to changes in draft netting in the marine environment and the closure of a fish farm in the local harbour area. The improved river bed conditions are likely to favour fish spawning conditions also.

This is an extremely important catchment for the international protection of *Margaritfera*. It is vital that all measures can be taken to remove risk of future siltation and nutrient elevation from the catchment in order to secure this population into the future.

Table 4.2 Assessment of *Margaritifera* Regulations in Bundorragha River 2009.

***Margaritifera* parameter**	**Requirement under Regulations**	**Status in Bundorragha**	**Pass or Fail**
Adult numbers	No recent decline in live adults	No recent decline in live adults	Pass
Dead shells	No evidence of non-natural dead shells (>1%)	No evidence of non-natural dead shells (>1%)	Pass
% individual mussels under 65mm	20%	21.08%	Pass
% individual mussels under 30mm	5%	7.48%	Pass
Siltation level	No artificially elevated levels of siltation - No silt plumes.	No silt plumes. Average redox potential loss at 5cm = 16%	Pass

4.2 CURRENT WATER QUALITY IN THE BUNDORRAGHA CATCHMENT

Trends from the Monitoring Results

The Environmental Protection Agency as part of the National Rivers Monitoring Programme and now its replacement Water Framework Directive Monitoring Programme (operational since 2007), have monitored the Bundorragha Freshwater Pearl Mussel catchment since 1982. The latest Q value assessments from the catchment were carried out in 2009. **Table 4.3** summarises trends in water quality information as measured through the Q-value system from the Bundorragha catchment. The table is arranged with the site highest up in the catchment first on the Glenummera river, to the site lowest down in the catchment which is on the Bundorragha river itself.

The trend in Q values for both the Glenummera and Bundorragha rivers is for Q4-5 and Q5 ratings since monitoring began in this catchment. Therefore all 3 sites pass the environmental objectives for macroinvertebrates in freshwater pearl mussel habitat.

Table 4.3 Q-values at EPA monitoring sites in the Bundorragha catchment between 1982-2009 (SMN and OMN specify sites on the WFD surveillance and operational monitoring networks respectively)

River	**Glenummera**	**Glenummera**	**Bundorragha**
Location	**North of Glendavock**	**1km u/s Doo Lough**	**Bridge East of Bundorragha**
Fullcode	32G050010	32G050070	32B010200
SMN	N	N	Y
OMN	Y	Y	Y
X	88486	85340	84182
Y	268260	267585	263413
1982	~	~	4
1986	~	~	4-5
1990	~	~	4-5
1994	~	~	4-5
1997	~	~	4-5
1999	~	~	4-5
2002	5	4-5	4-5
2006	5	4-5	4-5
2009	5	4-5	4-5

WFD Ecological Status

Surface water monitoring includes ecological and chemical parameters. For ecological status, quality elements, representing plants, insects and fish, along with supporting water quality, hydrology and morphological conditions are sampled and analysed in rivers and lakes to allow waterbodies to be classified into one of five classes of ecological status; high, good, moderate, poor and bad. New standards were set in the *Surface Waters Environmental Quality Objectives* Regulations *(SI 272 of 2009)*. A range of elements are measured in each water body, and a classification is produced based on a 'one out, all out' principle. This uses the poorest individual element result to set the overall classification. Once the status of monitored waterbodies is determined all waterbody types (e.g. river or lake) in the River Basin District (RBD) are clustered according to typology (physical characteristics) and risk assessment (from Article 5 characterisation) This provides a type and pressure profile of waterbodies which allows status to be extrapolated from monitored (donor) waterbodies to unmonitored (recipient) waterbodies. The components of overall status are illustrated in **Figure 4.5** below.

In the case of some water bodies, they are designated as 'artificial' or 'heavily modified'. This is because they may have been created or modified for a particular use such as water supply, flood protection, navigation or urban infrastructure. By definition, artificial and heavily modified water bodies are not able to achieve natural conditions. Instead the classification and objectives for these water bodies, and the biology they represent, are measured against 'ecological potential' rather than status.

In the case of the Bundorragha catchment, there are no designated artificial or heavily modified water bodies.

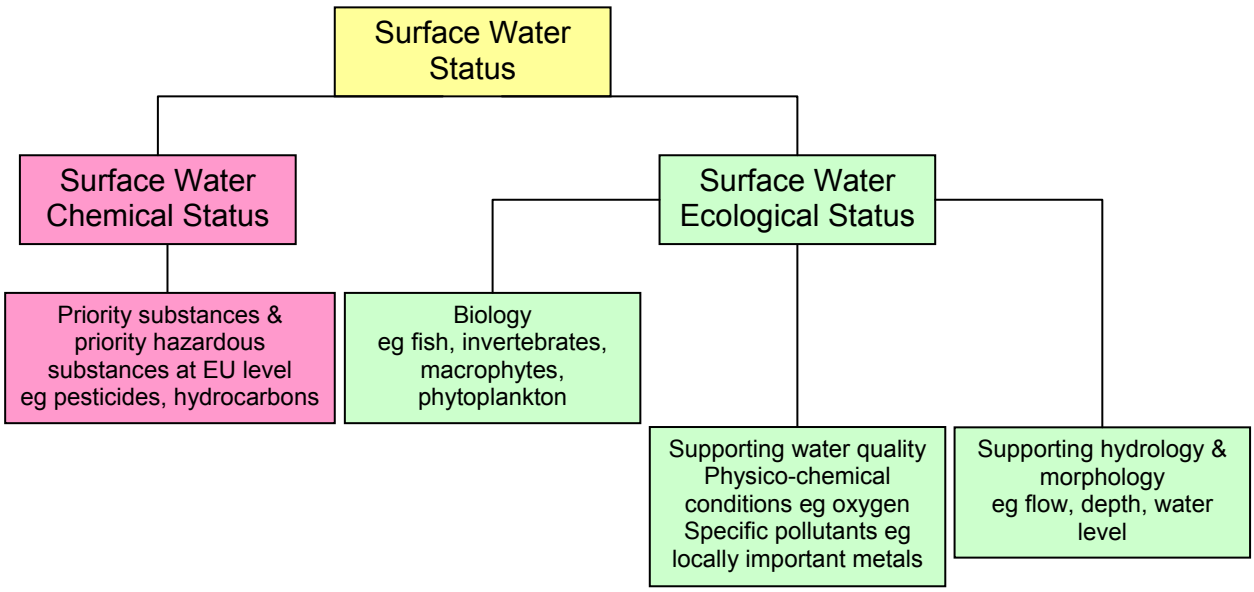


Figure 4.5 The components of overall status for surface water bodies

Under the assessment of ecological status macroinvertebrates include a special consideration of the conservation status of the freshwater pearl mussel in SACs protected for the species. In such areas where the freshwater pearl mussel is at unfavourable conservation status, the EPA must assign a status of 'less than good ecological status', where on the basis of specialist surveys undertaken to assess conservation status, the freshwater pearl mussel is found to be in unfavourable conservation status owing to water quality or hydrology in that water body (Freshwater Pearl Mussel Regulations, 2009).

Figure 4.6 shows the interim WFD status classification for the Bundorragha catchment as of December 2009 (note this does not include monitoring data from the 2009 survey year. Classification is based on data from the 2006-2008 survey years.). The Bundorragha catchment river water bodies

were classified as follows: 3 high status, and 1 good status waterbody. Macroinvertebrates determined status in 1 high status waterbody, and hydromorphology determine status in the 1 good status waterbody. The remaining two high status waterbodies were classified via extrapolation from monitored donor waterbodies. The freshwater pearl mussel population is at favourable conservation status in the Bundorragha.

The Bundorragha catchment lake water bodies were classified as follows: 2 high status (Cunnel and Glencullin loughs), and 2 good status (Doo and Fin loughs) waterbodies.

WFD Chemical Status

For chemical status, EU wide standards have been established for priority and priority hazardous substances which include certain metals, pesticides, hydrocarbons, volatiles and hormone-disrupting compounds. These standards have been transposed in Irish legislation *(SI 272 of 2009).* Exceedance of a standard results in a water body failing good chemical status. There are two classes for the chemical status of surface waters: good or fail.

The following Irish Dangerous Substances Monitoring Programmes were reviewed to see if any monitoring sites were located within the Bundorragha catchment:

- Dangerous Substances Screening Monitoring Programme (05-06)- No sites
- LA Dangerous Substances Monitoring Programme (02-05) – No Sites
- EPA Monitoring Data 99-00- No Sites
- EPA Monitoring Data 02-03- No sites

The Bundorragh Catchment was included in the WFD surveillance monitoring programme in 2008 (the rivers surveillance sites have been spilt to be monitored once over the years from 2007-2009). The site which was monitored is as follows:

- Bundorragha River- Br Bridge E. of Bundorragha

No substances exceeded the EQSs as given in the Surface Water Regulations 2009, for both the Priority Substances and Specific Relevant Pollutants.

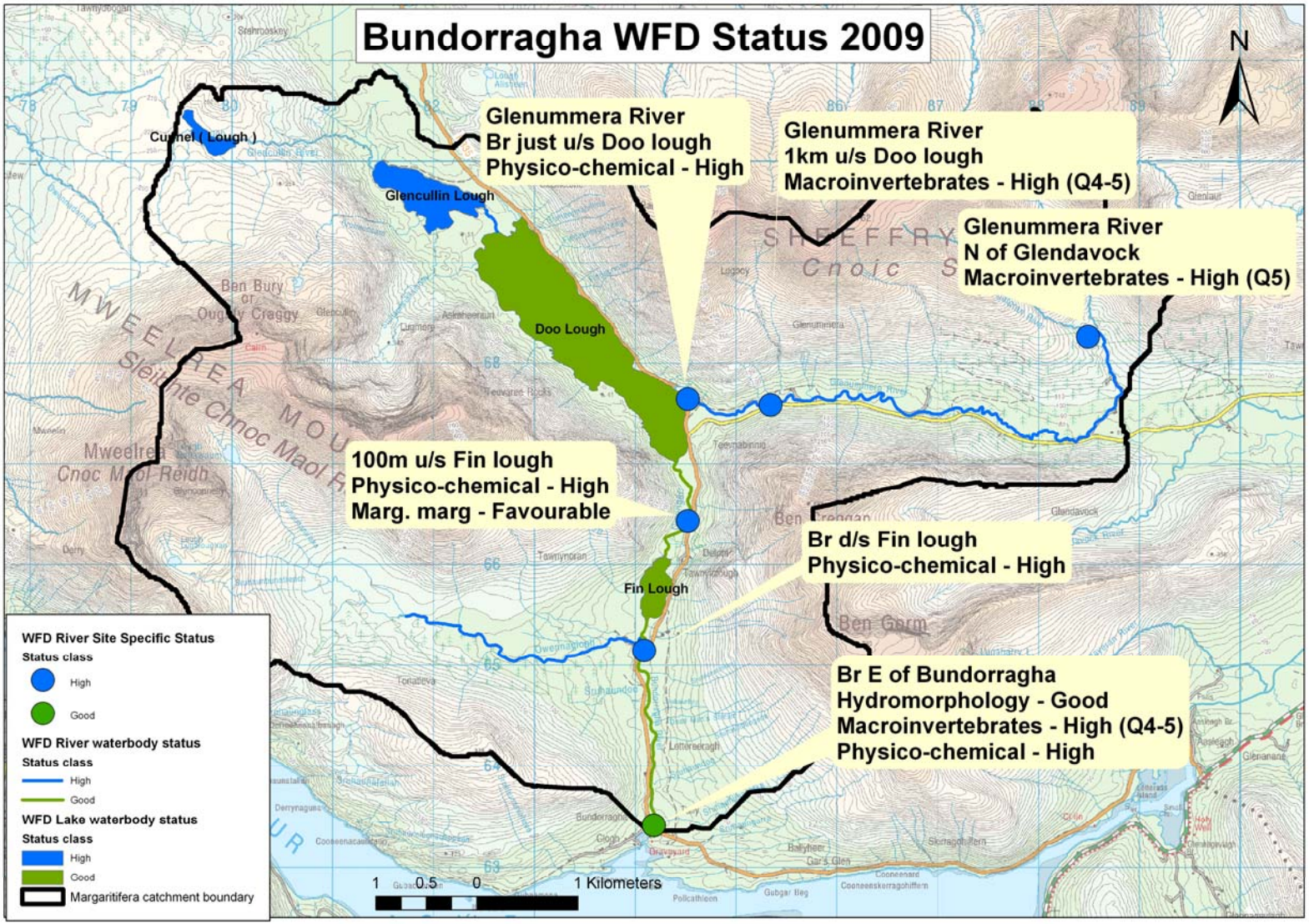


Figure 4.6 WFD river and lake status classification for the Bundorragha catchment

Catchment Water Quality Monitoring 2009

A robust monitoring programme is required to assess the status of the freshwater pearl mussel population and their habitat. The Ecological Quality Targets for designated pearl mussel sites under the Freshwater Pearl Mussel Regulations (2009) are detailed in Table 1.2. Assessment of the compliance with these environmental objectives was ascertained during monitoring undertaken during 2009. This monitoring also involved a catchment walkover risk assessment where the pressures within the catchments were documented, and this is presented in Chapter 3.

Results from that survey work are summarised below for macroinvertebrates, filamentous algae, diatoms, macrophytes and siltation. The morphological condition of the catchment was also assessed and is also reported on below. A Monitoring Methods Manual and also detailed background reports for each element monitored should be consulted for more detailed information on methodologies, results, and conclusions, and are available at www.wfdireland.ie.

Macroinvertebrates

Macroinvertebrate EQR's were all above the target ecological quality objective for pearl mussel sites (≥0.9) during this survey. This implies that surface water quality is presently meeting the ecological objectives for pearl mussel sites at all locations surveyed in the catchment.

The main channel of the Bundorragha River merits ratings of Q4-5 from Fin Lough to Killary Harbour. There was potential to assign Q5 to the sites, however, a Q4-5 to rating was assigned due to the fact that in addition to the diversity of Heptagniidae, there were just two sensitive Plecopteran species (*Isoperla sp*. and *Chloroperla sp*.) detected at each site.

The Glenummera, Owengarr and Owenaglogh Rivers all merit ratings of Q5 at the locations sampled. Macroinvertebrate assemblages were generally diverse, with sensitive Plecopteran and Ephemeropteran fauna well represented.

Table 4.4 Macroinvertebrate survey results

			Latest EPA Survey results	Survey results	EQR	WFD status
EPA Site Code	River	Site No.	2009	2009	2009	
32G050070	Glenummera	1	4-5	5	1.0	High
-	Owengarr	2		5	1.0	High
-	Owennaglogh	3		5	1.0	High
	Bundorragha	4		4-5	0.9	High
-	Bundorragha	5		4-5	0.9	High
32B010200	Bundorragha	6	4-5	4-5	0.9	High

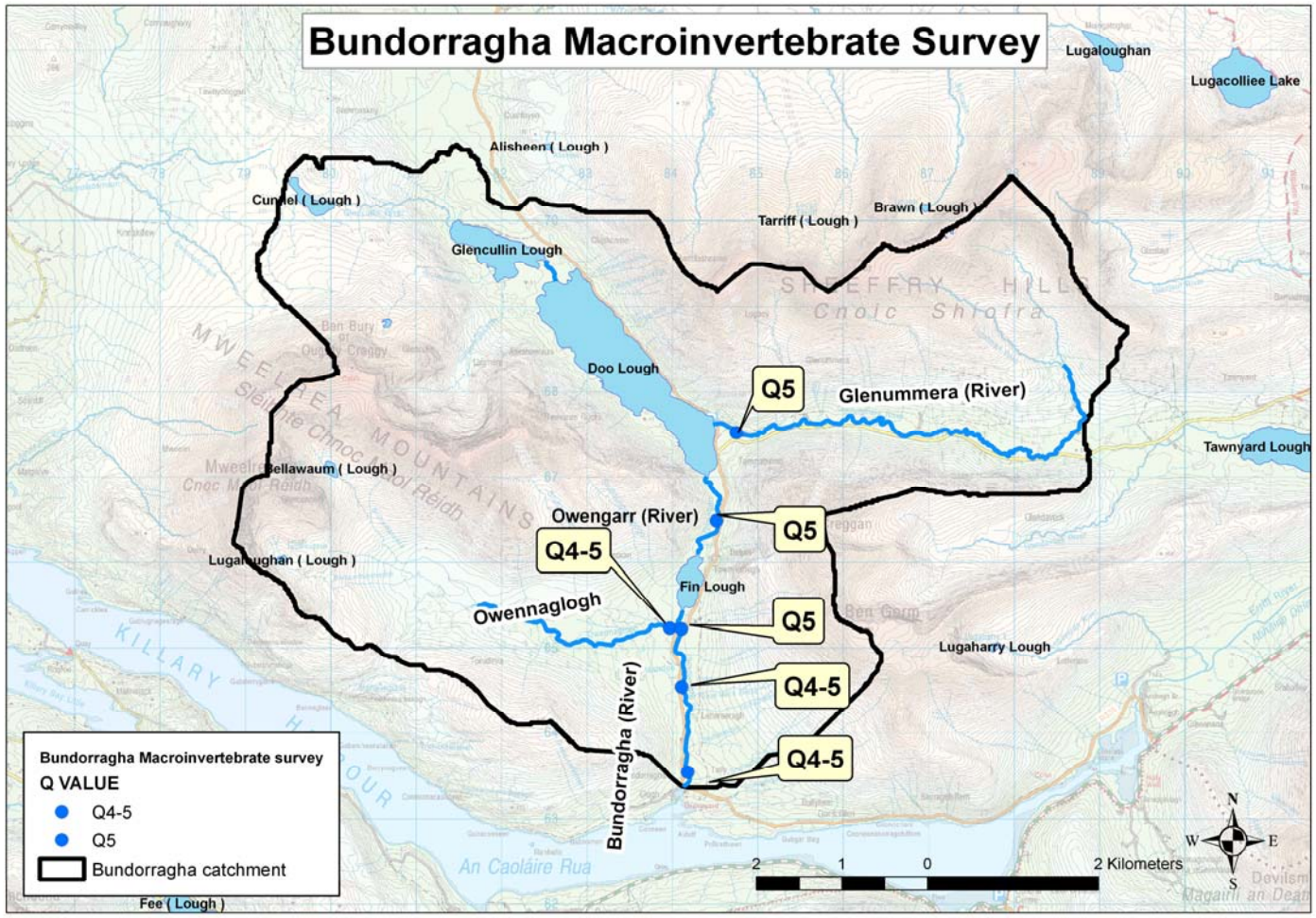


Figure 4.7 Macroinvertebrate survey results

Filamentous algae

Sampling was carried out at 4 sites in the Bundorragha catchment: one site on the Glenummera river, one on the Owengarr, and two sites on the Bundorragha river. A detailed inspection of a 10m length of each river site was conducted, and the nature of the stream environment, the substrata available for macroscopically visible growths and the nature and abundance of any macroscopic growth forms present were recorded. The abundance of each macroscopic element is estimated using a simple descriptor scale. This is based on the percentage of the stream or river bed (within the survey unit) that is covered by the assemblage as follows: 1=Rare, just visible in the field, covers <1% of the river bed; 2 = Occasional, covers 1% to <5% of the river bed; 3= Frequent, covers 5% to <25% of the river bed; 4 = Abundance, covers 25% to <50% of the river bed; 5 = Dominant, covers $\geq$ 50% of the river bed. The quantification is based on "qualified judgment".

Results are illustrated in **Figure 4.8** and detailed in **Table 4.5** below.

The Glenummera site surveyed just upstream of Doo lough had a low abundance of macroscopic algae at <5%.

The site sampled on the Owengarr had a low percentage of macroscopic algae, at <10%, with the dominant species identified being *Lemanaea fluviatilis*. This taxon has been identified at high and good status sites in surveys of Irish rivers, and is a red alga showing a preference for low nutrients and low alkalinity sites. It does not form mats which blanket the river bed like some filamentous green algae, or trap silt, and for these reasons is not considered to be a threat to freshwater pearl mussel habitats. When the site was resurveyed in September, a much transformed picture of the macroscopic algae was found. The abundance and composition of the assemblage had transformed to one dominated by green filamentous algae, namely *Bulbochaetae, Spirogyra, Zygnema* and *Mougeotia* species. Although present in high abundance, the species in themselves are not indicative of elevated nutrient levels as far as current knowledge of the genera suggests.

Both sites sampled on the Bundorragha, had a low abundance of macroalgae, and while macroscopic algae was evident at the site West of Tully, it was composed of ephemeral wispy filamentous green algae composed of *Spirogyra, Oedogonium, Zygenema* and *Bulbochaetae*.

