Appendix 3

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Freshwater Pearl Mussel

Draft

Bandon Sub-Basin Management Plan

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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 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).

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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 (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

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(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 stones, 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).

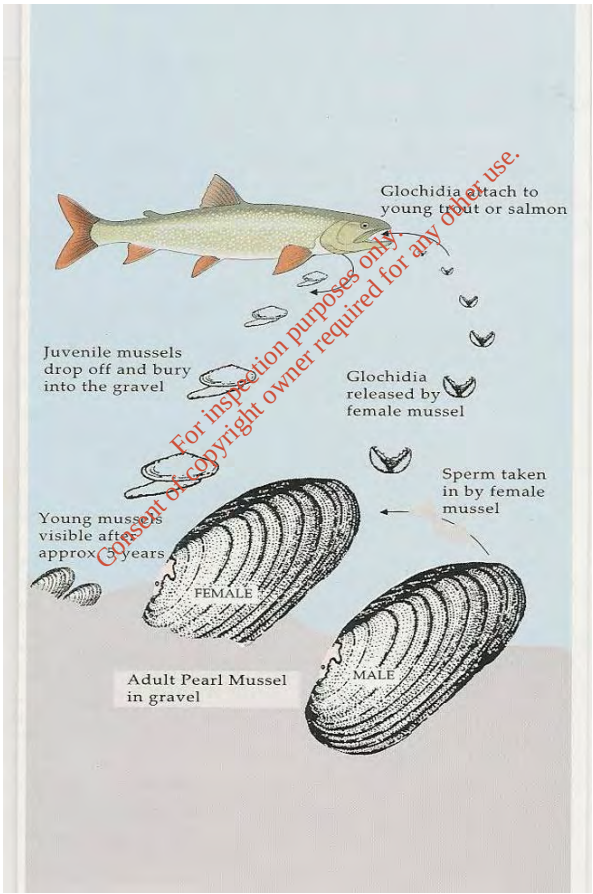

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Figure 1.1: Life cycle of *Margaritifera*

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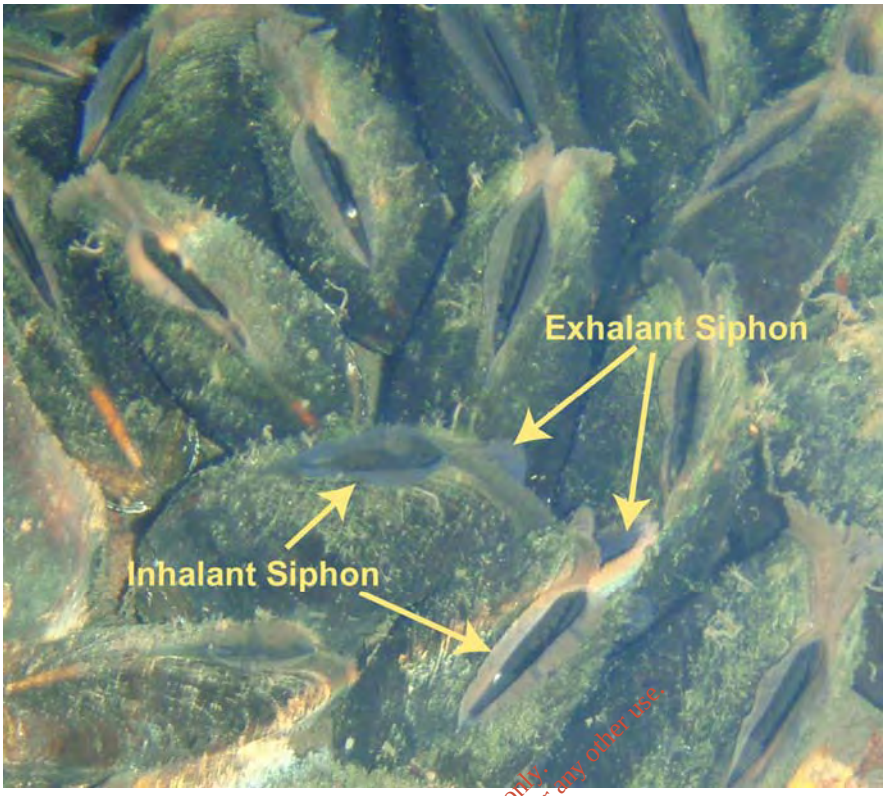

Figure 1.2: *Margaritifera* showing inhalant and exhalant siphons (Photo: Pete McCullough)

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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).