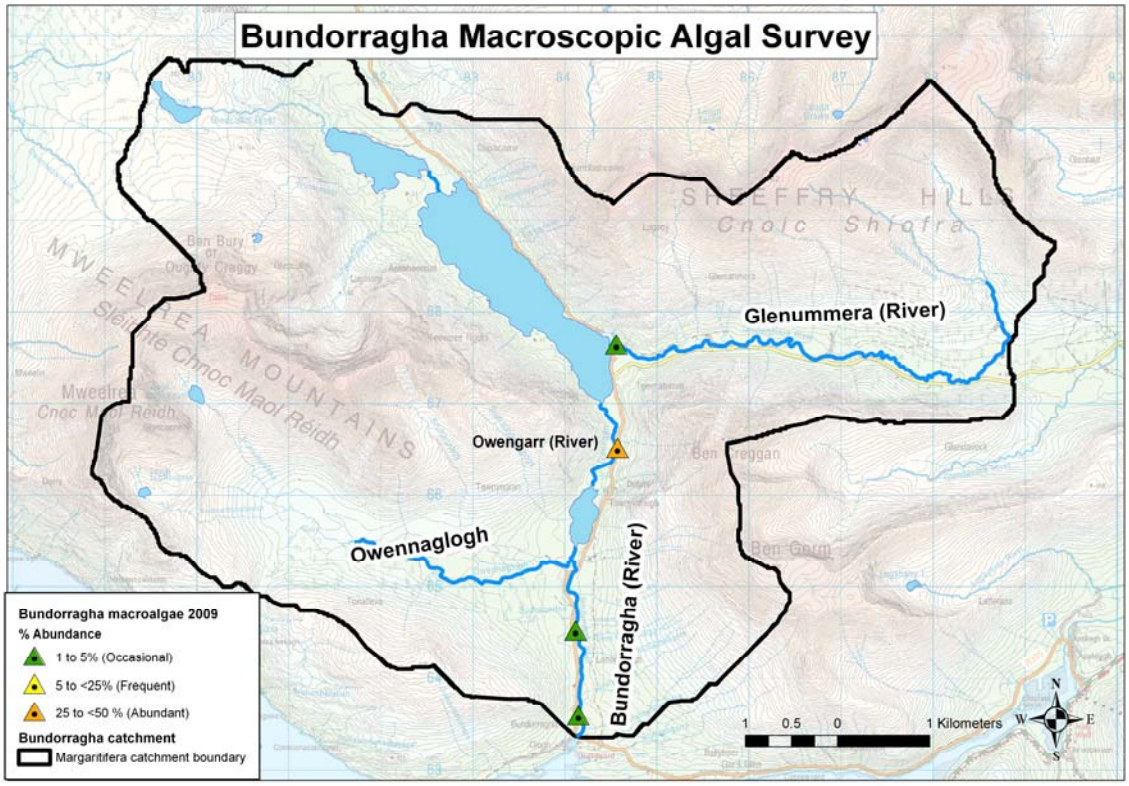


Figure 4.8 Macroscopic algal survey results

Table 4.5 September 2009 macroscopic algal composition and abundance for the Bundorragha river (final abundance: 1=Rare, just visible in the field, covers <1% of the river bed; 2 = Occasional, covers 1% to <5% of the river bed; 3= Frequent, covers 5% to <25% of the river bed; 4 = Abundance, covers 25% to <50% of the river bed; 5 = Dominant, covers ≥ 50% of the river bed)

River	Glenunmmera		Owengarr		Bundorragha		Bundorragha	
Location	**u/sDoo lough**		**d/s Doo lough**		**d/s Delphi Adventure Centre**		**West of Tully**	
Date sampled	**15/09/2009**		**15/04/2009**		**15/09/2009**		**15/09/2009**	
% Abundance of algae in field	**1 to <5%**		**25 to <50%**		**None visible**		**1 to <5%**	
	Presence/ absence	**Final abundance**	**Presence/ absence**	**Final abundance**	**Presence/ absence**	**Final abundance**	**Presence/ absence**	**Final abundance**
Bulbochaete sp			Present	1			Present	1
Mougeotia sp			Present	1				
Oedogonium sp	Present	1					Present	1
Spirogyra sp	Present	2	Present	3			Present	2
Zygnema sp			Present	4			Present	1

Diatoms

Diatoms can be found growing on most submerged surfaces. Areas of the river bed with naturally occurring moveable hard surfaces (large pebbles, cobbles and boulders) are recommended wherever possible for water quality sampling. For accurate identification of diatoms, it is necessary to remove all the cell contents and mount the diatoms using a mountant with a high refractive index. Diatom valves are identified and counted at 1000x magnification until a minimum of 300 valves are enumerated and identified. Results were entered in to excel and then analysed using a Microsoft windows programme (DARLEQ project – Diatom Assessment of River and Lake Ecological Quality). The program

implements a classification algorithm using a metric based on a revised Trophic Diatom Index (TDI). The programme calculates the TDI score, Ecological Quality Ratio (EQR) and status class for each sample. EQRs are produced by comparing the observed TDI with that expected to be obtained if the site was at reference condition i.e. in the absence of eutrophication pressures.

Results are illustrated in **Figure 4.9** and detailed in **Table 4.6** below.

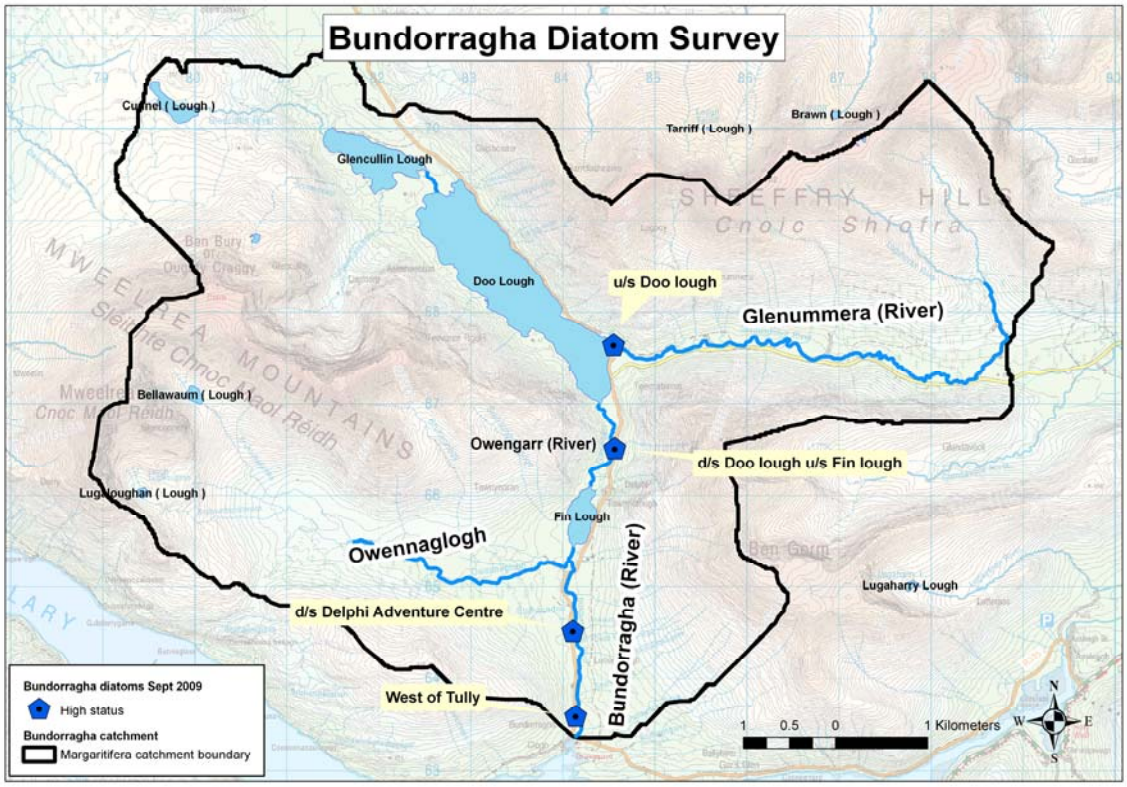


Figure 4.9 Diatom status results

Table 4.6 TDI Results – diatom index (column heading explanations: Sample Date – as stated**;** River – river name; Site – location from which sample was taken**;** EQR – Environmental Quality Ratio for each sampled based on predicted TDI for observed alkalinity and season**;** Class – WFD status class**;** % Plantic- % of taxa identified which were plantonic. These are excluded from status calculations; % Motile - % of taxa counted which were motile**;** % Organic tolerant - % of taxa which are organic tolerant)

SampleDate	River	Site	EQR	Class	% Planktic	% Motile	% Organic tolerant
14 April 2009	Glenummera	u/s Doo lough	0.9	Good	0	2.4	3.19
14 April 2009	Owengarr	d/s Doo lough	0.89	Good	0	0.59	10.96
15 Sept 2009	Owengarr	d/s Doo lough	1	High	0.2	4.37	4.37
14 April 2009	Bundorragha	d/s Delphi Adventure Centre	0.95	High	0.8	6	4.8
15 Sept 2009	Bundorragha	d/s Delphi Adventure Centre	0.97	High	0.2	3.8	4
15 Sept 2009	Bundorragha	West of Tully	0.98	High	1.37	10.39	1.57

The Glenummera site surveyed just upstream of Doo lough achieved good status from the diatom assessment. The main reason for not achieving high status was due to the reduced percentage composition of *Fragilaria capcucina* var. *gracilis* in the sample in comparison with other sites lower in the catchment which did achieve the high status class.

The site sampled on the Owengarr was deemed to be at good status due to the diatom assessment.

Both sites sampled on the Bundorragha, the first upstream of the freshwater pearl mussel known locations, and the second at the main habitat of the freshwater pearl mussel population, both achieved high diatom status.

Macrophytes and filamentous green algae

Habitat assessment was carried out at each of the sites selected for macroinvertebrate assessment. Included in this assessment was an analysis of instream vegetation, listing plant species occurring and their percentage coverage of the stream bottom at the sampling site, and dominant bankside vegetation, listing the main species overhanging the stream.

On the Bundorragha river, there were indications of perhaps slight nutrient input evidenced by increases in filamentous green algae (FGA) and macrophyte cover at the two lower Bundorragha River sites (downstream of Delphi Mountain Resort and upstream of Killary Harbour). Whilst macrophyte coverage values were not excessive in any of the riffle sites surveyed, cover was demonstrably greater at the site downstream of Delphi Mountain Resort compared to other sites. *Myriophyllum* sp. and *Juncus bulbosus* account for approximately 15% of rooted macrophyte cover at the site, which exceeds recommended ecological quality objectives for pearl mussel sites. Coverage of filamentous algae, whilst nowhere excessive, also exceeds the recommendations (≤5%) at the two sites on the Bundorragha river.

At the Glenummera, Owengarr and Owenaglogh Rivers there was no rooted macrophytes recorded at any sites.

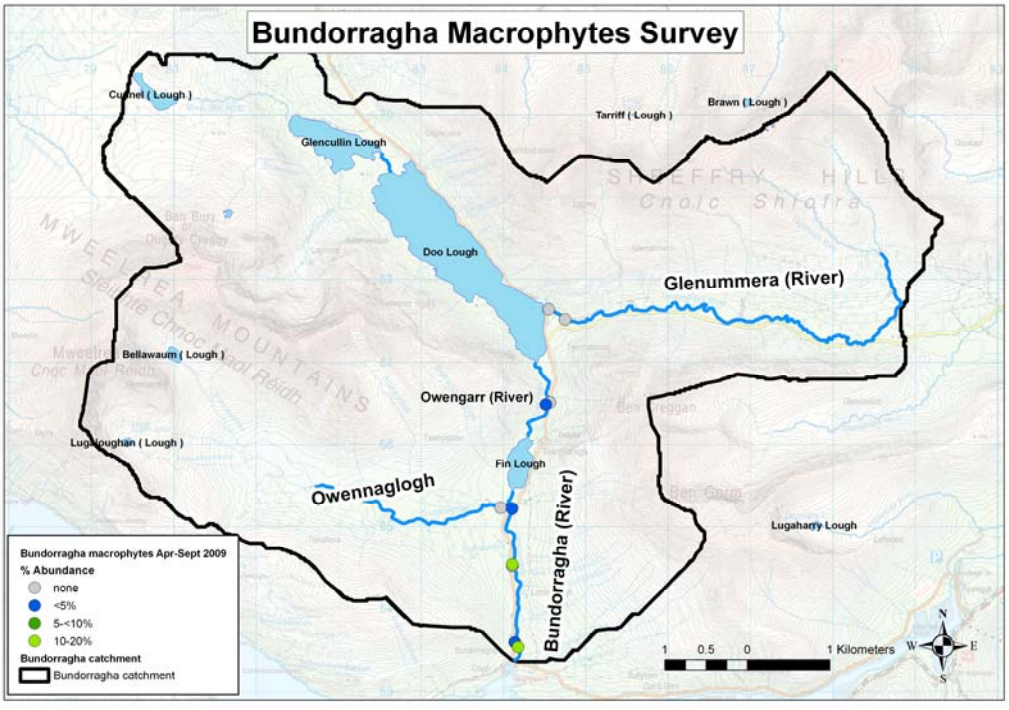


Figure 4.10 Macrophyte survey results

In addition to the general macrophyte catchment survey, macrophyte and filamentous green algae (FGA) growth were recorded in relation to their proximity to freshwater pearl mussels during the freshwater pearl mussel surveys.

While the macroinvertebrate work was carried out in May 2009, the survey in August 2009 for pearl mussels found rooted macrophytes and filamentous green algae to be at levels below 5%, i.e. within the target for favourable conservation status. The Pearl mussel Regulations 2009 refer to macrophyte cover at the site of the mussels rather than within the whole river as it is the direct impact of inappropriate growth that affects the mussel individuals. Mussel beds occur at stable areas of river bed, and it is here that silt and nutrient effects are most severe. More unstable areas or areas of deeper or highly shaded water are unlikely to support high macrophyte or FGA growth, whereas slow flowing areas with sediment accumulations are areas where macrophytes would be naturally present. While there were elevated macrophyte abundance levels close to mussel beds, the habitat itself was in good condition. However, the evidence of elevated nutrient input in the river in close proximity to mussel habitat demonstrates that this population is at risk of returning to unfavourable status and thus improved management measures are of the utmost importance.

Siltation

As stated, habitat assessment was carried out at each of the sites selected for macroinvertebrate assessment. The Freshwater Pearl Mussel Regulations require that there is no artificially elevated levels of siltation present at the pearl mussel habitat. This is evidenced by the absence of plumes of silt when the substratum is disturbed. The surveyor performs a substrate kick in order to ascertain whether a plume of silt is generated or not. The surveyor must then note one of the following three observations;

1. No visible silt plume (none)
2. Some visible silt (moderate)
3. A lot of visible silt (significant/heavy)

It is important to note that the silt assessments are indicative of the catchment rather than individually significant. There may be reasons for absence of silt or pockets of silt in any river. Silt will not settle in unstable, fast flowing habitats of rivers, but where present will accumulate in the more stable habitats where the silt can slow down and drop to the river bed. Unfortunately, the freshwater pearl mussel always occurs at stable habitats. The most important individual areas of silt assessment are in the mussel habitat itself. The Freshwater Pearl Mussel Regulations 2009 refer to habitat conditions at the site of the freshwater pearl mussel habitat for this reason. As seen in Section 4.1 above, there were no strong silt plumes at the site of freshwater pearl mussel habitat, with average redox potential loss at 5cm of 16%. Geist & Auerswald (2007) found that average redox potential loss at 5cm of less that 20% was required for juvenile survival. Hence the siltation levels of the Bundorragha Catchment are currently favourable.

Figure 4.11 illustrates the results from this assessment in the broader catchment. On the Bundorragha river, the silt plume was recorded as not significant in 6 locations assessed.

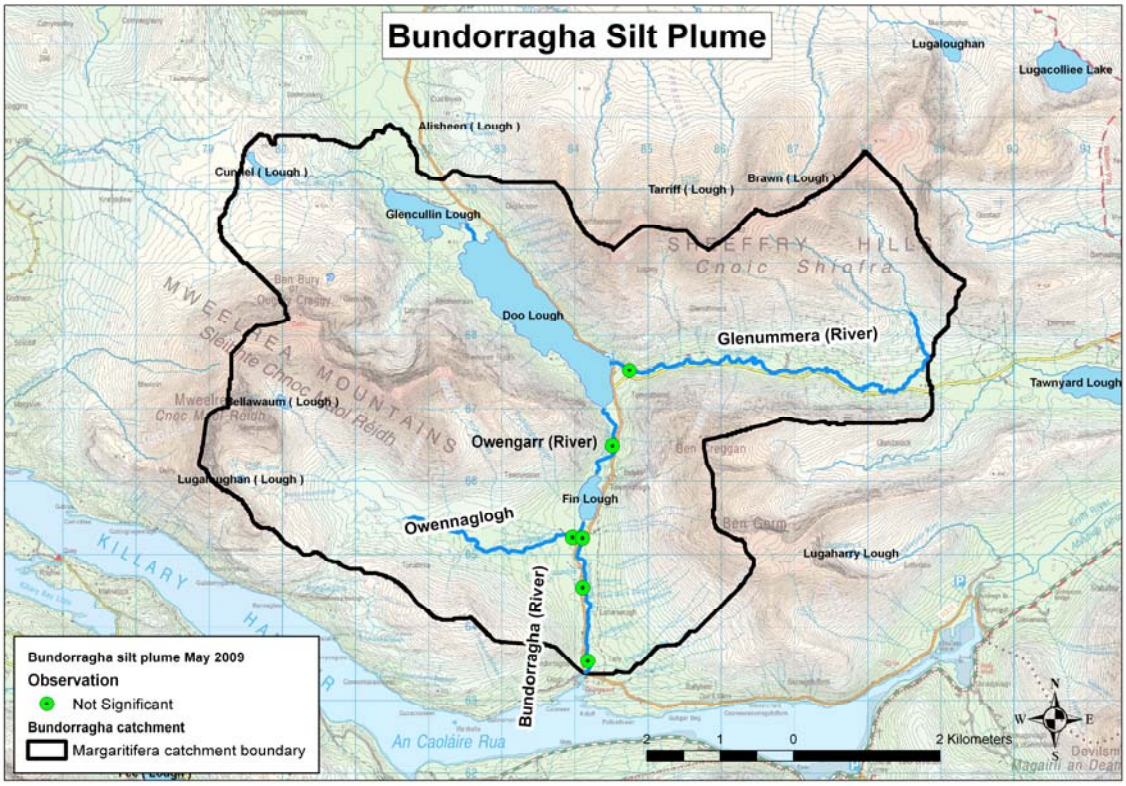


Figure 4.11 Silt plume survey results

Morphology

In order to assess the hydromorphological alterations within the Bundorragha catchment the EPA WFD classification tool called the River Hydromorphology Assessment Technique (RHAT) was utilised. It is a field technique which assigns a channel typology. This influences the rivers physical attributes assessed in the field. The technique assigns a morphological classification directly related to that of the WFD – high, good, moderate, poor and bad. RHAT surveys were carried out within pearl mussel habitat. The methodology classifies river hydromorphology based on a departure from naturalness, and assigns a morphological classification, based on semi-quantitative criteria. It is designed to be a rapid visual assessment based on information from desktop studies, using GIS data, aerial photography, historical data and data obtained from previous field surveys as well as observations in the field.

Classification of hydromorphology can be used to contribute to the status classification of water bodies at high ecological status only. However, RHAT plays a vital role in identifying why a water body might be failing to achieve good ecological status as it is based on the observed impact in the field. It can assist in deciding what indirect and direct efforts are needed to improve status and in helping to prevent further deterioration.

Two RHAT surveys were carried out within the Bundorragha catchment. Both surveys were carried out on the Bundorragha River at the lower end of the catchment where the Freshwater Pearl Mussel populations are located. One survey stretch was deemed to be at high status and one at good status. The survey stretch where RHAT number 1 was carried out was classified as a step/pool/cascade channel. While some natural cascades do exist along this stretch its classification is largely due to the unnatural flow created by the numerous weirs which are located along the stretch. Within the RHAT survey methodology three categories are scored out when the river channel is classified as a step/pool/cascade – these are Bank Structure and Stability, Bank Vegetation and Floodplain connectivity. The channel form and flow type scored 2 out of a possible 4 due to the presence of the weirs which were found to be altering and changing the flow pattern along the river stretch. Channel

vegetation scored three out of four due to the presence of greater than expected macrophyte growth for a river of this type. Both Filamentous Green Algae and *Ranunculus* were recorded with greater than 10% coverage. Both the substrate condition and the barriers to continuity scored three out of four both were marked down due to the presence and pressures caused by the weirs. The weirs may be problematic during low flows and as such a possible barrier to migration. The substrate condition was found containing high levels of fine sands and silt deposits which may be caused by the presence of the weirs and bridges. The riparian landcover was also given a score of three out of four. The surrounding landscape is largely peat but sheep grazing was evident with signs of over grazing, trampling and poaching also recorded along the survey stretch.

RHAT number 2 was carried out on the upper stretch of the Bundorragha catchment below Fin Lough. This section of the river has been over widened at the road bridge at the lower end of the survey stretch. Resectioning and reinforcements were recorded on the left and right banks at the bridge. This stretch was classified as a lowland meandering river type although it is found within an upland area. The river was in spate on the day in which the survey took place and therefore the substrate condition and the barriers to continuity categories of the RHAT survey could not be scored accurately. Overall this stretch of the Bundorragha was found to be in good condition. Only the Channel form and flow types together with the Riparian land cover was marked down due to sheep grazing.

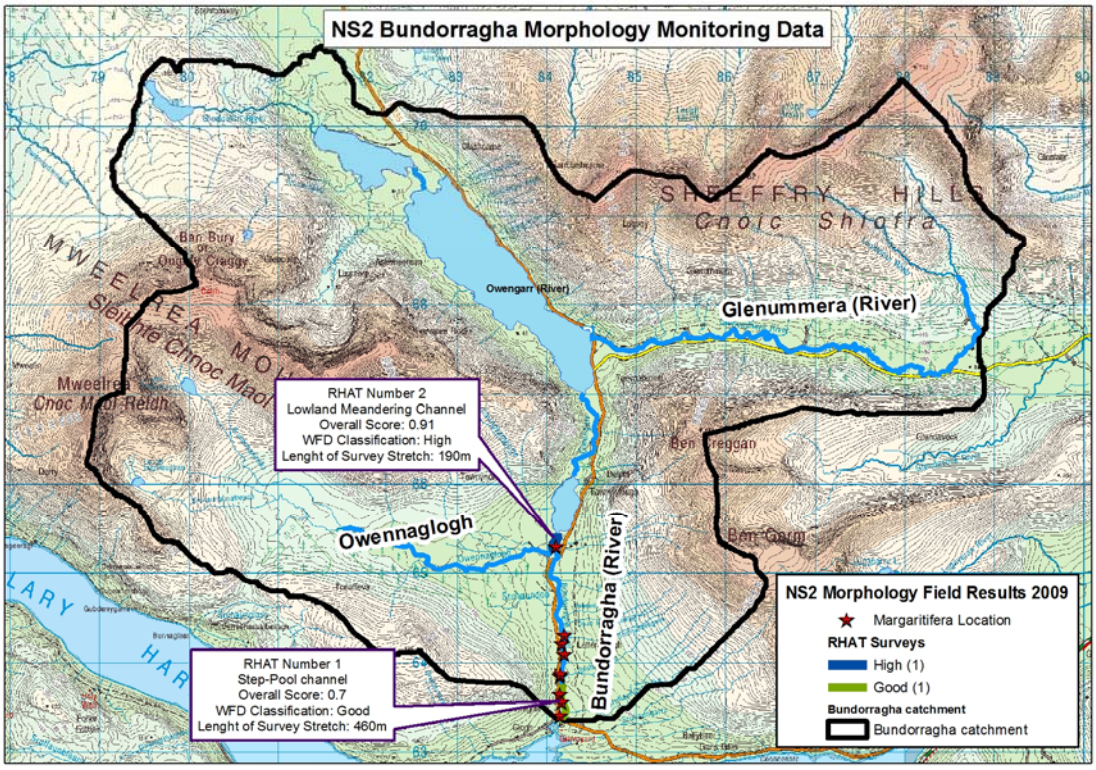


Figure 4.12 Morphology RHAT survey results

5 MONITORING

This chapter will be up-dated for the final plan to provide further detail on the future monitoring required for the Freshwater Pearl Mussel and its biological and general physico-chemical supporting elements. The specific stations at which each biological, physical and chemical element is to be monitored will be detailed in a background document and associated table. Further information on the methods, the timing of sampling and the responsible bodies will also be provided in the background material.

5.1 Overview

The monitoring programme for the Bundorragha catchment has been designed to evaluate the effectiveness of the measures in this Sub-basin Management Plan and the progress made towards restoring favourable conservation status.

This programme shall comprise monitoring of:

- Freshwater pearl mussels
- Other biological elements
- General physico-chemical components

And will fulfil the monitoring requirements set out in S.I. 296 of 2009 through monitoring the criteria listed in the Third Schedule and the elements listed in the Fourth Schedule.

5.2 Freshwater pearl mussels

For the purposes of examining the overall changes in the distribution and abundance of mussels, and their mortality rates permanent mussel transects (or similar, permanent count areas) will be counted annually, completing a full cycle of transect monitoring once every three years. Typically, six transects will be counted per population, with two counted per population per year. The locations of the permanent transects was chosen to cover the geographical range of mussels within the catchment, their range of population density and to best detect any changes resulting from the implementation of the measures. Further information on the location of the transects and the schedule for monitoring will be provided in the final plan and background documents. Transect monitoring involves counting the number of adult mussels visible on the substratum, as well as the cover abundance of silt, macroalgae and macrophytes, and is, thus, a good method of detecting events such as kills of adults, as well as providing an indication of the general health of the mussel habitat. This method does not yield information on the health of juvenile mussels or their riverbed habitat.

In order to monitor the conservation status of the mussel populations, in accordance with the two shell-length criteria set out in the Thrid Schedule of S.I. 296, 2009, quadrat searches will be conducted once every three years. Quadrat searches involve removing all of the mussels, both adults and juveniles, from a fixed area of substrate (50 cm X 50 cm) and measuring their length. This provides information on whether the population is recruiting or not and allows any changes in population age structure to be detected. Macroalgal and macrophyte cover is also assessed in each quadrat, along with sedimentation (through both visual means and redox potential measurement). Quadrat searches will be distributed throughout the mussel population, to determine the overall conservation status of the population, as well as targeted at sites subject to specific measures, in order to evaluate the effectiveness of such measures. In order to further elucidate whether the mussel population is recruiting or not, quadrat searches may be supplemented by experimental kick sampling to look for one to two year-old mussels. Further information on the schedule for quadrat monitoring will be provided in the final plan and background documents.

5.3 Monitoring of the biological and physical elements listed in the Fourth Schedule to S.I. 296 of 2009

Restoration of the mussel population to favourable conservation status is the ultimate criterion for measuring the success of the Sub-basin Management Plan. However, as this may take some time to achieve, objectives have been set for other more rapidly responding biological and physical elements under Schedule Four of S.I. 296, 2009 (see Table 1.1). Monitoring of these elements (macroinvertebrates, phytobenthos (diatoms and filamentous algae), rooted plants and silt) will be used to provide an early indication of progress towards restoration. See Chapter 4 for the results of the baseline surveys for these biological and physical elements conducted during 2009.

5.3.1 Macroinvertebrates and phytobenthos

One sampling station has been selected within the Bundorragha catchment for monitoring of macroinvertebrates and phytobenthos. This station is additional to the existing EPA surveillance and operational monitoring sites and is located within freshwater pearl mussel habitat. Both macroinvertebrates and phytobenthos will be sampled once every three years at this station.

5.3.2 Macroalgae, macrophytes and siltation

In addition to data on macroalgae, macrophytes and fine sediment gathered as part of the freshwater pearl mussel transect counts and quadrat searches (5.2 above), targeted surveys will be conducted at a minimum of two stations within mussel habitat in this catchment. Sites with easy access, such as bridges, will be selected to facilitate more frequent monitoring. Monitoring will be conducted once per month between June and September. Further information on the location of the monitoring stations and methods will be provided in the final plan and background documents.

5.4 Other monitoring of relevant biological elements and general physic-chemical components

In addition to the monitoring detailed in Sections 5.2 and 5.3 above, relevant biological and physico-chemical data will be provided by the on going WFD Monitoring Programme which includes a number of monitoring sites in the Bundorragha catchment (see Chapter 4).

6.0 SUMMARY OF MEASURES

Programmes of measures have been set out in the Western RBD River Basin Management Plan (RBMP) and these RBMP measures also apply in this freshwater pearl mussel catchment. Many of the measures are already provided for in national legislation and are being implemented. These include, for example, the Urban Waste Water Treatment Regulations 2001 to 2010 and the Good Agricultural Practice for the Protection of Waters Regulations of 2009. Others measures are under preparation (for example proposed authorisation regulations for abstractions and physical modifications). A full and detailed list of measures is provided in Table 6.1 and there is more information about the measures in the *national programme of measures background document* and also the suite of *programme of measures — technical studies background documents* where the specific measures for key water management issues are explained (available on www.wfdireland.ie).

A toolbox of freshwater pearl mussel measures has also been developed (Table 6.2) to address the specific pressures impacting on the mussel and its habitat in the 27 SAC catchments.

In the final Bundorragha Sub-basin Management Plan, detailed text and an additional table will be inserted to identify the specific measures from the toolbox of freshwater pearl mussel measures (Table 6.2) that are required to deal with the significant pressures in this catchment, as identified in Chapter 3, and the impacts detailed in Chapter 4. The specific locations in which the measures are to be applied will be identified, in so far as possible. Further explanations of the function of these measures shall be provided. **Summaries of these catchment-specific measures are provided in Chapter 7, Summary Action Programme.**

The generalized time frame for the implementation of the measures in this Sub-basin Management Plan is as follows:

- The relevant public authorities must examine and review, as required, authorised discharges by the 22nd of December 2011.
- All other measures in this sub-basin management plan shall be made operational by the 22nd of December 2012.

Progress on the implementation of the measures will be reported under the Habitats Directive in 2013 and under the WFD in 2015. Signs of improvement in the parameters listed in Schedule 3 and/or Schedule 4 of the Freshwater Pearl Mussel Regulations (S.I. 296 of 2009) should be evident by 2015.

Table 6.1 Measures under the RBMPs

What	Who leads	When & where
CO-ORDINATING ACTIONS		
Water Policy Regulations (SI 722 of 2003) as amended in 2005: **Purpose**: provide statutory basis for the provisions of the Water Framework Directive **Relevant Actions:**		
• Each public authority must exercise its functions in a manner which is consistent with, and contributes to, achieving the objectives of the plan.	Public authorities in Regulations	2009–2015 National
• Coordinate activities for the purposes of Articles 4, 5, 7, 10, 11 and 13 of the Directive and report to the European Commission. Maintain a register of protected areas	EPA	2009–2015 National
• Coordinate plan implementation at district level	Local authorities	2009–2015 Whole RBD
• Support ongoing public participation and RBD Advisory Councils	Local & public authorities	2009–2015 Whole RBD
• Coordinate with Northern Ireland authorities and participation groups on shared waters	DEHLG, EPA, local authorities	2009–2015 Shared waters
• Conduct public awareness and targeted education campaigns, including disseminating information using tools such as Water Maps	DEHLG, local authorities	2009–2015 National
Surface Water Objectives Regulations (SI 272 of 2009) and Groundwater Objectives Regulations (SI 9 of 2010): **Purpose:** to give effect to the measures needed to achieve the environmental objectives under Water Framework Directive and the Dangerous Substances Directive **Relevant Actions:**		2009–2015 National
Where necessary align the following plans and programmes with river basin management plans: • land use and spatial plans • conservation and heritage plans • water services strategic plans • pollution reduction plans including national action plan, IPPC programme, local authority discharge authorisation programmes, groundwater and surface water pollution reduction programmes, shellfish waters pollution reduction programmes, bathing waters management plans, waste management plans, freshwater pearl mussel sub-basin plans, groundwater protection schemes, eel and salmon fishery conservation plans	Local authorities, DEHLG-NPWS, DEHLG, EPA, Coillte, OPW	

What	Who leads	When & where
• waste and sludge management plans • major accident emergency plans • forest management plans • flood risk management plans (forthcoming)		
Other potential measures which are being considered but which require further development as outlined in Section 5.3. Agreed measures in relation to these issues can be introduced through update of Water Management Unit Action Plans during the implementation process: • Protection of high quality waters: • Mines and Contaminated Sites: • Physical impact of channelisation on river status: • Control of Abstractions, Impoundments and Physical modifications: • Estuarine and Coastal (Marine) Monitoring: • Integration of Water Quality and Planning: • Further research.	To be confirmed	2009–2015 National
Develop guidance and training for local authorities as required	Environmental Services National Training Group	2009–2015 National
BATHING WATERS DIRECTIVE (2006/7/EC)		
Bathing Water Quality Regulations (SI 79 of 2008): **Purpose:** to ensure that the quality of bathing water is maintained or improved to comply with bathing water standards in order to protect public health and the environment. **Relevant actions:**		2009–2015 Designated sites
Identify bathing waters. Monitor and classify bathing water quality status. Develop Bathing Waters Management Plans, including any necessary measures, to achieve bathing water quality standards. Disseminate bathing water quality information to the public.	Local authorities	
Cooperate on cross border bathing waters including exchange of information and joint action.	Local authorities, DEHLG, EPA	
BIRDS AND HABITATS DIRECTIVES (79/409/EEC and 92/43/EEC)		
European Communities (Natural Habitats) Regulations (SI 94 of 1997) as amended in 1998 and 2005: **Purpose:** to ensure the protection of habitats and species of European importance. **Relevant actions:**		2009–2015 Designated sites
Designate sites hosting habitats and species of European importance for inclusion in the Natura 2000 network as	DEHLG-NPWS,	

What	Who leads	When & where
needed. Establish appropriate conservation measures, and management plans where necessary, to ensure achievement of favourable conservation status. Ensure that appropriate assessment is carried out in relation to activities which are likely to impact on designated sites and, where necessary, regulate activities. Introduce compensatory measures to ensure the coherence of the Natura 2000 network if damaging activities are allowed to go ahead. Promote education on the need to protect species and habitats, encourage research necessary to achieve the aims of the regulations. **Environmental Objectives (Freshwater Pearl Mussel) Regulations (SI 296 of 2009):** **Purpose:** To set legally binding objectives for water quality in rivers, or parts of rivers, inhabited by freshwater pearl mussels Margaritifera and designated as Special Area of Conservation (SAC) so as to protect this species. The regulations also require steps to be taken to attain those objectives. **Relevant actions:** Establish environmental quality objectives. Undertake monitoring, assess conservation status and investigate pollution. Develop management plans (sub-basin plans of River Basin Management Plans), including any necessary measures, to ensure achievement of environmental quality objectives. Examine discharge authorisations to designated areas and establish if they require review. Monitor the implementation of the sub-basin management plans and ensure their implementation.	DEHLG Relevant parties DEHLG-NPWS, DEHLG, DEHLG DEHLG-NPWS Public authorities DEHLG	
DRINKING WATER DIRECTIVE (98/83/EC)		
European Communities (Drinking Water) (No. 2) Regulations (SI 278 of 2007): **Purpose:** to ensure that drinking water intended for human consumption is wholesome and clean. **Relevant actions:** Monitor for compliance with drinking water quality standards. Maintain a register of water supplies. Immediately investigate non-compliances and inform consumers. Prepare Action Programmes where the drinking water quality standards are not met. Prohibit water supplies considered to pose a potential danger to human health. Ensure compliance with the regulations and supervise group water schemes.	Local authorities Local authorities, HSE EPA	2009–2015 Designated sites

What	Who leads	When & where
Water Services Act (No 30 of 2007): **Purpose:** to facilitate the provision of safe and efficient water services and water service infrastructure for domestic and non-domestic requirements.		
Relevant actions: Monitor public water supplies and monitor and supervise private drinking water supplies. Develop Water Services Strategic Plans, including measures, to meet the Act's requirements including achievement of drinking water standards. Prohibit or restrict water supplies that pose a potential threat to human health or the environment. Inform consumers of non-compliances and ensure that remedial actions are taken where necessary. Prohibit or restrict certain water uses if there is a deficiency of supply. Implement a Rural Water Programme and a licensing system for the Group Water Scheme sector.	Local authorities	
Supervise and monitor water services authorities and issue compliance notices in relation to non-compliances. Plan and supervise investment under the Water Services Investment Programme.	DEHLG	
Supervise public water supplies	EPA	
MAJOR ACCIDENTS AND EMERGENCY DIRECTIVE (96/82/EC)		
European Communities (Control of Major Accident Hazards Involving Dangerous Substances) Regulations (SI 74 of 2006): **Purpose:** to ensure that operators of establishments where dangerous substances are present take all necessary measures to prevent the occurrence of major accidents and to limit the consequences of accidents for people and the environment.		2009–2015 Qualifying sites
Relevant actions: Prepare on-site emergency plans identifying major hazards and specifying prevention and mitigation measures.	Operators	
Prepare off-site emergency plans for action outside the establishment in the event of a major accident.	Local authorities	
Require written notification of activities involving specified dangerous substances. Require operators to demonstrate safe operation and storage and to investigate their operations in the event of a major accident. Organise inspections and measures where necessary. Supply information on major accidents to public authorities.	DETE	
Planning and Development Act (No. 30 of 2000) as amended in 2002: **Purpose:** to provide for the proper planning and development of urban and rural areas.		2009–2015 Qualifying sites
Relevant actions:		

What	Who leads	When & where
Ensure that adequate controls are in place for relevant new developments.	Local authorities	
ENVIRONMENTAL IMPACT ASSESSMENT DIRECTIVE (85/337/EEC)		
Environmental Impact Assessment Regulations (SI 349 of 1989) as amended from 1994 to 2006: **Purpose:** require that certain developments be assessed for likely environmental effects before planning permission is granted. **Relevant actions:** Require certain developments, by either the private or the public sector, to prepare Environmental Impact Assessments for consideration before planning permission is granted (taking account of objectives established in river basin management plans) and make them available to the public. Notify authorities in Northern Ireland of any planning application which is likely to have significant effects on the environment in Northern Ireland.	Planning authorities	2009–2015 National
SEWAGE SLUDGE DIRECTIVE (86/278/EEC)		
Use of Sewage Sludge in Agriculture Regulations (SI 148 of 1998) as amended in 2001: **Purpose:** require that sewage sludge is used in accordance with a nutrient management plan. **Relevant actions:** Supervise the supply and use of sewage sludge in agriculture and ensure that it is used in accordance with nutrient management plans. Maintain a register of sludge biosolids movements and use and make it available to the public. Ensure adherence to the code of practice in relation to the use of biosolids in agriculture.	Local authorities	2009–2015 National
Waste Management Act (No. 10 of 1996): **Purpose:** to regulate waste management in order to protect human health and the environment. **Relevant actions:** Prepare sludge management plans for the management of wastewater sludge (taking account of WFD objectives). Require measures to be taken in relation to the holding, recovery or disposal of waste in order to prevent or limit environmental pollution, where necessary. Require land owners to prepare nutrient management plans where necessary.	Local authorities	2009–2015 National
URBAN WASTEWATER TREATMENT DIRECTIVE (91/271/EEC)		
Urban Wastewater Treatment Regulations (SI 254 of 2001) as amended in 2004 and 2010: **Purpose:** to ensure that the environment is not adversely affected by the disposal of inadequately treated urban waste water through the provision of urban wastewater collection systems and treatment plants. **Relevant actions:** Design, construct, operate, maintain and monitor treatment plants to achieve requirements in relation to treatment standards, nutrient sensitive areas and WFD objectives. Choose discharge points so as to minimise impact on the	Local authorities, DEHLG	2009–2015 National

What	Who leads	When & where
environment. Ensure that sewage sludge can be disposed of safely. Financial investments can be made under the Water Services Investment Programme. **Water Services Act (No 30 of 2007):** **Purpose:** to facilitate the provision of safe and efficient water services and water service infrastructure for domestic and non-domestic requirements. **Relevant actions:** Plan and supervise provision of wastewater services under the Water Services Investment Programme. Prepare and implement Water Services Strategic Plans to support sustainable provision of wastewater services.	Local authorities	2009–2015 National
PLANT PROTECTION PRODUCTS DIRECTIVE (91/414/EEC)		
Authorisation, Placing on the Market, Use & Control of Plant Protection Products Regulations (SI 83 of 2003) as amended from 2003 to 2009: **Purpose:** to authorise plant protection product for use or placing on the market to ensure that no harmful effects arise for human and animal health and that there is no unacceptable impact on the environment **Relevant actions:** Notify the DEHLG of all new information on potentially dangerous effects of authorised plant protection products on the environment or groundwater. The conditions of authorisation are selected to minimise risks for consumers, workers and the environment. The use of a plant protection product in a manner other than specified on its approved label is illegal.	Relevant persons	2009–2015 National
NITRATES DIRECTIVE (91/676/EEC)		
Good Agricultural Practice for the Protection of Waters Regulations (SI 101 of 2009): **Purpose:** provide statutory support for good agricultural practice to protect waters against pollution from agricultural sources and give further effect to several EU Directives including the Nitrates Directive, dangerous substances in water, waste management, protection of groundwater, public participation in policy development and water policy (the Water Framework Directive). **Relevant actions:** Review the nitrates National Action Programme to determine its effectiveness, including Agricultural Catchment Programme studies, in consultation with all interested parties. Ensure implementation of the National Action Programme. Monitor as necessary for the purposes of the Regulations. Provide recommendations and direction to local authorities	DEHLG, DAFF EPA	2009–2015 National

What	Who leads	When & where
with respect to monitoring, inspections and measures. Carry out monitoring to establish the extent of pollution in surface and groundwaters attributable to agriculture and determine trends in the occurrence and extent of such pollution. Carry out farm inspections (to coordinate with other farm inspection programmes). **Additional actions: Agriculture:** Consider increasing farm inspections in karst areas with turloughs and piloting of environmentally friendly farming scheme Map turloughs' zones of contribution.	Local authorities, DAFF DAFF, DEHLG-NPWS	
INTEGRATED POLLUTION PREVENTION CONTROL DIRECTIVE (2008/1/EC)		
Environmental Protection Agency Acts (No 7 of 1992; No 27 of 2003) and Environmental Protection Agency (Licensing) Regulations (SI 85 of 1994) as amended in 1995, 1996, 2004 and 2008: **Purpose:** to prevent or reduce emissions to water, land and air, to reduce waste and to use energy and resources efficiently. **Relevant actions:** Ensure that operators of certain industrial and agricultural installations obtain IPPC licenses with conditions and ELVs based on BAT and relevant national and European legislation. Enforce licence conditions including monitoring. Maintain a register of licences and make available to the Commission and to the public. Undertake reviews of existing licences as required (taking account of WFD and Environmental Quality Objectives). Ensure cross border consultation where necessary. Obtain the consent of sanitary authorities for discharges to sewers	EPA Operator	2009–2015 National
COST RECOVERY FOR WATER SERVICES		
Water Pricing Policy: **Purpose:** to promote the conservation and efficient use of water resources in accordance with the Water Framework Directive **Relevant actions:** Develop and implement strategy to achieve water metering of domestic users connected to public water supplies. Introduce legislation to allow local authorities to charge domestic users for water services. Develop charging methodology for water services and introduce water charges for domestic users.	DEHLG DEHLG Local Authorities	2009–2015 National
PROMOTION OF EFFICIENT AND SUSTAINABLE WATER USE		
Water Services Act (No. 30 of 2007):		2009–2015

What	Who leads	When & where
Purpose: to facilitate the provision of safe and efficient water services and water service infrastructure for domestic and non-domestic requirements.		National
Relevant actions:		
Develop and implement strategy to achieve water metering of domestic users connected to public water supplies.	DEHLG	
Facilitate the provision of efficient water services.		
Rehabilitate and repair water works.	Local Authorities	
Ensure that water distribution systems are in a fit state and free from leaks.	Premises owner/occupier	
National Water Conservation (Leakage Reduction) Programme:		2009–2015
Purpose: to establish water conservation and leakage control strategies.		National
Relevant actions:		
Establish and maintain GIS-based water management systems. Establish an ongoing leakage control programme. Rehabilitate and replace defective water supply networks. Develop water conservation public awareness campaigns. Provide project-specific funding designed to meet specific leakage reduction targets.	Local authorities, DEHLG	
PROTECTION OF DRINKING WATER SOURCES		
Groundwater Protection Schemes:		2009–2015
Purpose: to protect groundwater sources by enabling regulatory authorities to take account of the potential risks to groundwater when considering the control and location of potentially polluting activities.		National
Relevant actions:		
Control the location and nature of developments and activities in accordance with groundwater protection schemes.	Local authorities	
Good Agricultural Practice for the Protection of Waters Regulations (SI 101 of 2009):		2009–2015
Purpose: the protection of waters against pollution caused by nitrates from agricultural sources.		National
Relevant actions:		
Exclude chemical and organic fertilisers and farm manures from within specified distances of wells, boreholes, springs or abstractions points	Farmers	
Planning and Development Act (No. 30 of 2000):		2009–2015
Purpose: to provide for the proper planning and development of urban and rural areas.		National
Relevant actions:		

What	Who leads	When & where
Control of developments and activities in order to protect water resources.	Local authorities, An Bord Pleanála DEHLG	
Water Policy Regulations (SI 722 of 2003) as amended in 2005: **Purpose**: to provide a statutory basis for the provisions of the Water Framework Directive including the establishment and maintenance of a Register of Protected Areas.		2009–2015 Designated sites
Relevant actions: Keep Register of Protected Areas, which includes protected drinking waters, updated.	EPA	
Also, identify and protect all surface and groundwater bodies that are used, or may be used in the future, as sources of drinking water for more than 50 people or where the rate of abstraction is > 10m^3 per day. Establish monitoring programmes for bodies of water providing >100 cubic metres as an average. Ensure that there is no deterioration of quality in identified bodies of water so as to reduce the level of purification treatment required.	To be assigned	
Consideration is also being given to the designation of safeguard zones around current and future abstractions under the Drinking Water Regulations.	To be assigned	
ABSTRACTION AND IMPOUNDMENTS		
Environmental Impact Assessment Regulations (SI 349 of 1989) as amended from 1994 to 2006: **Purpose:** require that certain developments be assessed for likely environmental effects before planning permission can be granted.		2012–2015 National
Relevant actions: Undertake environmental impact assessment for drilling for water supplies above specified thresholds, groundwater abstraction and artificial groundwater recharge schemes above specified thresholds and works for the transfer of water resources between river basins above specified thresholds.	Local authorities	
Water Pollution Act (No 1 of 1977) as amended in 1990: **Purpose:** to provide for the control of water pollution thereby protecting possible drinking water sources		2012–2015 National
Relevant actions: Maintain registers of abstractions and make available to the public.	Local authorities	
Water Supplies Act (SI 1 of 1942): **Purpose:** require that provisional orders be obtained by local authorities abstracting drinking water supplies.		2009–2015 Prioritised sites