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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).

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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

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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-grows. 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.

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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 not one of its populations are in favourable condition because none has 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.

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1.3.1.5 Other causes of declines in pearl mussel populations

With such a widespread and devastating decline in the world range of Margaritifera, many theories have been put forward as possible causes of decline, but investigations have found them to be insignificant.

The essential interaction with salmonid fish hosts led to an investigation as to whether a decline in fish hosts could be partially responsible for subsequent pearl mussel decline (Geist et al. 2006). However, this came to the opposite conclusion by confirming that functional pearl mussel populations, i.e. those having high numbers of juveniles present, had significantly lower densities and biomass of host fish than nonfunctional streams. The results clearly showed that low densities of host fish under oligotrophic conditions with functional stream substratum are more important for pearl mussel recruitment than higher densities of host fish coinciding with higher eutrophication levels and poor substratum quality.

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 mortalities 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 compared to that at the juvenile stage in situations where habitats are unfavourable.

The current and future direct and indirect effects of climate change have also been investigated as a possible cause of pearl mussel decline. While climate change is noted as a possible future threat to the pearl mussel (Hastie et al., 2003), due to potential increase of currently rare flood events, there is no evidence that climate change could be already contributing to local or worldwide decline of the species. In predicted modeling of climate space, the freshwater pearl mussel is expected to show neither gains nor losses of potentially suitable climate space, as it is simulated to occur almost all over Britain and Ireland into the next 80 years (Berry et al., 2007).

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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, 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 grow 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

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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 one-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 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 on the attributes of the mussel demographics, as set out in the draft European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations 2009.

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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.

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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 that 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.

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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)

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- 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)

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;*

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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.*

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1.6.2 How legal protection can be implemented

The EU Water Framework Directive (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.

One of the Directive's core environmental objectives relates to protected areas, requiring all such areas to achieve compliance with any standards and objectives by 2015 at the latest. Ireland's Special Areas of Conservation (SACs), established under the Habitats Directive, are part of the Water Framework Directive's Register of Protected areas and are therefore directly linked to this objective.

The Water Framework Directive requires that a programme of measures is established in order to achieve its environmental objectives. The programme shall 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 is to be established by 22 December 2009 and 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 part of 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 by 2015.

The sub-basin plans must comply with the draft European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations 2009 which 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.

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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. 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; 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).

None of the 96 populations in the country is considered to be in favourable conservation status, as 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.