What	Who leads	When & where
Relevant actions: Local authorities must adhere to conditions set down in provisional orders when abstracting drinking water from a water source.	Local authorities, DEHLG	
Planning and Development Act (No. 30 of 2000) as amended in 2002: **Purpose:** to provide for the proper planning and development of urban and rural areas.		2009–2015 Prioritised sites
Relevant actions: Local authorities must obtain planning permission for groundwater abstractions for public drinking water supplies.	Local authorities, An Bord Pleanála	
Additional actions: Abstractions: Good practice measures are available in the Programmes of Measures – technical studies – Abstractions and National Summary Programme of Measures background documents.		
POINT SOURCE DISCHARGES		
Environmental Objectives (Surface Water) Regulations (SI 272 of 2009): **Purpose:** The establishment of legally binding quality objectives for all surface waters and environmental quality standards for pollutants. Public authorities are required to examine and where appropriate, review existing discharge authorisations to ensure that the emission limits laid down in authorisations support compliance with the new water quality objectives/standards. .		2009–2015 National
Relevant actions: Establish measures to achieve the quality objectives and standards. Where necessary, consult with other public authorities and with relevant competent authorities in Northern Ireland.	Public authorities	
Set emission limits based on BAT when authorising new discharges to ensure achievement of the quality objectives. Review all existing discharge authorisations to take into account the new quality standards. Prepare programmes for the monitoring and inspection of farm installations to verify compliance.	Local authorities, EPA, DEHLG	
Classify waters and make the classification available in GIS. Establish an inventory of emissions discharges and losses of priority substances, priority hazardous substances and other pollutants.	EPA	
Prepare a plan for the progressive reduction of pollution by priority substances and the ceasing or phasing out emissions, discharges and losses of priority hazardous substances.	Coordinating local authority	
Environmental Objectives (Groundwater) Regulations (SI 9 of 2010): **Purpose:** The establishment of legally binding quality objectives for all bodies of groundwater and environmental		2009–2015 National

What	Who leads	When & where
quality standards for pollutants. Public authorities are required to examine and where appropriate, review existing discharge authorisations to ensure that the emission limits laid down in authorisations support compliance with the new water quality objectives/standards.		
Relevant actions: All direct discharges of pollutants into groundwater are prohibited subject to certain exemptions.	Local authorities	
Point source discharges and diffuse sources liable to cause groundwater pollution must be controlled so as to prevent or limit the input of pollutants into groundwater.	EPA	
Identify hazardous and non-hazardous substances for the purpose of preventing and limiting pollutant inputs	EPA	
Where necessary or appropriate, issue advice and/or give directions to a public authority or authorities concerned on the measures to be taken to prevent and limit inputs of pollutants into groundwater.	EPA	
Where necessary or appropriate, issue advice and/or give directions to a public authority or authorities concerned on the measures to be taken to prevent and limit inputs of pollutants into groundwater.	EPA	
Where necessary or appropriate: (a) review, or cause to have reviewed, existing codes of practice including other such mechanisms and controls already in place for the purpose of preventing or limiting the input of pollutants into groundwater; (b) identify such other areas and/or activities requiring the introduction of similar type controls so as to prevent or limit the input of pollutants into groundwater ; (c) direct a public authority to undertake a review and, where necessary, update a code of practice, or in the case of an activity requiring the introduction of new controls, prepare a new code of practice or system of control for the activity in question. A public authority must comply with the direction given by the Agency within the timeframe prescribed;	EPA	
Examine and if necessary review all existing discharge authorisations to groundwater to take into account the new quality standards and to prevent or limit inputs of pollutants to groundwater.	Relevant authorities	
Water Pollution Act (No 1 of 1977) as amended in 1990 and Water Pollution Regulations (SI 108 of 1978) as amended in 1992 and 1996: **Purpose:** to provide for the control of water pollution through prosecution for water pollution offences; use of pollution control conditions in the licensing of effluent discharges; issue of notices specifying measures to prevent water pollution.		2009–2015 National

What	Who leads	When & where
Relevant actions: License discharges to surface waters and sewers from small scale industrial and commercial sources. Review licenses at intervals of not less than 3 years. Keep registers of discharge licenses and make them available to the public.	Local authorities	
Prosecute for water pollution offences; attach appropriate pollution control conditions in the licensing of effluent discharges from industry, etc., made to waters or to sewers; issue notices specifying measures to be taken within a prescribed period to prevent water pollution; Issue notices to stop pollution of waters and requiring the mitigation or remedying within a period specified; seek court orders, including High Court injunctions.	Local authorities, Fisheries Boards, DEHLG-NPWS	
Notify local authorities of accidental discharges and spillages of polluting materials which enter, or are likely to enter, waters.	Relevant persons	
Wastewater Discharge Authorisation Regulations (SI 684 of 2007): **Purpose:** to provide for the authorisation by the EPA of urban waste water discharges by local authorities.		2009–2015 National
Relevant actions: Authorise Local Authority WWTPs (taking account of WFD objectives). Review licenses at intervals not less than 6 years. Enforce compliance with WWTP licensing conditions. Maintain a register of WWTP licences and certificates and make available on request.	EPA	
Water Services Act (No 30 of 2007): **Purpose:** to facilitate the provision of safe and efficient water services and water service infrastructure for domestic and non-domestic requirements.		2009–2015 National
Relevant actions: Prepare and implement Water Services Strategic Plans.	Local Authorities	
Duty of care on owners of premises to ensure that treatment systems for wastewater are kept in good condition.	Relevant Persons	
Additional actions: Urban Wastewater Treatment Plants: Measures for improved management: keep register of plant capacity and update annually; install facilities to monitor influent loads and effluent discharges in accordance with EPA guidelines and best practice; put auditable procedures in place to monitor compliance of licensed discharges; implement training procedures for staff involved with licensing of discharges; monitor receiving water quality upstream and downstream of the point of discharge.	Local Authorities	2009–2015 Prioritised Sites
Optimise treatment plant performance by the implementation of a performance management system supported by the	Local Authorities	

What	Who leads	When & where
use of decision making tools. Actions have been identified for certain categories of treatment plant: • Category 1 - Agglomerations with treatment plants requiring identifiable Capital Works. • Category 2 - Agglomerations with treatment plants requiring further investigation prior to Capital Works. • Category 3 - Agglomerations requiring the implementation of actions identified in Pollution Reduction Plans for Shellfish Waters designated under the Shellfish Water Regulations. • Category 4 - Agglomerations with treatment plants requiring improved operational performance through the implementation of Performance Management Systems. • Category 5 - Agglomerations requiring investigation of Combined Storm Overflows (CSOs). • Category 6 - Agglomerations where existing waste water treatment capacity is currently adequate but predicted loadings (based on assumed 3% growth in load per annum) would result in overloading requiring management of development. Good practice measures are available in the Programmes of Measures – technical studies – Municipal and Industrial Regulations, Urban Pressures and National Summary Programme of Measures background documents.		
Minerals Development Act (No 31 of 1940) as amended from 1960 to 1999: **Purpose:** to provide for the development and working of the mineral resources of the State whilst managing potential impact on the water environment		2009–2015 National
Relevant actions: Grant Prospecting Licenses for exploration of specified minerals in specified areas subject to conditions. Grant Minerals or Mining Licenses with respect to State owned minerals. Grant Mining Permissions to work substances in small quantities. Grant Unworked Minerals Licenses with respect to unworked minerals.	DCENR	2009–2015 Prioritised Sites
Energy Act (No. 40 of 2006): **Purpose:** to regulate the energy industry whilst managing potential impact on the water environment		
Relevant actions: Prepare Mine Rehabilitations Plans for the long-term rehabilitation of mine sites where it is considered necessary for the purposes of public or animal health or the environment.	DCENR Local authorities,	2009–2015 Prioritised Sites
Waste Management Act (No 10 of 1996) as amended in 2001: **Purpose:** to regulate waste management in order to protect human health and the environment.		
Relevant actions:	EPA, GSI	

What	Who leads	When & where
Prepare an inventory of closed waste disposal or recovery sites. **European Communities (Quality of Shellfish Waters) Regulations (SI 268 of 2006) as amended in 2009:** **Purpose:** to protect or improve shellfish waters in order to support shellfish life and growth by setting water quality requirements to be met. **Relevant actions:** Undertake monitoring and investigate pollution. Develop and implement Shellfish Pollution Reduction Programmes, including any necessary measures, to achieve shellfish water quality standards. **European Communities (Freshwater Pearl Mussel) Regulations (SI 296 of 2009):** **Purpose:** For the purpose of achieving the water quality objectives established for designated sites for the protection of freshwater pearl mussel populations. **Relevant actions:** Public authorities that authorise discharge to any of the listed rivers to set down emission limit values that aim to achieve the prescribed ecological quality targets; and to examine existing authorisations within a set time and review them as appropriate.	 DEHLG, Local authorities Public authorities	2009–2015 Designated sites 2009–2015 Designated sites
DIFFUSE SOURCE DISCHARGES		
Water Pollution Act (No 1 of 1977) as amended in 1990 and Water Pollution Regulations (SI 108 of 1978) as amended in 1992 and 1996: **Purpose:** to provide for the control of water pollution through prosecution for water pollution offences; use of pollution control conditions in the licensing of effluent discharges made to waters or to sewers; issue of notices specifying measures to be taken to prevent water pollution. **Relevant actions:** Serve notices or directions on persons requiring measures to be taken in order to prevent or control pollution of waters, where necessary. Notify local authorities of accidental discharges and spillages of polluting materials which enter, or are likely to enter, waters. **Planning and Development Act (No 30 of 2000) as amended in 2002:** **Purpose:** to provide for the proper planning and development of urban and rural areas. **Relevant actions:** Grant permission for on-site waste water treatment systems subject to site suitability assessment.	 Local authorities, Fisheries Boards, DEHLG-NPWS Relevant persons	2009–2015 National 2009–2015 National

What	Who leads	When & where
EPA Code of Practice for Wastewater Treatment Systems serving Single Houses (2009) **Purpose:** to provide guidance on the provision of wastewater treatment and disposal systems for new single houses. **Relevant actions:** the guidance addresses the following Assess site suitability for on-site wastewater treatment systems and identify minimum environmental protection requirements Select suitable wastewater treatment systems for sites in un-sewered rural areas Design and install septic tank systems, filter systems, packaged treatment systems and tertiary treatment systems, Maintenance requirements for on-site wastewater treatment systems. The guidance is supported by DEHLG circular letter (Reference PSSP 1/10) and Planning Guidelines on Sustainable Rural Housing (2005) Amend the Technical Guidance Document supporting the 1997 Building Regulations (SI 497 of 1997) relating to standards for "drainage and waste water disposal" (TGD-H of 2005) and issue a supporting Circular Letter to all Local Building Control Authorities. For existing unsewered properties, bring forward and consult on proposals for legislation to provide standards for the performance, operation and maintenance of septic tanks and similar on-site wastewater treatment systems and also for the monitoring and inspection of the performance of such treatment systems and set out the responsibilities of households served by those systems, including requirements to carry out remedial actions where necessary. **Additional actions: On-site systems:** Good practice measures are available in the Programmes of Measures – technical studies – On-site wastewater treatment systems and National Summary Programme of Measures background documents. **Forestry Act (No 13 of 1946) as amended in 1976 and 1988 and Aerial Fertilisation Regulations (SI 592 of 2006) as amended in 2007 and codes of practice, guidance documents administered through a grant support system:** **Purpose:** to provide for the development and regulation of forestry. **Relevant actions:**	Local authorities Planning authorities, developers, manufacturers designers, installers and operators Planning authorities & An Bord Pleanála DEHLG Minister for the Environment, Heritage and Local Government	2009–2015 National 2010 2009–2015 National

What	Who leads	When & where
Promote forestry with financial incentives. License forestry activity and where necessary, attach additional conditions in sensitive areas.	Forest Service	
Encourage sustainable, commercial afforestation. Ensure compliance with guidance and codes of practice.	Forest Service	
A new Forestry Bill, replacing the 1946 Forestry Act, has been drafted to strengthen sustainable forestry management. Provisions relating to water protection are; • All forestry operations must be carried out in accordance with any guidelines and regulations issued by the Minister for Agriculture, Fisheries and Food. • Allowing for change of land use from forestry to other sustainable uses.	Minister for the Department of Agriculture, Fisheries and Food	
In acid sensitive catchments apply a protocol agreed between the Department of Environment, Heritage and Local Government, the Forest Service, the EPA and COFORD for dealing with grant-aid applications in acid sensitive areas. All relevant applications received by the Forest Service are checked for alkalinity levels in run-off water. Borderline cases are referred to the Environmental Protection Agency for recommendations.	Forest Service, EPA	
2008 guidelines for the protection of Natura 2000 sites designated for the protection Freshwater Pearl Mussel populations from forestry activities are intended to ensure that forest operations such as afforestation, forest road construction, harvesting and forest planning are compatible with the protection of this particularly sensitive species. The guidelines describe a range of measures intended to reduce any potential negative impacts on the species arising from forest operations.	Forest Service	2009–2015 National
Strategic Plan for the Development of Forestry: **Purpose:** to provide for the development and regulation of forestry.		
Relevant actions: Adhere to forest management plans and the principles of sustainable forest management.	All stakeholders	
Ensure implementation of the National Forestry Standard and adherence to the code of best forest practice.	Forest Service	
Additional actions: Forestry: Good practice measures are available in the Programmes of Measures – technical studies – Forest and Water and National Summary Programme of Measures background documents.		2009–2015 Designated sites
Environmental Objectives (Freshwater Pearl Mussel) Regulations (SI 296 of 2009) **Purpose:** For the purpose of achieving the water quality objectives established for designated sites for the protection of freshwater pearl mussel populations.		

What	Who leads	When & where
Relevant actions: Develop management plans (sub-basin plans of River Basin Management Plans), including any necessary measures, to ensure achievement of environmental quality objectives.	DEHLG-NPWS, relevant public authorities	
AUTHORISATION OF DISCHARGES TO GROUNDWATERS		
Environmental Objectives (Groundwater) Regulations (SI 9 of 2010): **Purpose:** to provide for specifying the criteria for classifying groundwater status and identifying significant increasing pollution trends; provide for a proportionate risk–based response to groundwater protection.		2009–2015 National
Relevant actions: Review all existing discharge authorisations to take into account the new quality standards.	Local authorities	
Wastewater Discharge Authorisation Regulations (SI 684 of 2007): **Purpose:** Where a local authority proposes to discharge urban waste water effluent to groundwater an authorisation by the Environmental Protection Agency is required.		2009–2015 National
Relevant actions: Authorisation of Local Authority WWTPs effluent discharges discharging to groundwater.	EPA	
Water Pollution Act (No 1 of 1977) as amended in 1990: **Purpose:** to provide for the control of water pollution**.**		2009–2015 National
Relevant actions: License discharges to groundwaters from small scale industrial and commercial sources. Review licenses at intervals of not less than 3 years. Keep registers of discharge licenses and make them available to the public.	Local authorities	
PRIORITY SUBSTANCES		
Environmental Objectives (Surface Water) Regulations (SI 272 of 2009): **Purpose:** to provide for quality objectives for surface waters, EQSs for pollutants, review of discharge authorisations, classification of surface waters, inventories of priority substances.		2009–2015 National
Relevant actions: Prepare a plan for the progressive reduction of pollution by priority substances and the ceasing or phasing out of emissions, discharges and losses of priority hazardous substances. Establish an inventory of emissions discharges and losses of priority substances, priority hazardous substances and other pollutants and publish a summary of the	EPA, coordinating local authority	

What	Who leads	When & where
inventory.		
Chemicals Act (No. 13 of 2008): **Purpose:** to provide for the regulation of certain dangerous chemicals.		2009–2015 National
Relevant actions: Administration and enforcement of the European Registration, Evaluation and Authorisation of Chemicals regulations (REACH).	Health and Safety Authority	
Identify and manage risks linked to the chemicals manufactured or imported and registration of chemicals produced or imported in quantities greater than 1 tonne.	Manufacturers or importers of chemicals	
European Pollutant Release and Transfer Register Regulations (SI 123 of 2007): **Purpose:** the prevention and reduction of pollution by the establishment of a publicly accessible pollutant release and transfer register.		2009–2015 National
Relevant actions: Submit required data in relation to releases of pollutants and off-site transfers of pollutants and waste.	Operators	
Provide for electronic collection, assessment of data and report data to the EU Commission in relation to releases of pollutants and off-site transfers of pollutants and waste. Enforce regulations.	EPA	
PHYSICAL MODIFICATIONS		
Planning and Development Act (No 30 of 2000) as amended in 2002; Environmental Impact Assessment Regulations (SI 349 of 1989) as amended from 1994 to 2006: **Purpose:** to provide for the proper planning and development of urban and rural areas. Require that certain developments be assessed for likely environmental effects before planning permission is granted.		2009–2015 National
Relevant actions: Consider the environmental impacts of developments as part of the planning process.	Local authorities	
Additional actions: Physical modifications: Good practice measures are available in the Programmes of Measures – technical studies – Freshwater Morphology, Marine Morphology and National Summary Programme of Measures background documents.		
Investigate the ecological potential of heavily modified waters and implement identified mitigation measures.	Relevant public authorities	2009–2015 Prioritised sites

What	Who leads	When & where
OTHER ACTIVITIES IMPACTING ON WATER STATUS		
Alien species: Introduce new regulations under the Wildlife Act to control introduction or possession of any species of flora or fauna which may be detrimental to native species.	DEHLG	2009–2015 National
PREVENTION OR REDUCTION OF THE IMPACT OF ACCIDENTAL POLLUTION INCIDENTS		
Framework of Major Emergency Management **Purpose:** framework for emergency preparedness and response capability identifying hazards and risk to society, the economy, but also the environment including our natural water resource. **Relevant actions:** Prepare Major Emergency Plans with supporting plans, procedures and arrangements. Initiate a major emergency development programme for the implementation of the Major Emergency Plans. Co-ordinate the inter-agency aspects of major emergency preparedness and management in assigned regions. Ensure and promote implementation of the Framework.	 Local authorities, An Garda Síochána, HSE Dept of Justice, Equality & Law Reform, Dept of Health & Children, DEHLG	2009–2015 National
OTHER ISSUES		
Climate change: all measures have been assessed to ensure that the plan adequately considers the potential impacts of climatic change (see Chapter 6) – this will be reviewed as climate change information improves.	DEHLG, EPA	2009–2015 National
Invasive alien species: support measures being developed by the national alien species study (conducted by QUERCUS) and local investigations at district level	DEHLG-NPWS, local authorities	2009–2015 National
Cruising and boating: enforce pump-out control and speed restrictions at district level.	Waterways Ireland, local authorities	2009–2015 Prioritised sites
Peat extraction: enforce licensing controls and rehabilitation plans at district level.	EPA, local authorities, Bord na Móna	2009–2015 Prioritised sites

Table 6.2 Freshwater pearl mussel additional measures.

The following is the full national list of measures to address all pressures impacting on the freshwater pearl mussel and its habitat in the 27 SAC catchments. These measures will only be implemented if and where required in the Bundorragha catchment, subject to resource availability, on a prioritized basis and at those sites where investigations and risk assessment show that specific pressures need to be remediated to restore pearl mussels to favourable conservation status. To reiterate, not all of the measures listed below will apply in this catchment and any measures that do apply may only be implemented in restricted areas. A summary of the specific measures that apply to the Bundorragha catchment is given in Chapter 7. Further detail on the catchment-specific measures will be provided in the final plan.

	Freshwater pearl mussel measure	Who Leads	When and where
1	**Public Awareness**		
	An education and awareness campaign shall include, farm visits, public meetings, clinics, talks (to schools, etc.) and the distribution of leaflets. Topics covered will include the biology and ecology of pearl mussels and damage caused by pearl fishing, in-stream activities, sedimentation and nutrient enrichment. The measures necessary for their conservation shall be explained. Other issues such as litter prevention, the use of low phosphate detergent, correct disposal of domestic wastewater and disposal of oil shall be included in the campaign.	DEHLG (National Parks and Wildlife Service) and Local Authorities	
2	**Stakeholder Involvement**		
	Stakeholder assistance in the further development and design of measures will be encouraged, through meetings with relevant individuals and organisations.	Relevant public authority	
3	**Guidance**		
	Appropriate guidance will be provided to different sectors to assist with their compliance with the Freshwater Pearl Mussel Regulations (S.I. 296 of 2009) and Article 6 of the Habitats Directive (i.e. Appropriate Assessment).	DEHLG (National Parks and Wildlife Service)	
4	**Appropriate assessment under Article 6 of the Habitats Directive**		
	All plans, programmes and projects with the potential to impact on the pearl mussel SAC population, or any other Natura 2000 sites and their qualifying features, must be screened for Appropriate Assessment in accordance with Article 6 of the Habitats Directive, and, where judged necessary, an Appropriate Assessment must be conducted. In addition, all plans (e.g. Development Plans, forestry catchment management plans) and programmes (e.g. agri-environmental schemes) are likely to require Strategic Environmental Assessment (SEA).	Relevant regulatory authority	
5	**Habitats Directive Controls**		
5a	Notify stakeholders of measures required under the Sub-basin Management Plan.	DEHLG (National Parks and Wildlife Service)	
5b	Certain operations or activities within SACs require the consent of the Minister for the Environment Heritage and Local Government under the Habitats Regulations (S.I. 94 of 1997). This list is currently being revised. Once the list of these operations or activities (activities requiring consent/ notifiable actions) has been revised, it shall be formally notified to the relevant owners, occupiers or users in the	DEHLG (National Parks and Wildlife Service)	

	pearl mussel SACs.		
6	**Municipal and Industrial Discharges**		
6a	Examine and review all authorizations to discharge to waters within Freshwater Pearl Mussel SAC catchments, and revise those authorizations to comply with Schedule Four of S.I. 296 of 2009.	Local Authorities/ Environmental Protection Agency	
6b	Upgrade treatment to ensure compliance with any revised discharge standards set by the Regulatory Authority to ensure achievement of objectives set out in Schedule Four of S.I. 296 of 2009.	Operator	
6c	Municipal wastewater. Conduct investigations into and mitigate as required: i) The condition of the sewerage network and containment areas, ii) The extent of the sewerage network and connection of peripheral properties, iii) Storm overflows, iv) Wastewater Treatment Plant (WwTP) performance, v) Discharge quality, vi) Impacts on receiving waters.	Local Authorities	
6d	Municipal wastewater. Upgrade municipal wastewater treatment through: i) Provision of appropriate WwTP, ii) Connection of additional unsewered/sewered properties to WwTP, iii) Repair of damaged collecting systems, iv) Upgrade of WwTP capacity, v) Upgrade of treatment level, vi) Improvements in operational performance, vii) Additional monitoring.	Local Authorities	
6e	Municipal wastewater. Prioritise investment in WwTPs within pearl mussel SAC catchments under the Water Services Investment Programme (WSIP).	DEHLG (Water Inspectorate)	
7	**Quarries**		
7a	Examine and review all authorizations to discharge from quarries to waters within pearl mussel SAC catchments, and revise those authorizations to comply with Schedule Four of S.I. 296 of 2009.	Local Authorities	
7b	Upgrade treatment and mitigation measures to ensure compliance with any revised discharge standards set by the Local Authority to achieve of the objectives set out in Schedule Four of S.I. 296 of 2009. Mitigation measures will be designed to reduce sediment loss at source and/or intercept sediment along the pathway to the river.	Operator	

8	**Abstractions - Implementation of these measures will only occur at the specific sites where they are required.**		
8a	An Appropriate Assessment, under Article 6 of the Habitats Directive, shall be conducted for each abstraction identified as a significant potential risk in this Sub-basin Management Plan.	Local Authorities/Operator	
8b	Further investigation and screening for Appropriate Assessment shall be conducted of other existing or future abstractions identified in this Sub-basin Management Plan or within the life-cycle of this plan to assess potential significant impacts on the pearl mussel. Appropriate Assessments shall be conducted where necessary.	Local Authorities	
8c	Introduce reduction and remediation measures as appropriate to mitigate the impacts on pearl mussels from abstractions.	Local Authorities/Operator	
9	**Unnatural flows**		
	Conduct further investigations and, where necessary, an Appropriate Assessment under Article 6 of the Habitats Directive into the impacts of any flow regulation identified in this Sub-basin Management Plan on the pearl mussel population. Where necessary, a plan shall be made and implemented to control flows in a manner that supports the sustainable reproduction of the pearl mussel. Monitoring of the success of changes implemented shall be carried out.	Operator	
10	**Morphological alterations – appropriate control**		
	Enact necessary legislative change to control morphological alterations of surface waters. (Note: this measure is linked to measure 19 below, as developments such as alteration of the bed and banks of a river are currently exempted).	DEHLG	
11	**Morphological alterations - remediation of morphological pressures**		
	Undertake the required morphological remediation measures at locations identified under this Sub-basin Management Plan, or through further investigation during the life-cycle of the plan (up to 2015).	DEHLG (National Parks and Wildlife Service), Central and Regional Fisheries Boards, DAFF (Marine)	
12	**Morphological alterations - sand and gravel extraction**		
	No sand, gravel or stone shall be removed from rivers designated for freshwater pearl mussel, unless an appropriate assessment determines that there will be no significant negative impacts on the pearl mussel. (Note: sand and gravel extraction should be controlled under measure 10 above).	Local Authorities/Planning Authorities	
13	**Catchment Modelling**		
	Model/predict sediment, nutrient, and dangerous substance losses in pearl mussel SAC catchments to assist in developing and targeting measures for diffuse pollution.	Local Authorities/ Environmental Protection Agency /DAFF /DEHLG	
	Agricultural Measures **(Note:** Appropriate agricultural measures shall be implemented in areas that have been identified as presenting significant actual or potential risks of sediment and/or nutrient loss, hydrological pressures and/or dangerous substances loss and are, therefore, likely to impact upon the pearl mussel population.)		

14	**Agri-environmental scheme**		
14a	Develop and roll-out an agri-environmental scheme, which could, if appropriate, be incorporated into other existing schemes, for target areas within pearl mussel SAC catchments to achieve the objectives of this plan. (Work is ongoing to identify the target areas).	DAFF and DEHLG	
14b	The overall objective would be that all farms within the target areas in pearl mussel SAC catchments would have a farm plan under Measure 14a.	Owner, occupier, user	
14c	The specific measures for each farm, required under the agri-environmental scheme (14a), will be produced with the assistance of appropriately trained advisers/planners.	Owner, occupier, user	
14d	Production of the farm plans under the agri-environmental scheme (14a) will require a comprehensive farm walk-over survey and risk assessment.	Owner, occupier, user and registered farm planners/advisers	
14e	Appropriate training in risk assessment and management responses shall be provided to all farm advisers.	DAFF and DEHLG	
14f	Farm plans in the target areas may include any of the following measures, but only if they are found, under Measure 14d, to be required:	Owner, occupier, user and registered farm planners/advisers	
14f	i) Fence livestock from watercourses to avoid direct damage to and trampling on pearl mussels.	Owner, occupier, user	
14f	ii) Nutrient and sediment management plans are required for all farms.	Owner, occupier, user and registered farm planners/advisers	
14f	iii) Soil testing for phosphorus, pH, organic content, aluminium, iron and calcium, on a field by field basis, shall inform the nutrient management plan.	Owner, occupier, user and registered farm planners/advisers	
14f	iv) Fence drains, streams and rivers to prevent bank and channel disturbance/erosion.	Owner, occupier, user	
14f	v) Prevent or mitigate machinery and/or livestock access to and through watercourses (ramps and fords)	Owner, occupier, user	
14f	vi) Locate drinking water troughs away from watercourses (>30 m), steep slopes adjacent to watercourses and waterlogged land.	Owner, occupier, user	
14f	vii) Reduce soil disturbance (tillage, ploughing, digging, cultivation, etc.), in critical source areas for sediment.	Owner, occupier, user and registered farm planners/advisers	
14f	viii) Reduce stocking rates to sustainable levels where there is significant risk of erosion due to overgrazing.	Owner, occupier, user and registered farm planners/advisers	

14f	ix) Install appropriately sized, designed and located sediment traps/barriers where required, e.g. in drainage ditches.	Owner, occupier, user and registered farm planners/advisers	
14f	x) Locate or relocate gateways away from high-risk areas, in order to prevent sediment loss to watercourses. Where risks to watercourses remain, mitigate by providing gravel hardcore around gateway.	Owner, occupier, user and registered farm planners/advisers	
14f	xi) Locate trackways away from drains and river margins. Prevent direct connectivity and sediment loss from tracks to watercourses.	Owner, occupier, user and registered farm planners/advisers	
14f	xii) Develop measures to increase infiltration and slow surface run-off, e.g. through tree planting.	Owner, occupier, user and registered farm planners/advisers	
14f	xiii) Reduce application of fertiliser, slurry or farmyard manure, particularly within critical source areas for nutrients.	Owner, occupier, user and registered farm planners/advisers	
14f	xiv) Establish site-specific buffer zones along drains and watercourses to intercept sediment and nutrients. Design of these buffer zones will factor-in precipitation, run-off, slope, soil type (including erodability, current phosphorus concentration and P-retention capacity), adjacent land use, stocking densities etc. (Options for buffer zones include grass, trees or Native Woodland Scheme)	Owner, occupier, user and registered farm planners/advisers	
14f	xv) Create artificial wetlands or filter beds in target areas to address point sources e.g. farmyards or eroding drains.	Owner, occupier, user and registered farm planners/advisers	
14f	xvi) Strict adherence to guidelines on pesticide usage (See measures 15 d and i and 22b). Pesticides, herbicides and veterinary products should not be applied near watercourses, on waterlogged land or on steeply sloping land adjacent to watercourses.	Owner, occupier, user and registered farm planners/advisers	
14f	xvii) Reduce application of lime, if required.	Owner, occupier, user and registered farm planners/advisers	
14g	Inspect implementation of all pearl mussel measures required by farm plans.	DAFF and DEHLG	
14h	Apply weighting to farms in agri-environmental scheme in the farm selection process for cross-compliance monitoring, in order to increase likelihood of inspection.	DAFF	
14i	Train agricultural inspectors in the risk assessment and pearl mussel measures required under the agri-environmental scheme.	DAFF	
14j	Monitor the effectiveness of pearl mussel measures implemented under agri-environmental schemes	DAFF and DEHLG	

14k	Make all data provided and collected under the agri-environmental scheme available to the relevant public authorities e.g. LA, DAFF, EPA, DEHLG.	DAFF and DEHLG	
15	**General Agricultural Measures – to be applied only when and where necessary throughout all freshwater pearl mussel SAC catchments**		
15a	Locate supplementary feeding stations away from watercourses (>30 m), steep slopes adjacent to watercourses and waterlogged land. Move such stations regularly to avoid nutrient build-up and excessive poaching.	Owner, occupier, user and registered farm planners/advisers	
15b	Avoid removal or disturbance of bank side/ riparian vegetation and maintain all existing buffer zones along watercourses.	Owner, occupier, user and registered farm planners/advisers	
15c	Assess possible impacts of drain maintenance works, and take appropriate steps to avoid or mitigate.	Owner, occupier, user and registered farm planners/advisers	
15d	Locate sheep dipping stations or other livestock treatment facilities away from watercourses.	Local Authorities, owner, occupier, user and registered farm planners/advisers	
15e	Include and promote measures for pearl mussel as options in other agri-environmental schemes that can be taken-up in non-target areas in the mussel SAC catchments. (Work is ongoing to identify the target areas).	DAFF and DEHLG	
15f	Utilise Native Woodland Scheme for conversion of agricultural land along riparian corridors and within identified critical source areas for sediment and nutrients.	DAFF (Forest Service)	
15g	Prioritise GAP Regulation (S.I. 101 of 2009) farm inspections within pearl mussel SAC catchments.	Local Authorities	
15h	Increase farmer awareness of Freshwater Pearl Mussel Sub-basin Management Plans through informal farm visits.	Local Authorities	
15i	Provide advice and training to farmers in relation to the use (location, frequency of application, volume, weather etc.), storage and disposal of sheep-dips toxic to freshwater pearl mussels.	DAFF (Veterinary Medicine Section)	
15j	Provide agricultural land-use data to relevant public authorities, including agriculture type, livestock density, soil phosphorus concentrations, fertiliser use, slurry spread grounds and application rates, to allow identification and mapping of target areas, etc.	DAFF	
16	**On-site Wastewater treatment Systems**		
16a	Prioritise the monitoring and inspection of on-site systems in pearl mussel SAC catchments.	Local Authorities	
16b	Within the Bundorragha pearl mussel SAC catchment, prioritise the monitoring and inspection of on-site wastewater treatment systems in accordance with this Sub-basin Management Plan, i.e. within priority sub-catchments, priority stretches and/or on extreme and very high risk potentials.	Local Authorities	

16c	Install new, and upgrade older, on-site wastewater treatment systems to comply with all standards issued by DEHLG and codes of practice issued by the EPA, e.g. Code of Practice Wastewater Treatment and Disposal Systems serving Single Houses.	Developers, manufacturers, designers, installers, owner, occupier, user	
16d	Operate and maintain all on-site wastewater treatment systems in accordance with any standards issued by DEHLG.	Owner, occupier, user	
16e	Where appropriate, use constructed wetlands for treating/polishing household effluent from unsewered properties.	Local Authorities/ owner, occupier, user	
16f	Where an on-site wastewater treatment system is impacting the pearl mussel population, remove by tanker as a temporary measure until system is upgraded/ connected to municipal systems.	Local Authorities/ owner, occupier, user	
17	**Forestry**		
17a	Develop a long-term, forestry catchment management plan, with key stakeholders, with the aim of minimising hydrological, sediment, nutrient and other potential impacts from forests and all forestry operations. The potential significant risks will be identified through detailed, site-specific risk assessment. Particular attention must be paid to sensitive areas. The target areas identified for Measure 14a above should be used to inform the definition of sensitive areas. The forestry catchment management plan will recognize that site specific measures for forest stands within the pearl mussel catchment are required and will identify, to the extent possible, the most appropriate measures for each site from the following suite of measures, which shall be implemented as and where appropriate:	DAFF (Forest Service)	
17a	i) The option of not felling to be considered in sensitive areas, on a site-by-site basis.	DAFF (Forest Service) and forest owner	
17a	ii) Coniferous plantations within sensitive areas of the catchment will be subject to final felling and replacement with continuous-cover native woodland or semi-natural bog/moor, where it is demonstrated to be technically feasible and silviculturally possible, and where adverse impacts on the protected area will not occur as a result of the measure.	DAFF (Forest Service) and forest owner	
17a	iii) Establish riparian zone management prior to clearfelling, where technically feasible and following specific site-by-site assessment to determine the most appropriate buffer width and vegetative cover. The establishment of such management should not result in adverse impacts on water status.	DAFF (Forest Service) and forest owner	
17a	iv) Change the tree species mix (for example to broadleaves) on replanting where soil-type permits and it is technically feasible and silviculturally possible. This measure will be site-specific. On sensitive sites, restocking with less nutrient demanding conifer species should also be considered.	DAFF (Forest Service) and forest owner	
17a	v) Limit felling coupe size where it is technically feasible and where a risk assessment indicates that wind-throw is not likely to occur. The measure is also site-specific and the coup size should be linked to a multi-year felling plan for a given waterbody that would indicate the percentage of forest area to be felled and the expected nutrient and sediment release.	DAFF (Forest Service) and forest owner	

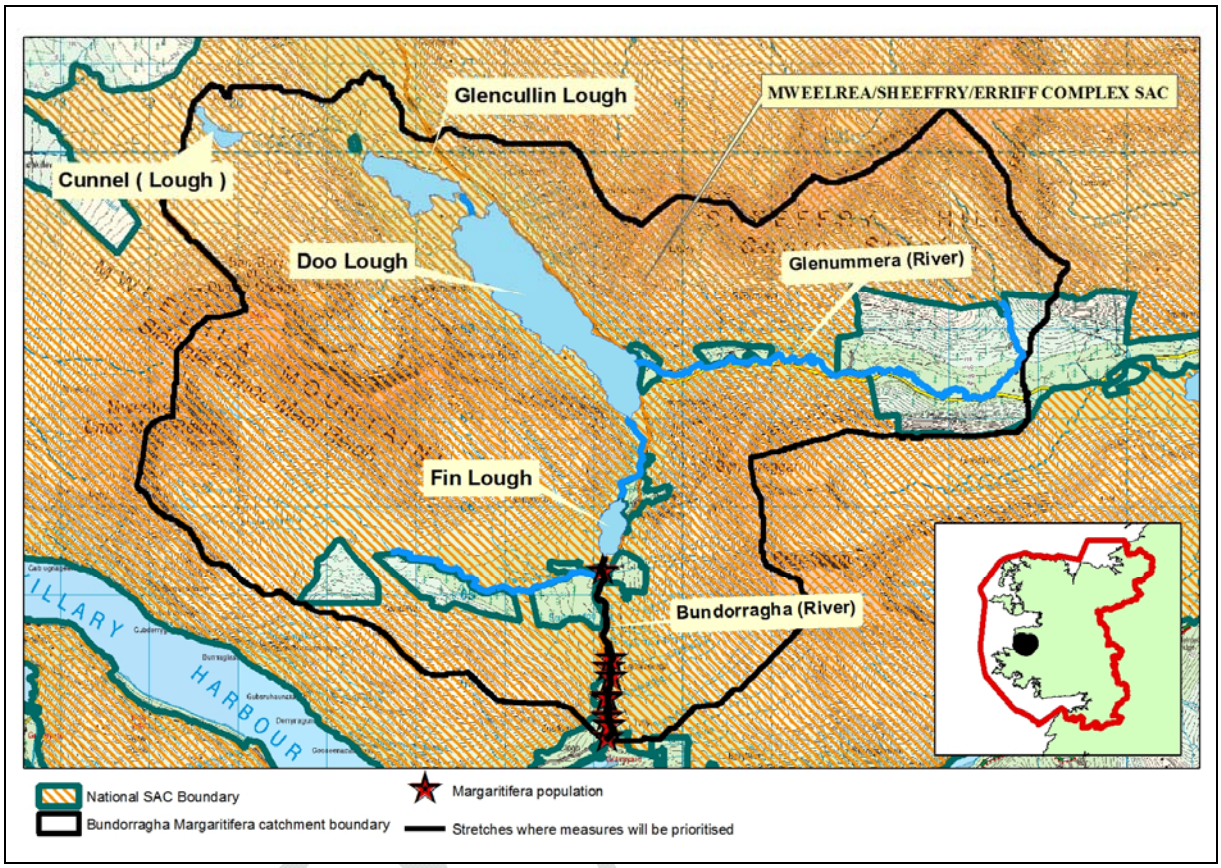
17a	vi) Felling coup size shall be determined through a multi-year forest management plan that will predict nutrient and sediment loading and identify acceptable annual felling as a percentage of the catchment. The measure shall take account of the potential for adverse impacts such as wind-throw and overall forest stand stability in the design of the coupe sizes to be felled. Strict adherence to the Forestry and Freshwater Pearl Mussel Requirements and any other appropriate requirements/guidance is also required.	DAFF (Forest Service) and forest owner	
17a	vii) Following felling of existing forest-stands, restore blanket bog and wet heath through drain blocking and appropriate site management, where it is demonstrated to be technically feasible and where adverse impacts on the protected areas will not occur as a result of the measure. The sites where this measure is to be applied must be agreed with NPWS.	DAFF (Forest Service) and forest owner	
17a	viii) Following site-specific assessment, remove bank-side trees by motor mechanical means and as whole trees where technically feasible and where the potential to impact on the protected species is identified as being less by these means than that by standard harvester and forwarder.	DAFF (Forest Service) and forest owner	
17a	ix) Eutrophication and sedimentation - enhance sediment control through improved design of sediment traps, increased numbers and wider distribution of sediment traps and blankets.	DAFF (Forest Service) and forest owner	
17a	x) Main silt traps will be large enough for *Margaritifera* conservation purposes. In the design of silt traps reference shall be made to Altmüller & Dettmer, 2006. Ensure that the sediment management system is capable of blocking sediment in preferential flow paths to watercourse.	DAFF (Forest Service) and forest owner	
17a	xi) Prohibition of fertilisation on sensitive sites	DAFF (Forest Service) and forest owner	
17a	xii) Avoid or limit planting on un-enclosed peatland sites (blanket bog, raised bog, fen peat and heathland) and limit forest cover on less sensitive peatland sites such as cutaway, enclosed and improved peats. The latter should be based on a site-by-site assessment.	DAFF (Forest Service) and forest owner	
17a	xiii) Ensure the audit of existing drainage networks in forest catchments is undertaken as per Best Management Practice prior to any felling	DAFF (Forest Service) and forest owner	
17a	xiv) Enhanced drainage network management – minimize drainage in peat soils to reduce potential for nutrient entry to surface waters, where technically feasible.	DAFF (Forest Service) and forest owner	
17a	xv) Pesticide use – reduce and monitor pesticide usage in forests. Reduce usage through allowing forest stands to lay fallow by delaying any restocking by 3-5 years, using pre-dipped plants from nurseries and by developing alternate biological control methods. Where feasible, a register of pesticide use should be maintained.	DAFF and forest owner	
17a	xvi) Establish native riparian woodland as a buffer including the establishment of continuous-cover, native bank-side tress at mussel habitat locations to produce dappled shade with no tunnelling of the river, where appropriate, technically feasible and silviculturally possible	DAFF (Forest Service) and forest owner	
17a	xvii) Roading associated with forestry should be subject to risk assessment and carried out strictly in	DAFF (Forest Service) and	

	accordance with existing national guidelines.	forest owner	
17a	xviii) Establishment of continuous-cover, native bank-side trees at mussel habitat locations to produce dappled shade with no tunnelling of the river.	DAFF (Forest Service) and forest owner	
17a	xix) Trees that are at risk of falling into the river shall be removed or partly removed (e.g. where some boughs are falling into the river) by suitably trained and experienced forestry personnel at mussel locations and, where necessary and technically feasible, be replaced by appropriate native species.	DAFF (Forest Service) and forest owner	
17a	xx) Undertake further research into buffer zones to identify optimum buffer zone design and establishment methods to enhance nutrient and sediment interception	DAFF (Forest Service)	
17a	xxi) Where the continued development of young forest stands is judged to pose a significant future threat to the pearl mussel population due to their location, stand size or being situated on blanket peats, fen peats, raised bogs or heath peats, then such immature forest stands shall be removed through felling-to-waste and any drainage system installed should be blocked and the natural hydrology restored, to the extent possible.	DAFF (Forest Service) and forest owner	
17a	xxii) Where the risk of felling-to-waste of immature forest stands on sensitive sites is regarded as high for the pearl mussel population, consideration shall be given to abandoning such stands and restoring the natural hydrology, where technically feasible.	DAFF (Forest Service) and forest owner	
17b	A monitoring programme to assess the effectiveness of the forestry measures will be developed.	DAFF and DEHLG	
17c	Produce guidance, including mitigation measures, for forest tracks and brash mats, especially in relation to crossings of drains, streams and other watercourses. Review the Forest Road Manual to update mitigation measures for all water crossings by forest machinery.	DAFF (Forest Service)	
18	**Peat Cutting - Implementation of these measures will only occur at specific sites where they are required.**		
18a	Where turf-cutting and associated drainage have been identified as a significant silt source, drains shall be filled or effectively silt trapped, and an effective buffer zone established to trap overland-movement of peat silt before it reaches the rivers.	DEHLG (National Parks and Wildlife Service), Environmental Protection Agency, Local Authorities	
18b	Where impacts from peat cutting (e.g.. hydrological & siltation) are identified and cannot be mitigated along the pathway, reduction and/or cessation of peat cutting will be required.	DEHLG (National Parks and Wildlife Service), Environmental Protection Agency, Local Authorities	
19	**Planning**		
19a	Activities such as field drainage, land reclamation, site/land clearance should be made subject to further planning control in sensitive areas of the catchment.	DEHLG	
19b	Areas where further development represents a significant risk to pearl mussel conservation shall be identified and development restrictions implemented, as necessary.	DEHLG and Local Authorities	