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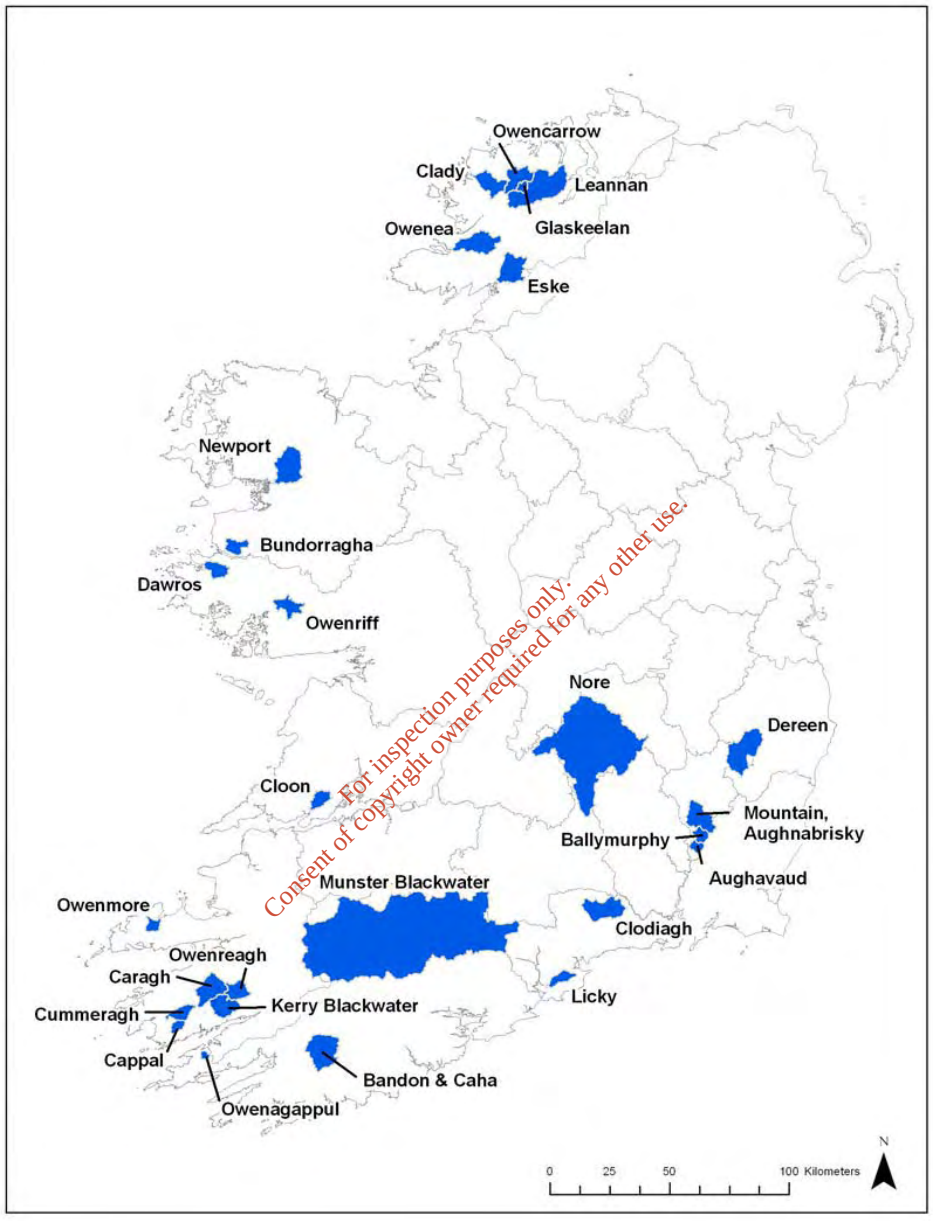

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Figure 2.1 Map of the catchments of the specified pearl mussel populations.

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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)
1	Bandon	002171	Bandon River cSAC	Bandon & Caha
2	Aughavaud (Barrow)	002162	River Barrow and River Nore cSAC	Aughavaud
3	Ballymurphy (Barrow)	002162	River Barrow and River Nore cSAC	Ballymurphy
4	Mountain (Barrow)	002162	River Barrow and River Nore cSAC	Mountain, Aughnabrisky
5	Bundorragha	001932	Mweelrea/ Shreefry/ Erriff Complex cSAC	Bundorragha
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
7	Clady	000140	Fawnboy Bog/ Lough Nacung cSAC	Clady
8	Owenriff (Corrib)	000297	Lough Corrib cSAC	Owenriff, Glengawbeg
9	Currane	000365	Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment cSAC	Capall, Cummeragh
10	Dawros	002031	The Twelve Bens/ Garraun Complex cSAC	Dawros
11	Eske	000163	Lough Eske and Ardnamona Wood cSAC	Eske
12	Kerry Blackwater	002173 & 000365	Blackwater River (Kerry) cSAC & Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment cSAC	Blackwater, Kealduff, Derreendarragh
13	Gearhameen (Laune)	000365	Killarney National Park, Macgillycuddy's Reeks and Caragh River Catchment cSAC	Gearhameen & Owenreagh
14	Glaskeelan (Leannan)	002047	Cloghernagore Bog and Glenveagh National Park cSAC	Glaskeelan
15	Leannan	002176	Leannan River cSAC	Leannan

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

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

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

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3 STATUS OF THE FRESHWATER PEARL MUSSEL *MARGARITIFERA MARGARITIFERA* IN THE BANDON CATCHMENT

3.1 INTRODUCTION TO THE BANDON CATCHMENT

The Bandon pearl mussel catchment is drained by the Bandon and Caha rivers and lies east of the Shehy Mountains. The River Bandon rises in the Shehy Mountains in west Cork and flows east through Dunmanway, Ballineen, Enniskeane, Bandon and Inishannon to Kinsale Harbour. This is primarily a salmon and sea trout river but there are also plenty of small trout, particularly in the lower reaches. As per **Figure 3.1** the Bandon River SAC incorporates stretches of the Bandon pearl mussel catchment.

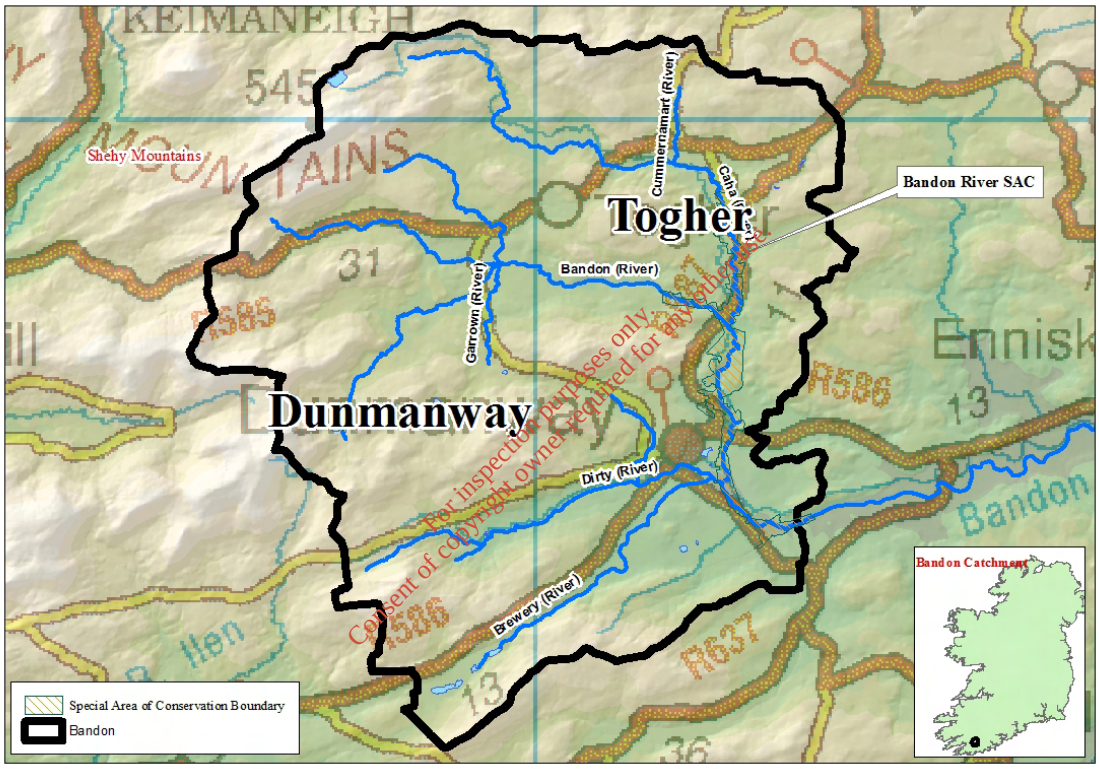

Figure 3.1 Overview of Bandon Catchment indicating extent covered by SACs and main towns

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 Bandon/Caha catchment is pasture which forms 48.61% of the total land use in this catchment. Peat bog areas form 21.87% with coniferous forests accounting for 10.08%