20	**Infrastructure (roads and bridge) impacting on the river - Implementation of these measures will only occur at the specific sites where they are required.**		
20a	All planned future roads or bridges of any size shall be assessed for potential negative impacts on mussel populations during construction and operation. Future roads or bridges of any size should be subject to morphological controls (see Measure 10).	Local Authorities and National Road Authority	
20b	Remediate hydromorphological damage caused by temporary or permanent roads and bridges, where such remediation work has been judged necessary and, through Appropriate Assessment and/or EIA, unlikely to significantly impact on the environment.	Local Authorities/NRA	
20c	Remediate hardcore or surfacing that includes substantial limestone content, where such work has been judged necessary and, through Appropriate Assessment and/or EIA, unlikely to significantly impact on the environment.	Local Authorities/NRA	
21	**Leisure management - Implementation of these measures will only occur at the specific sites where they are required.**		
21a	Angling – conduct surveys to determine whether fishing access is contributing to destabilising river banks and develop remedial measures, as necessary.	DEHLG (National Parks and Wildlife Service), Fisheries Boards, angling rights holders and angling clubs	
21b	Angling – avoid trampling on pearl mussels by fishing from the bank.	Anglers	
21c	Angling - provide notices and leaflets advising anglers of the sensitivity of pearl mussels, the areas where care is necessary to avoid trampling on mussels and/or disturbing river banks and bed, and the penalties for causing damage to the species and its habitat.	Fisheries Boards, angling rights holders and angling clubs, DEHLG (National Parks and Wildlife Service)	
21d	River morphological works shall comply with any new guidance for *Margaritifera* and fisheries enhancement to ensure that any works are beneficial to both. These shall be subject to morphological controls under Measure 10.	Fisheries Boards, Local Authorities and DEHLG (National Parks and Wildlife Service)	
21e	Kayaking/canoeing – liaise with kayaking/canoeing clubs using pearl mussel rivers, enforce restrictions on use where necessary and provide information to kayakers/canoeists and other recreational users through signs, leaflets etc.	DEHLG (National Parks and Wildlife Service)	
22	**Dangerous Substances - Implementation of these measures will only occur at the specific sites where they are required.**		
22a	Review the substances approved for use in sheep-dip and other pesticides in use in freshwater pearl mussel catchments. Incorporate findings of a review of *Margaritifera* toxicity research into such a review.	DAFF (Pesticides Control Unit)	
22b	Provide advice and training to pesticide users, e.g. public authorities and farmers, in relation to the use (location, frequency of application, volume, weather etc.), storage and disposal of pesticides toxic to freshwater pearl mussels.	DAFF (Pesticides Control Unit)	
23	**Pearl fishing**		

	Facilitate the early detection of pearl fishing incidents and ensure the prosecution of pearl fishing crimes	Garda Síochána, DEHLG (National Parks and Wildlife Service)	
24	**Assisted breeding programmes**		
	If and when necessary, augment freshwater pearl mussel population through assisted breeding and release programmes.	DEHLG/ DEHLG (National Parks and Wildlife Service)	

7.0 Bundorragha Summary Action Programme



Catchment details	Bundorragha Sub-Basin Management Plan
Species	*Margaritifera margaritifera*
Special Area of Conservation (SAC)	IE001932 Mweelra/Sheeffry/Erriff complex
River Basin District	Western RBD
Water bodies codes associated with catchment where measures may be applied	WE_32_378, WE_32_3998, WE_32_3995, WE_32_1767
Water bodies containing Freshwater Pearl Mussels	WE_32_1767
County	Mayo
Catchment area	48.3 km^2
Total river length in catchment	13.05 km
Total river length within SAC	10 km
Intentional and/or direct damage to Pearl Mussels	Damaging the pearl mussel or its habitat, including **pearl fishing** is strictly forbidden under the Wildlife Act (1976), the Wildlife (Amendment) Act (2000), and the European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations (2009), with a maximum penalty of €500,000, or imprisonment for a term not exceeding 3 years, or both

STATUS	
Freshwater Pearl Mussel Status	The Freshwater Pearl mussel population is at favourable conservation status in the Bundorragha catchment. It is currently ranked as 1st out of the 27 Freshwater Pearl Mussel SAC populations in the country on the basis of population status, habitat condition and current pressures. This improvement in status, since the previous survey, is primarily attributable to reduction in siltation and macrophyte abundance on the Bundorragha river. It has very large populations of adults, all ages of juveniles, and some juveniles in more than one area. The catchment meets all of the five Environmental Quality Objectives (EQOs) as specified in Schedule 4 of the European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations, S.I. 296 of 2009.
Water Framework Directive Status	*Water Framework Directive Status from the River Basin Management Plans* (classification is based on monitoring data from 2006-2008)
River status	3 high status and 1 good status
Status elements	Macroinvertebrates determined status in waterbody WE_32_3998, and hydromorphology determined status in waterbody WE_32_1767. The remaining two waterbodies were classified on the basis of extrapolated status from monitored donor waterbodies.

RISKS	
Point sources	***Significant risks – impacts observed through survey/monitoring*** Five sheep dipping facilities are located within the catchment adjacent to both rivers and lakes. Delphi Mountain Resort and Spa discharges under licence to groundwater approximately 650-700m from the Bundorragha River and approximately 200 m from its tributary, the Sruhaundoo. The effluent treatment system is a Packaged Membrane Bioreactor (MBR) system. The discharge is pumped to a sand polishing filter and the discharge from the sand polishing filter is percolated via a series of radial percolation trenches designed by Bord Na Mona. Inspection of the discharge point in 2006 by NPWS, gave rise to concerns that the effluent was not discharging to ground, but rather resurfacing a short distance downslope. ***Potential significant risks*** There are also four Section 4's within the catchment
Quarries	***Significant risks – impacts observed through survey/monitoring*** One unlicensed quarry was recorded on the Glencullin Tributary for the extraction of sand and gravel. This has the potential to release sediment to the catchment. ***Potential significant risks*** N.A
Agriculture	***Significant risks – impacts observed through survey/monitoring*** Poaching along the river banks of the Bundorragha was evident. Overgrazing by sheep has been a significant issue in the catchment, and requires further investigation to ensure vegetation has recovered sufficiently to prevent further soil erosion. ***Potential significant risks*** The lack of access to detailed agricultural land-use data precludes detailed risk assessment, but data from orthophotos/NPWS Commonage Framework Plans, Livestock Unit Density maps and soil types indicates that a large percentage of the catchment is covered by relatively un-intensive landuse. Sheep grazing is the most common agricultural use however this does also have its associated risks of nutrient/sediment losses. All agricultural activities that can lead to soil erosion (e.g. drainage, land reclamation, ploughing, poaching, overgrazing) and/or nutrient losses

	(e.g. slurry-spreading, fertilisation) are potential significant risks within the Bundorragha catchment.
On-site waste water treatment systems	***Significant risks – impacts observed through survey/monitoring*** ***Potential significant risks*** 14 on-site systems on extreme risk potential and 1 on very high risk OSWWTS on high risk potential settings pose potential significant risks in terms of nutrient loss. In particular, inappropriately designed and/or poorly maintained OSWWTS are a potential significant risk.
Forestry	***Significant risks – impacts observed through survey/monitoring*** Harvesting occurred in the Glenummera forest in 2009 in accordance with the *Forestry and Freshwater Pearl Mussel Requirements*. Despite the mitigation measures and considerable care in their implementation on this difficult site, localised soil disturbance and significant overland flows of water (under high rainfall conditions) occurred. This resulted in the transportation of silt towards and possibly into the Glenummera river. ***Potential significant risks*** The following forest operations are considered significant risk factors: fertilisation on peat and peaty soils (nutrient enrichment); drainage, other ground preparation, road-construction, thinning and clearfelling on peat, peaty and other highly erodible soil types, particularly on steep slopes (sedimentation). Forestry on drained peat and peaty soils is also considered a potential significant risk owing to resultant hydrological changes and ammonia losses from peat decomposition. Sites not planted in accordance with the Forest Service Guidelines and *Forestry and Freshwater Pearl Mussel Requirements* are unlikely to have effective buffering of watercourses.
Other issues **Recreation**	***Significant risks – impacts observed through survey/monitoring*** Use of the Bundrorragha river for water sports to be investigated for potential damaging impacts. ***Potential significant risks*** N/A
Weirs	***Significant risks – impacts observed through survey/monitoring*** Numerous stone weirs constructed on the Bundorragha river to create pools and rapids for fisheries enhancement. ***Potential significant risks*** N/A
Peat cutting	***Significant risks – impacts observed through survey/monitoring*** Some peat cutting was observed being carried out upstream of Glencullin Lough with the potential to release nutrients and sediment to the channel ***Potential significant risks*** N/A

ACTION PROGRAMME – MEASURES	
Function of Measures Proposed	The Bundorragha is currently ranked as 1st out of the 27 Freshwater Pearl Mussel SAC populations in the country on the basis of population status, habitat condition and current pressures. Currently the observed and potential impacts in the catchment are relatively low; however, Measures are required to reduce the pressures further to ensure the long-term favourable conservation status of the population. In addition, due to the small size of the catchment, even a small increase in nutrients or silt in the catchment, could have a large detrimental effect on the pearl mussel population. The location of Delphi Mountain Resort and Spa at the top of the Bundorragha river represents a potential threat to the Freshwater Pearl Mussel population.

Policy and Regulatory Framework	This sub-basin management plan is published by the Minister for the Environment, Heritage and Local Government in accordance with S.I. 296 of 2009. It is the duty of a listed public authority to take such steps as are necessary and appropriate to the discharge of its functions to implement these measures. The Minister shall monitor the implementation by public authorities of the sub-basin management plans. Public authorities must track and report all relevant measures and actions. Progress on the implementation of measures will be reported under both the Habitats Directive (2013 and every six-years thereafter) and the WFD.
About the measures	***The measures below are priority measures specific to the Bundorragha catchment. (See also Table 6.2)*** ***Note: All measures listed in Tables 6.1, 6.2 together with the summary action programme are potentially applied to the catchment.***
Public Awareness	An education and awareness campaign shall include public meetings, talks (schools, etc.), clinics and the distribution of leaflets. Topics covered will include the biology and ecology of pearl mussels and damage caused by e.g. pearl fishing, in-stream activities, sedimentation and nutrient enrichment. The measures necessary for their conservation shall be explained.
Stakeholder Involvement	Stakeholder assistance in the further development and design of measures will be encouraged.
Guidance	Appropriate guidance will be provided to different sectors to assist with their compliance with the Freshwater Pearl Mussel Regulations.
Planning	Activities such as field drainage, land reclamation, site/land clearance shall be made subject to planning control, i.e. shall no longer be exempted developments.
Habitats Directive Controls	Stakeholders will be notified of the measures required under this Sub-basin Plan. The activities requiring consent (or Notifiable Actions) under S.I. 94 of 1997 are being revised and shall be formally notified to the relevant owners, occupiers or users in the mussel SACs.
Point Source	All discharge licences or authorisations must comply with the EQOs set out in SI 296 of 2009. All WwTP, IPPC and Section 4 and Section 16 discharge licences must be reviewed to assess compliance with EQOs and additional conditions imposed as required. No sheep dipping plunge pools within 30 m of the river or any tributary or drain in direct hydrological connectivity with the river. Following a joint inspection of the polishing filter and its surrounds by Mayo County Council and NPWS, the Discharge Licence at Delphi Mountain Resort shall, if judged necessary, be reviewed. Such a review shall include a detailed hydrogeological assessment to investigate if the effluent can discharge fully to ground and if there is sufficient thickness of unsaturated mineral soil beneath the polishing filter to adequately treat the effluent, for the life-time of the resort and spa.
Quarries	Inspection by Mayo Co. Co. of the Quarry located on the Glencullin Tributary is required and a license to be issued if appropriate.
Agriculture	Agricultural measures for freshwater pearl mussels will be rolled-out in target areas within Freshwater Pearl Mussel SAC catchments under an agri-environemtal scheme(s). (Note: work is ongoing to identify the target areas). Measures shall include detailed assessment of soil nutrient status, sediment and nutrient management plans, fencing to prevent erosion and trampling on mussels, etc. Guidance and training shall be provided in relation to risk assessment, and the implementation and inspection of required measures. Weightings shall be applied to increase GAP Regulation (S.I. 101 of 2009) and Cross-compliance inspections in these catchments. Continued adherence with a de-stocking plan for the Bundorragha catchment. Continue the implementation of the commonage framework plans for this catchment; plan references – MA-15-A2, MA-15-B2, MA-15-F2, MA-15-K1, MA-15-L1, MA-15-U1, and MA-4-A.
On-site waste water treatment systems	Inspection and appropriate remediation of all domestic on-site waste water systems (OSWWS) in the catchment with those adjacent to the

	Bundorragha river as a priority. The Department of the Environment, Heritage and Local Government will be bringing forward legislation in the first half of 2010 that provides for the setting of standards for the performance and operation of all septic tanks and similar on-site wastewater treatment systems. The legislation will also provide for the monitoring and inspection of the performance of such treatment systems and will set out the responsibilities of households served by those systems (including requirements to carry out remedial actions where necessary).
Forestry	A long-term, forestry catchment management plan shall be prepared with the aim of minimising hydrological, sediment, nutrient and other potential impacts from forests and all forest operations during the entire crop cycle. There is a need to further develop and refine the deployment of avoidance and mitigation measure and appropriate monitoring to ensure that even on the most difficult forest sites that potential risks to pearl mussels are avoided.
Other issues	
Recreation	No wading allowed in the Bundorragha river, with the exception of for the purposes of fish release or statutory monitoring. Introduce a public awareness campaign in relation to no wading or kayaking through the introduction of signage along the river bank.
Weirs	Control silt in the catchment to reduce the risk associated with the weirs on the Bundorragha river.
Peat cutting	No new peat cutting in the catchment without prior assessment and appropriate mitigation. Assessment and mitigation (e.g. silt traps) of active areas of peat cutting shall also be undertaken.

Future & Planning Issues

The Freshwater Pearl Mussel is extremely sensitive to sedimentation and eutrophication, therefore any activity that can give rise to sediment and nutrient inputs to water has the potential to impact on the species.

It is the duty under S.I. 296 of 2009 of a listed public authority to take such steps as are necessary and appropriate to the discharge of its functions to implement the measures in this sub-basin plan.

All plans (e.g. catchment management plans for forestry), programmes (e.g. new agri-environmental schemes) and projects (e.g. new one-off houses) with the potential to impact on Natura 2000 sites must be screened for Appropriate Assessment in accordance with Article 6 of the Habitats Directive, and an Appropriate Assessment must be conducted, where judged necessary (see http://www.npws.ie/en/WildlifePlanningtheLaw/AppropriateAssessment/; http://ec.europa.eu/environment/nature/natura2000/management/guidance_en.htm).
In addition, all plans and programmes are likely to require Strategic Environmental Assessment (SEA).

The key issues for the future management of the Bundorragha catchment are:

- Minimisation of sediment losses arising from site clearance works for development, agriculture or other purposes,
- Minimisation of sediment and nutrient losses arising from land-use change (e.g. increased stocking-rates),
- Prevention of nutrient and sediment losses from new on-site wastewater systems associated with one-off houses,
- Control of hydro-morphological pressures, including drainage, drainage-maintenance, bank stabilisation works etc.
- Control of municipal and industrial discharges to meet Environmental Quality Objectives set out in Schedule 4 of SI 296 of 2009,

The key legal and policy measures required to mitigate impacts from on-going and future activities and to restore the Freshwater Pearl Mussel habitat are:

- Freshwater Pearl Mussel-measures in agri-environmental scheme
- Catchment management plans for forestry
- Proper licensing, upgrade and operation of WwTPs and associated infrastructure

- Proper licensing, mitigation and maintenance of other point-source discharges
- Changes to planning law to control currently exempted developments that can give rise to sediment and nutrient losses (e.g. land reclamation, clearance and in-fill for agriculture)
- Proper design, operation and maintenance of OSWWS

Objectives

Achievement of favourable conservation status for the freshwater pearl mussel population under the Freshwater Pearl Mussel Regulations S.I. 296, 2009.

Relevant public authorities must examine and review, as required, authorised discharges by 22nd December 2011.
All other measures in this sub-basin management plan shall be made operational by 22nd December 2012.
Implementation of the measures will be reported under the Habitats Directive in 2013 and under the WFD in 2015.
Signs of improvement in the parameters listed in Schedule 3 and/or Schedule 4 of the Freshwater Pearl Mussel Regulations (S.I. 296 of 2009) should be evident by 2015.

8 REFERENCES & BIBLIOGRAPHY

Allott, N.A., Mills, W.R.P., Dick, J.R.W., Eacrett, A.M., Brennan, M.T., Clandillon, S., Philips, W.E.A., Critchley, M. & Mullins, T.E. (1990). *Acidification of surface waters in Connemara and South Mayo*.. Report, DuQense Ltd, Dublin.

Altmüller, R. & R. Dettmer (2006): Erfolgreiche Artenschutzmaßnahmen für die Flussperlmuschel *Margaritifera margaritifera* L. durch Reduzierung von unnatürlichen Feinsedimentfrachten - Erfahrungen im Rahmen des Lutterprojekts. Informationsdienst Naturschutz Niedersachsen. Heft 4/06, 192-204

Anonymous (2004). Margaritifera margaritifera: *Stage 1 and Stage 2 survey guidelines*. Irish Wildlife Manuals No. 12. The National Parks and Wildlife Service, Dublin.

Anonymous (2005). Northern Ireland Species Action Plan: Freshwater Pearl Mussel *Margaritifera margaritifera*. Northerm Ireland Environment Agency. http://www.ni-environment.gov.uk/fwpearlmussel_pdf.pdf.

Araujo, R. & Ramos, M.A. (2001). *Action plans for* Margaritifera auricularia *and* Margaritifera margaritifera *in Europe*. Nature and Environment, No. 117. Council of Europe Publishing, Strasbourg.

Baillie, J. & Groombridge, B. (1996). *The 1996 Red List of Threatened Animals*. IUCN, Gland, Switzerland. 368pp.

Barko, JW, Gunnison, D & Carpenter, SR (1991). Sediment interactions with submersed macrophyte growth and community dynamics. *Aquatic Botany* 41, 41-65.

Barko, J.W. & Smart, R.M. (1980). Mobilization of Sediment Phosphorus by Submersed Freshwater Macrophytes. *Freshwater Biology* 10, 229-238.

Bauer, G. (1987). Reproductive strategy of the freshwater pearl mussel *Margaritifera margaritifera*. *J. Anim. Ecol*. 56, 691-704.

Bauer, G. & Vogel, C. (1987). The parasitic stage of the freshwater pearl mussel *Margaritifera margaritifera*. I. Host response to Glochidiosis. *Arch. Hydrobiol*. 76, 393-402.

Bauer G., Hochwald, S. & Silkenat, W. (1991). Spatial distribution of freshwater mussels: the role of host fish and metabolic rate. *Freshwater Biology* 26, 377-386.

Bauer, G. (2000). Factors affecting Naiad occurrence and abundance. In: Bauer, G. & Wächtler, K. (Eds.). Ecology and Evolution of the Freshwater Mussels Unionoida. Ecological Studies 145. Springer, Berlin. P155-161.

Beasley, C.R. & Roberts, D. (1996). The current distribution and status of the freshwater pearl mussel *Margaritifera margaritifera* L. in northwest Ireland. *Aquatic Conservation: Marine and Freshwater Ecosystems* 6, 169– 177.

Berry, P.M., O'Hanley, J.R., Thomson, C.L., Harrison, P.A., Masters, G.J. & Dawson, T.P. (Eds.) (2007). Modelling Natural Resource Responses to Climate Change (MONARCH): MONARCH 3. UKCIP Technical Report, Oxford

Bogan, A.E. (1993). Freshwater Bivalve Extinctions (Mollusca: Unionoida): A Search for Causes. *Integrative and comparative Biology* 33, 599-609.

Bowman, J.J. & Bracken, J.J. (1993). Effect of runoff from afforested and nonafforested catchments on the survival of brown trout (*Salmo trutta*) in two acid sensitive rivers in Wicklow, Ireland. *Biology and the Environment*: *Proceedings of the Royal Irish Academy* 93B, 143–50.

Clarke, S.J. (2002). Vegetation growth in rivers: influences upon sediment and nutrient dynamics. *Progress in Physical Geography* 26, 159-172.

Cosgrove, P.J., & Young, M. (1998). *The status of the freshwater pearl mussel* Margaritifera margaritifera *in Scotland.* A report to Scottish Natural Heritage, Edinburgh.

Cranbrook, Earl of (1976). The commercial exploitation of the freshwater pearl mussel, *Margaritifera margaritifera* L. (Bivalvia: Margaritiferidae) in Great Britain. *J. Conch. Lond*. 29: 87-91.

Colosimo, M, & Wilcock, P.R. (2005). Alluvial sedimentation and channel adjustment in an urbanizing Maryland watershed. *J. American Water Resources Association.* ? Colosimo. M. & P.R. Wilcock, (2007), Alluvial sedimentation and erosion in an urbanizing watershed, Gwynns Falls, Maryland, *J. American Water Resources Association* 43(2),499-521.

Cunjak, R.A. (1991). The parasite-host relationship of glochidia (Mollusca: Margaritiferidae) on the gills of young-of-the-year Atlantic salmon (*Salmo salar)*. *Can. J. Zool*. 69, 353-358.

Curran, J.C. & P.R. Wilcock (2005). The Effect of Sand Supply on Transport Rates in a Gravel-Bed Channel. *J. Hydraulic Engineering.* 131 (11), 961pp.

Daly, K., Jeffrey, D. & Tunney, H. (2001). The effect of soil type on phosphorus sorption capacity and desorption dynamics in Irish grassland soils. *Soil Use and Management* 17, 12-20.

Department for Environment, Food and Rural Affairs UK (2004). *Water quality: A diffuse pollution review*. DEFRA, London. , 12-28.

Dietrich, W.E., Kirchner, J.W., Ikeda, H. & Iseya, F. (1989). Sediment supply and the development of the coarse surface layer in gravel-bedded rivers. *Nature* 340, 215-217.

Dolmen, D., Arnekliev, J.V., & Haukebo, T. (1995). Rotenone tolerance in the freshwater pearl mussel *Margaritifera margaritifera. Nord. J. Freshwater Res*. 70, 21-30.

Donald T. Monteith*, John L. Stoddard*, Christopher D. Evans3, Heleen A. de Wit4, Martin Forsius5, Tore Høga°sen, Anders Wilander6, Brit Lisa Skjelkva°, Dean S. Jeffries, Jussi Vuorenmaa5, Bill Keller, Jiri Kopa´cek & Josef Vesely, Dissolved organic carbon trends resulting from changes in atmospheric deposition chemistry, Nature, Volume 450, 22 November 2007, p 537 – 540.

Ellis, M.M. (1936). Erosion silt as a factor in aquatic environments. *Ecology* 17, 29-42.

Eriksson, M.O.G., Henrikson, L., & Oscarson, H.G. (1981). Effects of acidification on freshwater molluscs in Alvsborgs lan. *Lansstyrelres, Alvsborgs lan* 2, 1-12.

Eriksson, M.O.G., Henrikson, L., & Oscarson, H.G. (1982). Acidification - a threat against the pearl mussel. *Sveriges Natur* 73, 16-19.

Eriksson, M.O.G., Henrikson, L., & Oscarson, H.G. (1983) The pearl mussel in Sjuharadsbygden. *Sjuharadsnatur* 4, 58-63.

European Commission (2006). Assessment, Monitoring and Reporting under Article 17 of the Habitats Directive: Explanatory Notes and Guidelines.