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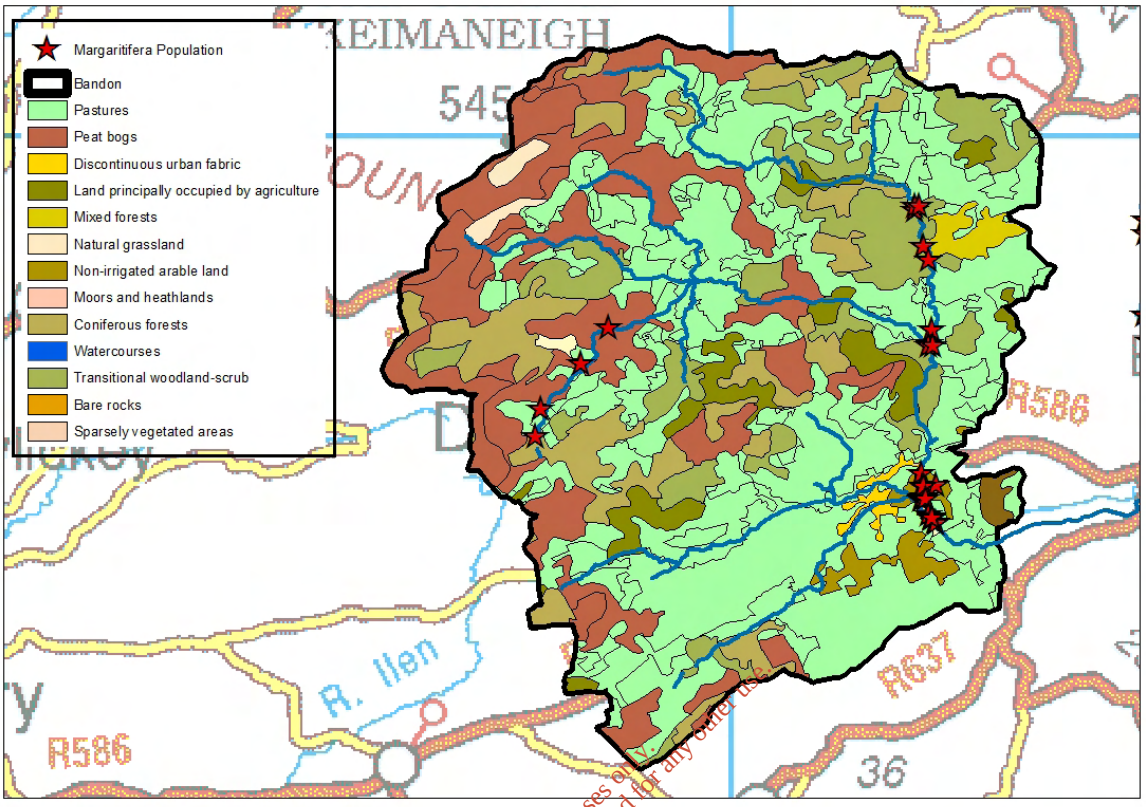

Figure 3.2 Corine Landcover within the Bandon Catchment

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3.2 CURRENT STATUS OF THE BANDON AND CAHA SUB- CATCHMENT

Pearl mussels have been known from the Bandon River and its tributaries the Blackwater and Caha for many years, but as yet there has not been a full survey of the mussel distribution or potential habitat in the catchment.
Survey work was carried out on a 1.5 km section upstream of Dunmanway for an Environmental Impact Assessment for the Bandon River (Dunmanway) Drainage Scheme to relieve flooding in the Dunmanway area (RPS Cairns, 1996). Ninety four cross-sections of 1.5m in width were surveyed (Gittings *et al*., 1998). Three monitoring exercises were carried out on permanently marked transects (Ross, 2001, 2003, 2005). The spatial distribution of mussels in the Caha River was mapped out in 2002 (McMahon, 2003). NPWS staff also completed a Stage 2 survey of the Blackwater in 2004.

Although incomplete, the distribution of pearl mussel in the Bandon River is known to be widespread, with records from as high as Cullenagh Lake to as low as Bandon Town. The Caha and Blackwater Rivers also have wide distributions of the mussel.

Where surveyed, the pearl mussel in the Bandon main channel was found to be abundant in places, with up to 75 individuals per metre square in places (Ross, 2005).