Evans C.D, D.T. Monteith, D.M. Cooper, Long-term increases in surface water dissolved organic carbon:Observations, possible causes and environmental impacts, Environmental Pollution 137 (2005) 55-71.

Fischenick, J.C., (2003). *Effects of rip rap on riverine and riparian ecosystems*. Wetlands Regulatory Assistance Programme. US Army corps of Engineers.

Geist, J. (2005). *Conservation genetics and ecology of European freshwater pearl mussels* (Margaritifera margaritifera L.). PhD Thesis. Technischen Universität München.

Geist, J., Porkka, M. & Kuehn, R. (2005). The status of host fish populations and fish species richness in European freshwater pearl mussel (*Margaritifera margaritifera*) streams. *Aquatic Conservation: Marine and Freshwater Ecosystem*s 16, 251-266.

Geist, J., Porkka, M., & Kuehn, R. (2006) The status of host fish populations and fish species richness in European freshwater pearl mussel (*Margaritifera margaritifera*) streams. Aquatic Conservation: Marine and Freshwater Ecosystems, 16, 251–266.

Hastie, L.C., & Young, M.R. (2003). *Conservation of the Freshwater Pearl Mussel. 2. Relationship with Salmonids.* Conserving Natura 2000 Rivers. Conservation Techniques Series No. 3. English Nature, Peterborough.

Hastie, L.C., Boon, P.J. & Young, M.R. (2000). Physical microhabitat requirements of freshwater pearl mussels, *Margaritifera margaritifera* (L.). *Hydrobiologia* 429, 59-71.

Hastie, L.C., Cosgrove, P.J., Ellis, N., & Gaywood, M.J. (2003). The threat of climate change to freshwater pearl mussel populations. Royal Swedish Academy of Sciences *Ambio* 32, 40-46.

Henriksen, A., Posch, M., Hultberg, H. & Lien, L. (1995). Critical loads of acidity for surface waters - Can the ANC(limit) be considered variable? *Water Air and Soil Pollution* 85, 2419-2424.

Johnston, G. (1850) Introduction to Conchology. Bentley & Fley, London.

Karna, D.W. & Millemann, R.E. (1978). Glochidiosis of Salmonid fishes. III. Comparative susceptibility to natural infection with *Margaritifera margaritifera* (L.) (Pelecypoda: Margaritanidae) and associated histopathology. *J. Parasitol*. 64, 528-537.

Kelly-Quinn, M., Tierney, D., Coyle, S. & Bracken, J.J. (1997). *A study of the effects of stream hydrology and water quality in forested catchments on fish and invertebrates. AQUAFOR report Vol. 3: Stream Chemistry, Hydrology and Biota, Wicklow Region*. COFORD, Dublin.

Killeen, I.J., Oliver, P.G. & Fowles, A.P. (1998). The loss of a freshwater pearl mussel (*Margaritifera margaritifera*) population in NW Wales. Journal of Conchology Special Publication 2: 245-250.

Killeen, I.J. & Moorkens, E.A., 2008. A rapid survey for the freshwater pearl mussel *Margaritifera margaritifera* (L., 1758) in the Aughavaud river, County Carlow. Report for the National Parks and Wildlife Service, Dublin.

Levasseur, M., Bergeron, N.E., Lapointe, M.F., & Bérubé, F. (2006). Effects of silt and very fine sand dynamics in Atlantic salmon (*Salmo salar*) redds on embryo hatching success. *Can. J. Fish. Aquat. Sci*. 63, 1450-1459.

Lacroix, G.L. (1989). Ecological and physiological responses of Atlantic salmon in acidic organic rivers of Nova Scotia, Canada. *Water, Air and Soil Pollution* 46, 375-386.

Lucey J. (1993). The distribution of *Margaritifera margaritifera* in southern Irish rivers and streams. *J. Conch. Lond*. 34, 301-310.

Lucey J. (2005). The Irish Pearl. A cultural, social and economic history. Wordwell, Bray.

Lucey, J. (2006). The pearl mussel, *Margaritifera margaritifera* (L.), in hard water in Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy* 106 B: 143-153

Madsen, J.D., Chambers, P.A., James, W.F., Koch, E.W. & Westlake, D.F. (2001). The interaction between water movement, sediment dynamics and submersed macrophytes. *Hydrobioliga* 444, 71-84.

Maitland, P.S., Lyle, A.A. & Campbell, R.N.B. (1987). *The status of fish populations in waters likely to have been affected by acid deposition in Scotland*. Natural Environment Research Council contract report to the Department of Environment and the Commission of the European Communities. Institute of Terrestrial Ecology, Edinburgh.

Marking, L.L. & Bills, T.D. (1979). Acute effects of silt and sand sedimentation on freshwater mussels. In: Proceedings of the UMRCC symposium on Upper Mississippi River Bivalve molluscs. J.R. Rasmussen, (Ed.). Upper Mississippi River Conservation Committee, Rock Island, Illinois. 204-211.

McAllister, D., Craig, J., Davidson, N. & Seddon, M. (1999). *The Biodiversity Impacts of Large Dams.* Report to IUCN, Gland.

Mellinger, P.J. (1973). The Comparative Metabolism of Two Mercury Compounds as Environmental Contaminants in the Freshwater Mussel, *Margaritifera margaritifera* In: Trace Substances in Environmental Health-VI. D.D. Hemphill (Ed.). University of Missouri, Columbia, MO. 173-180.

Meyers, T.R. & Millemann, R.E. (1977). Glochidiosis of salmonid fishes. I. Comparative susceptability to experimental infection with *Margaritifera margaritifera* (L.). (Pelecypoda: Margaritanidae*). J. Parasitol*. 63, 728-733.

Moorkens, E. A. (1991). *The freshwater pearl mussel* Margaritifera margaritifera *in the south east of Ireland*. M.Sc. Thesis, Trinity College, Dublin.

Moorkens, E. A. (1995). *Mapping of proposed SAC rivers for* Margaritifera margaritifera. Volumes 1 & 2. Report for the National Parks and Wildlife Service, Dublin.

Moorkens, E. A. (1996). *Studies on the Biology and Ecology of* Margaritifera *in Ireland*. PhD Thesis, Trinity College, Dublin.

Moorkens, E.A. (1999). *Conservation Management of the Freshwater Pearl Mussel* Margaritifera margaritifera*. Part 1: Biology of the species and its present situation in Ireland.* Irish Wildlife Manuals No. 8. The National Parks and Wildlife Service, Dublin.

Moorkens, E. A. (2004). *Pilot Project for Monitoring Populations of the Freshwater Pearl Mussel. Baseline survey of the Owenriff River SAC, County Galway*. Report for the National Parks and Wildlife Service, Dublin.

Moorkens, E. A. (2005a). *Monitoring Populations of the Freshwater Pearl Mussel. Baseline survey of the Newport River cSAC, County Mayo*. Report for the National Parks and Wildlife Service, Dublin..

Moorkens, E. A. (2005b). *Monitoring Populations of the Freshwater Pearl Mussel. Baseline survey of the Bundorragha River cSAC, County Mayo*. Report for the National Parks and Wildlife Service, Dublin..

Moorkens, E. A. (2005c). *Monitoring Populations of the Freshwater Pearl Mussel. Repeat survey of the Owenriff River SAC, County Galway*. Report for the National Parks and Wildlife Service, Dublin.

Moorkens, E. A. (2005d). Margaritifera margaritifera *survey of the River Owenea in the vicinity of Glenties, County Donegal*. Report for Donegal County Council.

Moorkens, E. A. (2006a). *Monitoring Populations of the Freshwater Pearl Mussel. Baseline survey of the Eske River cSAC, County Donegal*. Report for the National Parks and Wildlife Service, Dublin.

Moorkens, E. A. (2006b). *Monitoring Populations of the Freshwater Pearl Mussel. Baseline survey of the Clady River cSAC, County Donegal*. Report for the National Parks and Wildlife Service, Dublin.

Moorkens, E. A. (2006c). *Monitoring Populations of the Freshwater Pearl Mussel. 2006 repeat survey of the Owenriff River cSAC, County Galway*. Report for the National Parks and Wildlife Service, Dublin.

Moorkens, E. A. (2006d). Irish non-marine molluscs – an evaluation of species threat status. *Bull. Ir. biogeog. Soc*. 30, 348-371.

Moorkens, E.A. & Costello, M. J. (2004). Survival of the freshwater pearl mussel *Margaritifera margaritifera* after opening with mussel tongs. In: Molluscan Biodiversity and Conservation. I.J. Killeen & M.B. Seddon (Eds). Journal of Conchology Special Publication No. 3, 91-94.

Naden, P., Smith, B., Jarvie, H., Llewellyn, N., Matthiessen, P. Dawson, H., Scarlett, S. & Hornby, D. (2003). *Siltation in Rivers. A review of monitoring techniques. Conserving Natura 2000 Rivers.* Conservation Techniques Series No. 6. English Nature, Peterborough.

Nezlin, L.P., Cunjak, R.A., Zotin, A.A. & Ziuganov, V.V. (1994). Glochidium morphology of the freshwater pearl mussel (*Margaritifera margaritifera*) and glochidiosis of Atlantic salmon (*Salmo salar*): a study by scanning electron microscopy. *Can. J. Zool.* 72, 15-21.

O'Grady, M. (2006). *Channels and Challenges. The enhancement of salmonid rivers*. Central Fisheries Board, Dublin. 142pp.

Okland, J. & Okland, K.A. (1986) The effects of acid deposition on benthic animals in lakes and streams. *Experientia* 42, 471-486.

Oliver, G., Meechan, C.J. & Trew, A. (1993) *Report on the 1992/93 survey of the freshwater pearl mussel (*Margaritifera margaritifera *L., 1758) in the river Wye.* Report to the Countryside Council for Wales.

Purser, G.J. (1988). *Factors affecting the distribution of the freshwater pearl mussel (*Margaritifera margaritifera *L.) in Britain*. PhD Thesis, University of Aberdeen.

Raddum, G.G. & Fjellheim, A. (2004) Acidification in Norway — Status and trends biological monitoring — Improvements in the invertebrate fauna. *Water, Air & Soil Pollution* 85, 647-652.

Rooney, N., Kalff, J. & Habel, C. (2003). The role of submerged macrophyte beds in phosphorus and sediment accumulation in Lake Memphremagog, Quebec, Canada. *Limnology and oceanography* 48, 1927-1937.

Ross, E.D. (1984). *Studies on the biology of freshwater mussels (Lamellibranchia: Unionacea) in Ireland*. MSc Thesis, National University of Ireland, Galway.

Ross, E.D. (1988). *The reproductive biology of freshwater mussels in Ireland, with observations on their distribution and demography*. PhD Thesis, National University of Ireland, Galway.

Ross, E.D. (1999). *A survey of four rivers in the south-west of Ireland for the freshwater pearl mussel* Margaritifera margaritifera *(L.)*. Report for the National Parks and Wildlife Service, Dublin.

Ross, E.D. (2004a). *A Pilot Project to Develop a Monitoring Protocol for the Freshwater Pearl Mussel* Margaritifera margaritifera *(L.) in the Blackwater River, County Kerry, Ireland.* Report for the National Parks and Wildlife Service, Dublin.

Ross, E.D. (2004b). *A Pilot Project to Develop a Monitoring Protocol for the Freshwater Pearl Mussel* Margaritifera margaritifera *(L.) in the Caragh River, County Kerry, Ireland*. Report for the National Parks and Wildlife Service, Dublin.

Ross, E.D. (2005a). *Initiation of a monitoring program for the freshwater pearl mussel,* Margaritifera margaritifera *(L.) in the Licky River.* Report for the National Parks and Wildlife Service, Dublin.

Ross, E.D. (2005b). *Initiation of a monitoring program for the freshwater pearl mussel,* Margaritifera margaritifera *(L.) in the Ownagappul River.* Report for the National Parks and Wildlife Service, Dublin.

Ross, E. (2006a). *Initiation of a monitoring program for the freshwater pearl mussel,* Margaritifera margaritifera *(L.) in the Clodiagh River (Suir).* Report for the National Parks and Wildlife Service, Dublin.

Ross, E. (2006b). *Initiation of a monitoring program for the freshwater pearl mussel,* Margaritifera margaritifera *(L.) in the Mountain River (Barrow)*. Report for the National Parks and Wildlife Service, Dublin.

Ross, E.D. (2006c). *Report on searches for juvenile* Margaritifera margaritifera *(L.) in the Blackwater River (Co. Kerry).* Report for the National Parks and Wildlife Service, Dublin.

Ross, E.D. (2006d). *Report on searches for juvenile* Margaritifera margaritifera *(L.) in the Caragh River, Co. Kerry.* Report for the National Parks and Wildlife Service, Dublin.

Ross, E.D. (2006e). *Report on searches for juvenile* Margaritifera margaritifera *(L.) in the Dereen River (Co. Carlow).* Report for the National Parks and Wildlife Service, Dublin.

Skinner, A., Young, M. & Hastie, L. (2003). *Ecology of the Freshwater Pearl Mussel.* Conserving Natura 2000 Rivers. Ecology Series No. 2. English Nature, Peterborough.

Smith, D.G. (1976). The distribution of the Margaritiferidae: A review and a new synthesis. *Bull. Amer. Malac. Union* 42.

Smith, D.G. (1978). Biannual gametogenesis in *Margaritifera margaritifera* (L.) Northeastern North America. *Bull. Amer. Malac. Union* 1978, 49-53.

Smith, D.G. (1979). Sexual characteristics of *Margaritifera margaritifera* (Linnaeus) populations in Central New England. *Veliger* 21, 381-383.

Southern Regional Fisheries Board, Central Fisheries Board & Compass Informatics (2008). *Assessment of the Risk of Barriers to Fish Migration in the Nore Catchment.* Report for the Shannon River Basin District Project Freshwater Morphology Programmes of Measures and Standards Study. www.wfdireland.ie

Stelfox, A.W. (1911). A list of the Land and freshwater Mollusks of Ireland. *Proc. R. Ir. Acad*. 29B, 65-164.

Stelfox, A.W. (1929). Land and freshwater Mollusca. *Proc. R. Ir. Acad*. 39B, 6-10.

Valovirta, I. (2001). Restoration of Rivers for *Margaritifera margaritifera*. In: The Freshwater pearl mussel in Europe: Population status and conservation strategies.. Wasserwirtschaftsamt, Hof. 120-123

Vinogradov, G. A., Klerman, A. K., Komov, V. T. & Kheming, T. A. (1987). Regulation of acid-base mantle fluid homeostasis in bivalve mollusc *Margaritana margaritifera* (Eulamellibranchia, Margaritiferidae) on drying up and acidification of medium. *Zoologičeskij žurnal* 66, 989-995.

Wells, S.M., Pyle, R.M. & Collins, N.M. (1983). *The IUCN Invertebrate red data book.* International Union for the Conservation of Nature and Natural Resources, Gland (Switzerland), 145-156.

Wood, P.J. (1997). Biological Effects of Fine Sediment in the Lotic Environment. *Environmental Management* 21, 203-217.

Young, M. (2005). *A literature review of the water quality requirements of the freshwater pearl Mussel (*Margaritifera margaritifera*) and related freshwater bivalves*. Commissioned report No. 84. Scottish Natural Heritage, Inverness.

Young, M.R. & Williams, J.C. (1983a). Redistribution and local recolonisation by the freshwater pearl mussel *Margaritifera margaritifera* (L.). *J. Conch. Lond*. 31, 225-234.

Young, M.R. & Williams, J.C. (1983b). The status and conservation of the freshwater pearl mussel *Margaritifera margaritifera* Linn. in Great Britain. *Biol. Cons*. 25, 35-52.

Ziuganov, V.V. & Nezlin, L.P. (1988). Evolutionary aspects of symbiosis of pearl mussels and salmonid fishes. In: The problems of macroevolution. Moscow, Nauka. 110-111. (In Russian).

Ziuganov,V., Zotin, A., Nezlin, L. & Tretiakov, V. (1994). *The freshwater pearl mussels and their relationships with salmonid fish.* VNIRO, Moscow. 104pp.

Ziuganov, V.V. (2005). A paradox of parasite prolonging the life of its host. Pearl mussel can disable the accelerated senescence program in salmon. *Biology Bulletin* 32, 360-365 (In Russian with English abstract).

http://circa.europa.eu/Public/irc/env/monnat/library?l=/habitats_reporting/reporting_2001-2007/guidlines_reporting&vm=detailed&sb=Title

APPENDIX A

Literature Review

INTRODUCTION TO THE FRESHWATER PEARL MUSSEL MARGARITIFERA MARGARITIFERA

Background

1.1 Current status

Margaritifera margaritifera

1.1.1 The family *Margaritiferidae* (Bivalvia : Unionoida) consists of a number of different genera with a disjunct relictar distribution in the holarctic, east and south-eastern Asia (Baranescu, 1990). The largest genus is *Margaritifera* which is circumpolar in distribution.

1.1.2 Within the genus *Margaritifera*, the most widely distributed species is *Margaritifera margaritifera*. Populations are known from North America, northern and central Europe and Russia. The species is very seriously declining throughout its range and is listed in the IUCN red data book as endangered worldwide (Baillie & Groombridge, 1996). In a recent review of conservation status of Irish molluscs, *Margaritifera margaritifera* was found to be "critically endangered" in Ireland (Moorkens, 2006a).

1.1.3 The freshwater pearl mussel is protected under Annex II and V of the European Community Council Directive on Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC). It is listed on Appendix 3 of the Bern Convention. Under Irish law, it is illegal to interfere with *M. margaritifera* (Statutory Instrument No. 112, 1990). This in turn conferred protected faunal species status for the species under the fifth schedule of the Wildlife Act (1976), and other subsequent protections under the Wildlife (Amendment) Act 2000.

1.1.4 It is estimated that 90% of individuals of this species died out within Europe during the 20th Century (Bauer 1986). In the EU, most countries' pearl mussel populations are considered to be completely extinct (e.g. Poland), almost extinct (e.g. Denmark) or have small senescent populations which, in the absence of major river habitat recovery, will become extinct by the end of the lives of the current generation (e.g. Austria, Latvia, Luxembourg, Belgium) (Araujo & Ramos, 2001). A few countries have populations with some juvenile recruitment (Scotland, Finland, Sweden), but recruitment in most cases is found to be inadequate to replace existing adults.

1.1.5 Freshwater pearl mussels are flagship, indicator, keystone and umbrella species (Geist, 2005).

1.1.6 Greater than 70% of Unionidae and Margaritiferidae taxa are listed as endangered or threatened, making them one of the most endangered faunal groups throughout the world. Of the 300 species of freshwater mussels living in North America, where this faunal group has reached its peak of radiation, 210 species are imperilled (Bringolf *et al*., 2007b).

1.1.7 In Ireland, *M. margaritifera* is geographically widespread in rivers of low pH, and the Republic of Ireland has an estimated 12 million individuals, or approximately 46% of the EU population (Geist, 2005).

1.1.8 The high number of individuals belies the seriousness of the status of *M. margaritifera* in Ireland, as most populations have experienced a dramatic decline in recent years (Moorkens, 1999; Moorkens & Costello, 1994, Moorkens *et al.*, 1992). Deterioration in river bed and river water quality has resulted in the majority of mussel populations failing to recruit young mussels over the last 30 year period, and widespread extinction of mussel populations is predicted if causal factors of decline remain in place.

1.2 Margaritifera durrovensis (*Margaritifera margaritifera*)

1.2.1 In 1926, B.B. Woodward found an unusual shell in the P.B. Mason collection which was labelled from the river Nore at Durrow (Phillips, 1928). He wrote to R.A. Phillips, who went to look for further specimens. In October 1926, Phillips, along with A.W. Stelfox, R.J. Welch and C. Oldham found the population. Five specimens from this expedition are preserved in spirit in the Dublin museum, labelled from the river Nore below Abbeyleix. Descriptions of the Nore mussels were given (Bloomer, 1927, 1928). Anatomical distinctions were based on a furrow present in the *M. durrovensis* foot and differences in muscle scarring patterns on the *M. durrovensis* shell compared with *M. margaritifera* (Bloomer, 1928). This was followed by Phillips (1928) paper naming *M. durrovensis* as a species new to science.

1.2.2 The taxonomic status of *M. durrovensis* has been argued ever since Phillips first published his species description. A year after Phillips' paper, Stelfox (1929) published additions to his Irish list. He included *M. durrovensis*, but compared its thickened form with the forms of *Pisidia* found in hard water, and stated, in his opinion, that the Nore mussel was a variety of *M. margaritifera* which had become acclimatised to hard water. However, he stated that "considerable research work will be necessary before these problems can be settled", thereby showing his uncertainty.

1.2.3 Haas (1948) concurred with Stelfox, and called *M. durrovensis* the "lime-phase" of *M. margaritifera*. His investigation was limited to one Nore specimen, which he thought was similar in form to *Unio brunneus* Bonhomme, 1840, of which he had also seen only one specimen.

1.2.4 The dismissal of the species and subspecies classification of *M. durrovensis* was supported by Chesney *et al.* (1993), who formed their conclusions on the basis of shell, anatomical and enzyme polymorphism comparisons of *M. durrovensis* with a number of *M. margaritifera* populations. Subsequently, Moorkens (1996) looked at morphometric taxonomical differences between shell sets from various rivers and different species within the *Margaritifera* genus. While it was evident that there were large "within species" differences among populations of *M. margaritifera*, it was shown in the study that *M. durrovensis* demonstrated greater morphometric differences to *M. margaritifera* than *M. falcata* and *M. auricularia* do.

1.2.5 Holmes *et al.* (2001) found good genetic separation between *M. durrovensis* and *M. margaritifera* populations.

1.2.6 Machordom *et al*. (2003) found that Ireland had populations linked genetically to two separate lineages. Two mitochondrial lineages (albeit very closely related) were identified: a northern lineage extending from Ireland to the Kola Peninsula including the western Atlantic coast, and a second cluster distributed from Ireland to the Iberian Peninsula.

1.2.7 Geist & Kuehn (2005) studied the genetics of 24 European pearl mussel populations. The analyses of nine microsatellite loci with different levels of polymorphism revealed a high degree of fragmented population structure and very different levels of genetic diversity within populations. These patterns were explained by historical and demographic effects and have been enforced by anthropogenic activities. Even within drainages, distinct conservation units were detected.

1.2.8 Early indications from examination of *M. durrovensis* genetic material by Geist (pers. comm.) suggest that this genetic population fits in to this fragmented population model.

1.2.9 Recent work by Geist *et al.* (2008) suggests that recently dead shells may be a good source of DNA for future genetic work. The genetic material is derived in this case from periostracum.

1.2.10 The taxonomic status of *Margaritifera durrovensis* remains inconclusive but is probably best described as a rare ecophenotype of *M. margaritifera*, a status which concurs with Machordom *et al*. (2003) and Chesney *et al.* (1993), the most recent bivalve guide to the region (Killeen *et al*., 2004), and the most recent published Irish list of Molluscs (Anderson, 2005).

1.2.11 *Margaritifera durrovensis* was known from the Barrow, Nore and Suir main channels, but living specimens have not been found outside the Nore since 1993 (Moorkens, 1996).

1.2.12 Some rivers with hardness levels that are intermediate between the Nore and the typically acid stream habitats of *Margaritifera* have been found, e.g. the varieties known as *Unio brunneus* from the River Viaur, France (Haas, 1948) and *M. margaritifera var. siluriana*, from the River Wye, Wales (Ellis, 1962). However, none have the distinctive slender shape that is particular to *M. durrovensis*.

1.2.13 The taxon that relates to *Margaritifera durrovensis* is considered to be restricted to the River Nore in the Republic of Ireland.

1.2.14 The Council Directive 97/62/EC of 27 October 1997 adapting to technical and scientific progress Directive 92/43/EEC on the conservation of natural habitats and of wild fauna placed *Margaritifera durrovensis* on Annex II and Annex V as a separate taxon.

1.2.15 The most recent monitoring surveys for *M. durrovensis* indicate that, while there may be outliers downstream, its main population is now restricted to approximately 10km length of river and 500 individuals, and that there is no evidence of reproduction (Moorkens, 2004a, 2005a).

1.2.16 *Margaritifera durrovensis* is listed by the IUCN as "Critically endangered" (Baillie & Groombridge, 1996). It clearly also falls into this category in an Irish context (Moorkens, 2006a).

2.0 CURRENT FACTORS CAUSING LOSS OR DECLINE

2.1 Margaritifera margaritifera

2.1.1 There are a number of factors leading to the decline and loss of pearl mussel populations internationally and most of those are evident in Ireland and are outlined below.

2.1.2 The loss of pearl mussel populations mostly occurs from continuous failure to produce a new generation of mussels due to loss of clean gravel beds, which have become infiltrated by fine sediment. This blocks the required levels of oxygen from reaching young mussels. Juvenile mussels spend their first five years buried within the river bed substrate.

2.1.3 Other losses that lead to unsustainable populations are from untimely deaths of adult mussels through kills from major pollution incidents, such as toxic poisoning (e.g. from sheep dip), eutrophication (through smothering of adult mussels by filamentous algae or macrophyte growth).

2.1.4 Losses of adult mussels typically begin in the central channel of the river where the effects of pollution are most seriously manifested, leaving residual surviving mussels lying close to river banks. The *Margaritifera* life strategy relies on the production of very large numbers of early life stages due to the high percentage of losses over time (Young & Williams, 1984). Sustainable *Margaritifera* populations require the prevention of both chronic pollution and once-off pollution incidents from their freshwater habitat.

3.0 ENVIRONMENTAL FACTORS CONTRIBUTING TO LOSS OR DECLINE

3.1 Sediment quality

3.1.1 In the field, sediment quality can be measured using redox potential differences between various depths in the stream bed. Redox potential at sites without juvenile mussel recruitment differ significantly from those with juvenile recruitment (Geist & Auerswald, 2007). The latter has no detectable differences between the redox potential (Eh) of the open water and the interstitial water at 5 or 10 cm depth.

3.1.2 Excessive siltation to river beds can lead to compaction or concretion of the river bed, which further lowers the chances of oxygen exchange at depth. Compaction can be measured by penetration resistance using commercial penetrometers. Stream beds where pearl mussel recruitment is absent were found to have a more variable and higher penetration resistance, indicating unfavourable compaction is a problem (Geist & Auerswald, 2007).

3.1.3 Changes of river bank vegetation from more natural to more unnatural vegetation and hydrogeology are considered to have a negative impact on *Margaritifera*. Juvenile mussels can gain early nutrition through movement of water from *Carex*-dominated vegetation from the river bank rhizosphere into the hyporheic zone (Hruska, 1999).

3.1.4 Other ways in which mussel populations can decline and be lost is through adult mussel kills, or loss of host fish which are essential to the life cycle of *Margaritifera*. Further details of the life cycle can be found in Moorkens (1999).

3.1.5 The Republic of Ireland currently has approximately 120 rivers with *Margaritifera*. A small number of *Margaritifera* populations were extirpated in the 19th Century by chronic pollution (e.g. mine waste, Avoca River). Many other rivers ceased recruitment in the 1970's, which is thought to be linked with the intensification of agricultural practices, in particular the introduction of artificial fertilisers and the change from hay to silage management of fields in mussel catchments following Ireland's entry into the then European Economic Community.

3.1.6 Rivers that have retained large numbers and had successful recruitment in the 1990's were mainly found in remote small catchments with low intensity agriculture, often downstream of large water bodies i.e. one or more lakes.

3.1.7 Decline in these most important mussel rivers in recent years has been linked with the first intensive usage of the catchment, mainly clearfelling of coniferous forestry, overgrazing and housing development.

3.1.8 Physical siltation, once introduced to a pearl mussel river, can continue to cause very serious effects on a long term basis (Ellis, 1936, Marking & Bills, 1979, Naden *et al*., 2003, Araujo & Ramos, 2001, Killeen *et al*., 1998). Direct ingestion of silt by adult mussels can lead to rapid death. If, however, the mussels clam-up as a response to a siltation episode and if the siltation is prolonged, they will die from oxygen starvation over a period of several days. During a time of year when water temperatures are high, oxygen depletion in the body occurs more rapidly, and they will die more rapidly. The evolutionary primitive *Margaritifera* gills and the annual brooding of young in all four of the gills demand a continuous and high supply of oxygen. If the mussels survive the initial silt episode, the food/oxygen deprivation from clamming will cause them to become stressed from which they will take a long time to recover. If during that recovery period, there are further incidents of mobilisation of silt then the stressed mussels are more susceptible to death than mussels in a cold river in unstressed conditions. Thus they may continue to die over a period of several months, particularly over a summer.

3.1.9 Once a silt load enters a river that holds a pearl mussel population, it can continue to cause harm. Silt causes river changes, which in turn change the dynamics of the river into the future (Curran & Wilcock, 2005; Colosimo & Wilcock, 2005; Dietrich *et al*., 1989). Both bed and suspended materials, and subsequent changes in channel form associated with changes in sediment supply, may affect mussels in many ways at various stages in their life cycle. The direct kill to adults is only the first stage in the damage that silt causes to the population. Sediment that infiltrates the sediment decreases oxygen supply in the juvenile habitat, which prevents recruitment of the next generation. The sediment subsequently provides a medium for macrophyte growth, a negative indicator in pearl mussel habitats. Macrophytes then smother the juvenile habitat even further, and the macrophytes trap more sediment which exacerbates the problem in the long term. One of the most essential requirements for pearl mussel conservation is the removal of risk of any sediment reaching the river, as any one single incident has such long term ramifications.

3.1.10 Silt infiltration of river bed gravels can also have a negative effect on the essential species of fish that host the mussel glochidial stage (Levasseur *et al*., 2006).

3.1.11 Major physical silt threats arise from land clearance for development, ploughing, coniferous forestry, overgrazing of land leading to loss of vegetation cover, road and bridge building and peat cutting, particularly mechanical peat extraction. Direct access of grazing animals to the river can lead to bank erosion and poaching.

3.1.12 Nutrient and organic pollution leading to eutrophication is associated with agriculture, coniferous clearfell forestry, industrial effluents and insufficient treatment of urban wastewater and wastewater from on-site systems.

3.1.13 The low levels of nutrient input that lead to damage are most important to note. In particular, the normal background ortho-phosphate level of 0.005mg/l P is considered to be essential to the maintenance of oligotrophic waters for reproducing pearl mussel rivers (Moorkens, 2006a).

3.1.14 Small increases in ortho-phosphate can lead to deleterious algal or macrophyte growth, so maintaining low levels at all times is considered to be essential. One large input of ortho-phosphate can lead to an algal bloom incident, which in turn leads to organic silt, causing adult and juvenile deaths and increased trophic status in the river on a long term basis.

3.1.15 An increase in trophic status can lead to a major habitat change, particularly a change from *Fontinalis*-dominated river bed to *Myriophyllum* and *Ranunculus*-dominated riverbed. These macrophytes are indicators of unfavourable condition in *Margaritifera* rivers and provide conditions for further silt trapping and continued loss of habitat due to changes of flow, sediment and nutrient dynamics (Clarke, 2002; Wood, 1997; Madsen *et al*., 2001; Barko *et al*., 1991). Phosphorus pollution events that have resulted in macrophyte growth result in phosphorus that continues to be released and mobilised by the macrophytes at later dates (Barko & Smart, 1980; Rooney *et al*., 2003).

3.1.16 Fine silt arising from organic decay infiltrates juvenile gravel habitat in the same way that physical silt does. It also provides a further inappropriate nutrient source for the future and its decomposition leads to significant decreases in oxygen.

3.1.17 Habitat destruction can occur through canalisation, boulder removal, arterial drainage and other physical changes, replacing natural channel reach patterns of pools and riffles with more uniform runs that suit neither the pearl mussel nor its host fish (Valovirta, 2001; Moorkens, 1999, 1996; Hastie *et al.*, 2000).

3.1.18 Bank reinforcement actions are a response to external damage to river banks at the site of reinforcement or elsewhere but has had ramifications at the site of reinforcement. The reinforcement structures in themselves can affect river dynamics both upstream and downstream of the works (Fischenick, 2003; O'Grady, 2006). Hard reinforcement measures are considered to be damaging activities in pearl mussel rivers.

3.1.19 Flow regulation can have serious negative effects on pearl mussel populations (Mc Allister *et al.*, 1999; Araujo & Ramos, 2001). These manifest mainly in two ways. Firstly, consistent unnatural flows, particularly more prolonged low flows can cause stress to adult and juvenile mussels by raising temperature, reducing oxygen, concentrating pollutants and providing conditions for silt deposition. Secondly, rapid changes in flow regime such as where sluices or dams are opened and closed regularly, is damaging to pearl mussel populations by causing energy effort of individuals to be concentrated on digging into substrate or moving around leading to a state of continuous stress, and by disrupting natural stages of the life cycle due to regular flooding and spate flow. High losses of annual glochidial production or newly dropped juvenile mussels occur during flood conditions. Recent monitoring surveys of *Margaritifera* rivers with regulated flows in Ireland (Moorkens survey) and the UK (Killeen survey) have found reduced recruitment.

3.1.20 Fisheries activities have increased in rivers as a response to a lowering of river habitat quality. Fishing weirs, dams, croys, fishing platforms, pool dredging, footbridges and weed control all threaten the conservation status of *Margaritifera* populations during both their construction and operation stages (Hastie & Young, 2003).

3.1.21 While wood products are considered to be less harmful in bank protection than rock armouring (O'Grady, 2006), these wood products should not have been treated with preservatives including copper, chromium or other compounds that are toxic to unionids. Copper and chromium leaching from preserved wood into damp soil were shown to result in significant losses (5.34-15.6% Cu; 1.85-2.35% Cr) to the environment (García-Valcárcel & Tadeo, 2007).

3.1.22 Liming of land has a negative effect on *Margaritifera* populations, through direct toxic effects, and through increased growth rates leading to shortened life expectancy and, thus, loss of reproductive years (Bauer *et al.*, 1991; Skinner *et al.*, 2003). In some countries, acidification problems are so severe that liming is considered to have a more positive than negative effect (Henrikson *et al.*, 1995). However, environmental water chemistry analysis in declining Irish pearl mussel rivers are associated with high peaks of calcium and conductivity levels.

3.1.23 Toxic pollution can have very serious and long term effects on a pearl mussel river. Juvenile and adult pearl mussels, being benthic suspension feeders, are exposed to pollutants in surface water, sediment, interstitial water and through ingestion of filtered particles with sorbed contaminants. Associations between mussel decline and upstream reduced water quality have been documented for decades (Augspurger *et al.*, 2007; Fuller, 1974).

3.1.24 Early life stages of mussels were shown to be among the most sensitive aquatic organisms in toxicity testing with copper and ammonia, and this led to the development of captive breeding of mussels of various species for glochidial production for toxicity testing (Augspurger *et al.,* 2007; Keller *et al*., 2006; Milam *et al.*, 2005; Augspurger *et al*., 2003). There is now a standard guide for methodologies for reliable toxicity testing of freshwater mussels (American Society for Testing and Materials, 2006).

3.1.25 Unionid mussels are considered to be among the most sensitive of all invertebrates to water pollution, and of these, *Margaritifera* is considered to be particularly sensitive, so much so that it is difficult to breed adequate numbers of glochidia for toxicity testing. Results from other species of unionids are considered to be relevant to *Margaritifera*, but may perhaps underestimate their further sensitivity to some pollutants. Nevertheless, recent advances in Unionid toxicity testing has determined that reviews are needed for US EPA water quality criteria (WQC) in order to bring them up to standards that will be protective of freshwater mussels (Augspurger *et al.*, 2007).

3.1.26 The EC (Quality of Salmonid Waters) Regulations 1988 state that at a water hardness level of 50mg/l the copper levels should be less than 0.022 mg/l Cu. Glochidial testing of a variety of unionid mussels in the USA found copper 48hour EC50 values at a water hardness level of 50mg/l of as low as 0.0065 mg/l Cu, with six out of eight species tested with lower EC50 levels than the Salmonid Regulation values (Wang *et al*., 2007). The results of juvenile mussel toxicity testing were even more serious, with ten day EC50 values at a water hardness level of 50 mg/l of as low as 0.0048 mg/l Cu, with all newly transformed juveniles of 6 species tested with lower EC50 levels than the Salmonid Regulation values.

3.1.27 Glochidia and juvenile mussels of a range of unionid species were found to be much more sensitive than typical surrogate species (*Daphnia magna, Ceriodaphnia dubia, Hyalella aztaca,* fathead minnow, and rainbow trout) in acute toxicity responses to ammonia (Wang *et al.,* 2007). Lethal and sub-lethal effects of ammonia were seen on juvenile unionids (Newton & Bartsch, 2007).

3.1.28 Standardised chronic toxicity tests with two month old juvenile mussels indicate that the early life stages of freshwater mussels are chronically sensitive to copper and ammonia, and may not be adequately protected by U.S. EPA levels (March *et al*., 2007).

3.1.29 The use of median levels in standard water quality requirements and in water quality reporting can be unhelpful to species that are highly sensitive to acute effects of rare events. A risk assessment of water quality in three streams supporting endangered freshwater mussels found that chlorine concentrations exceeded regulatory standards up to 17-fold upstream of endangered mussel beds, and that in some habitat areas the

levels rapidly decreased with distance from the source, in other areas with little turbulence elevated chlorine levels were found up to 300m from an outfall (Ward *et al.*, 2007). Outfalls with even slightly elevated copper, chlorine and ammonia can be a limiting factor in mussel survival and recovery.

3.1.30 A significant threat is agricultural and forestry pesticides, and chemical sheep dip is considered to be a very serious risk to pearl mussel populations, and the most likely cause of a number of major mussel kills (Moorkens, 1999; Skinner *et al*., 2003; Young, 2005; Cosgrove & Young, 1998). Organophosphates and synthetic pyrethroides used in sheep dipping are highly toxic to species that are a lot less sensitive to pollution than *Margaritifera*. The pearl mussel is too endangered to justify specific laboratory toxicity testing, but this should not be used as a reason to be ambiguous about the threat such pesticides present to *Margaritifera*. Pesticides present the greatest risk when used in a form that requires mixing in large quantities of water, which is why sheep dip is the most obvious threat. However, there are also a number of pesticides that are used in a concentrated state for spraying and prolonged or large scale use close to water courses, or spillage into watercourses also presents a risk. The most common example is permethrin but there are likely to be others. Other substances which have been shown to be directly toxic to *Margaritifera* are rotenone, methylmercury chloride and mercuric nitrate (Mellinger, 1973; Dolmen *et al*., 1995). Negative effects of diffuse and direct sources of heavy metals zinc, lead, cadmium, copper, nickel, silver, mercury, persistent organic pollutants (POPs), such as DDT and its metabolite DDE, and polychlorinated biphenyls (PCBs) on other bivalve species have led to the conclusion that *Margaritifera* would be also at risk from these substances. Given the sensitivity of the pearl mussel, exact quantities below which risks from these substances are removed is not known and a precautionary approach should be used to ensure such products do not enter watercourses inhabited by *Margaritifera*. Chronic toxicity testing suggests that juvenile mussels may be at risk from prolonged exposure to environmentally relevant concentrations of chlorpyrifos and permithrin and their formulations (Bringolf *et al.*, 2007c).

3.1.31 The technical grade fungicides chlorothalonil, pyraclostrobin and propiconazole were found to be highly deleterious to glochidia and juvenile unionid mussels (Bringolf *et al.*, 2007a).

3.1.32 Glyphosate, alone and in combination with surfactant blends that allow penetration of the waxy surfaces of plant leaves, is in widespread use, and are expected to increase further with the spread of genetically modified strains of crop (Monsanto Roundup and variations). Roundup was found to be acutely toxic to glochidia and juvenile mussels, and toxicity testing found that the surfactant was the most toxic component, and likely to be responsible for much of the toxicity of the overall product (Bringolf *et al.*, 2007b).

3.1.33 Road wash and surface drainage is a source of diffuse pollution, of nutrients, silt and toxic substances on an ongoing basis, as well as the severe siltation risks during construction (Araujo & Ramos, 2001; Department for Environment, Food and Rural Affairs, 2004). As the road network development in Ireland is still actively underway, road development as well as ongoing risks from roads that are proximal to pearl mussel rivers are considered to present a significant threat to this species.

3.1.34 Other sources of contaminants from surface drainage, particularly in more urban sections of mussel rivers, are domestic household and garden activities, and intermittent release of sewage during periods of malfunction, where such a pathway exists.

3.1.35 Loss of host fish is regularly cited as a potential reason for pearl mussel decline (Araujo & Ramos, 2001; Anon, 2005). A study on the status of host fish populations and on fish species richness in European pearl mussel populations (Geist *et al*., 2005) characterised typical fish communities in pearl mussel streams and revealed that a lack of host fish only seems to be limiting pearl mussel reproduction in specific areas. It has also been found that the most genetically diverse pearl mussel populations are associated with postglacially colonised rivers that retain oligotrophic status and high numbers of individuals (Geist & Kuehn, 2008). The host fish from these rivers displayed low genetic diversity. Intact and functional pearl mussel populations were found to occur under extremely oligotrophic conditions with lower host fish densities and biomasses than in disturbed central European populations without juvenile recruitment. In Ireland, adequate numbers of host fish occur in at least some rivers with inadequate *Margaritifera* recruitment, however, where nutrient levels have increased, more host fish may be required as compensation. A comparison of trout versus salmon dominated rivers of Ireland quickly shows that 100% of pearl mussel rivers are salmon and sea trout rivers, thus while brown trout make an effective host fish, the natural home of *Margaritifera* in Ireland is within low productivity rivers dominated by salmonids that go to sea to get nutrition. Salmon and *Margaritifera* have been cited as symbiotic in their relationship, with both species providing a beneficial role for the other (Ziuganov & Nezlin, 1988; Ziuganov *et al*., 1994). Pearl mussels filter the river water and increase its purity, and salmon gills host mussels during their glochidial stage. Pearl mussels have also been shown to prevent early senility in salmon and thus extend their life expectancy (Ziuganov, 2005). It is likely that host fish numbers need not be very high due to the natural adaptation of pearl mussels to live in rivers with low food levels and very low productivity (Bauer *et al*., 1991), but an unnatural decline in host fish will inevitably threaten *Margaritifera*. As well as habitat decline and acidification (see below), impediments to fish movement from artificial barriers can result in losses of mussel populations (Bogan, 1993).

3.1.36 Acidification has been well documented as a threat to salmonid populations both internationally (e.g. Maitland *et al*., 1987; Henrikson *et al*., 1995; Lacroix, 1989) and in Ireland (Bowman & Bracken1993; Allott *et al*., 1990; Kelly Quinn *et al*., 1997). In Ireland, acidification is linked with coniferous plantations in acid-sensitive areas rather than industrial pollution. As salmonid hosts can come from anywhere within the pearl mussel catchment, protection for the entire catchment from acidification is essential.

3.1.37 Acidification has also been noted a direct threat to *Margaritifera* from the first international IUCN red data book for invertebrates (Wells *et al*., 1983). Work carried out in Scandinavia has provided evidence for pearl mussel decline from acidification (Okland & Okland, 1986; Eriksson *et al*., 1981, 1982, 1983; Henriksen *et al*., 1995; Raddum & Fjellheim, 2004). A lowering of pH directly influences pearl mussels through a gradual destruction of their calcareous shell, and also their genital organs (causing infertility), and through problems with regulation of acid-base mantle fluid homeostasis (Vinogradov *et al*., 1987).

3.1.38 Climate change is likely to contribute to the serious threat to survival of *Margaritifera*. It is unlikely (in the foreseeable future) that Irish habitats will be outside the temperature range of the species, but increased temperatures will lead to a

faster metabolic rate and consequently a shorter life expectancy and thus reduced reproductive episodes per individual, that may exacerbate an already lowered recruitment level. The likely scenario of increased summer droughts and winter storm and flood events may negatively affect the species by increasing the frequency of stressful "natural" events. These may result in increased siltation incidents during flooding. Habitat space may be reduced due to loss of river bed in drought conditions, or instability of gravel beds that are currently stable, through frequent flooding. Climate change may have an as yet unforeseen affect on the salmonid host species or on the food web that they rely on. Changes in sea level may increase the salinity of a higher percentage of the lower reaches of some mussel rivers, and this would have particularly serious ramifications for populations that have now become restricted to the bottom end of rivers. Hastie et al. (2003) predict that a number of Scottish populations may be lost due to climate change.

3.1.39 *Margaritifera margaritifera* has been exploited for its pearls since Roman times, and Ireland's mussels were well known sources of pearls for many years (Lucey, 2006; Cranbrook, 1976). Pearl fishing has been cited as a threat to pearl mussels across most of its range, and in countries with very low numbers of individuals such as Germany, there are historical records of pearl fishing causing population decline. Recent records of pearl fishing in Ireland are anecdotal, and generally involve Scottish visitors, some of whom come from families that traditionally made a visit to known haunts at periodic intervals. The decline in pearl mussels and the lack of sufficient recruitment has made any pearl fishing unsustainable and the use of tongs to open mussels for pearls has been shown to be damaging (Moorkens & Costello, 2004). Thus pearl fishing is outlawed in Ireland and any illegal fishing is considered to pose a threat to that population.