A census of the pearl mussel in the same 1.6 km stretch of lowland river in the vicinity of Dunmanway was taken as part of the environmental impact study for a flood relief scheme (Gittings *et al.,* 1998). This was prior to the publication of standard survey methods for the species, and a cross-section count approach was taken, with ninety-four cross-sections (2–3 m wide) counted and habitat parameters recorded. The total population of the 1.6 km stretch was estimated to be 14,194 and four juveniles were recorded (less than 30 mm and approximately 7 years or younger). High mussel

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densities were associated with shaded channels and low channel depths, although association of mussels with shade is not considered to be positive, suggesting some eutrophication impact of open areas may have occurred in the past (Moorkens, 2000).

Ross carried out studies in the Bandon at Dunmanway between 2000 and 2005 as part of monitoring for engineering works associated with the OPW Bandon River (Dunmanway) Drainage Scheme. This involved counting mussels in permanent transects across the river, and marking some mussels that were translocated as part of the mitigation for the scheme (Figure 3.2.1).

A total of 519 mussels were removed from the river between Dunmanway Bridge and a riffle at the upper end of the impacted stretch. Figure 3.2.2 contains a shell length frequency distribution of a large sample (n = 331) of these mussels. Mussels were observed to range in size from 37.9 mm to 126 mm. This related to approximately eight years of age and upwards.

Ross (2005) reported some significant areas of filamentous algal fouling of the river bed in the Bandon River.

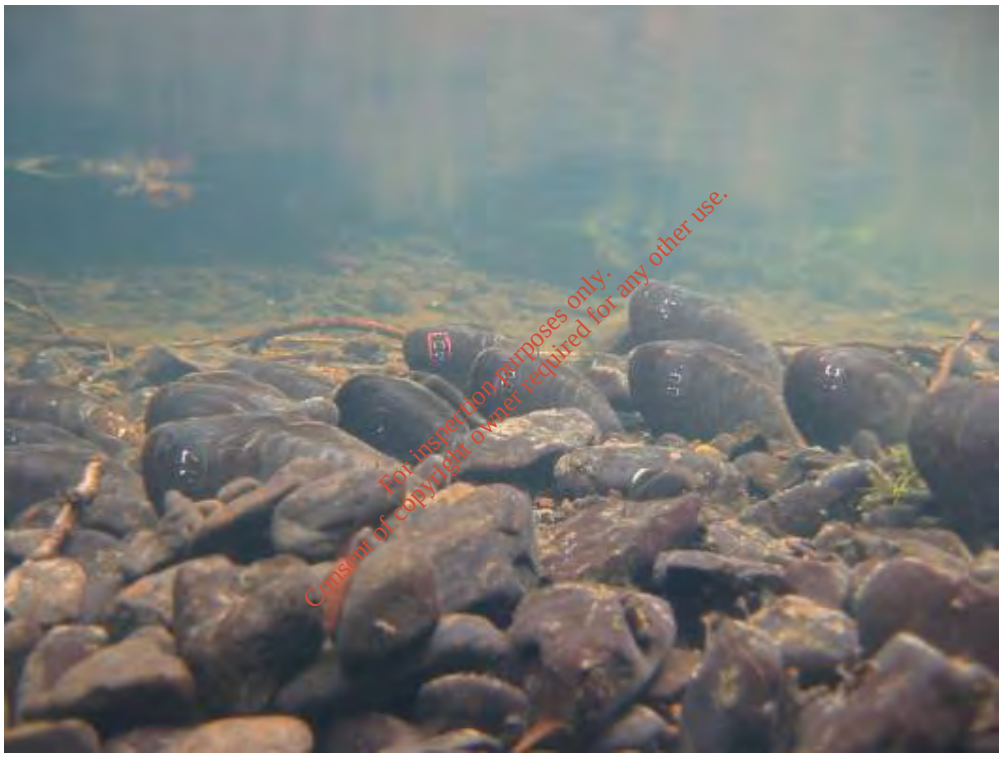

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Plate 3.1 Underwater photograph of some of the marked mussels in the Bandon River. Note the numbered pieces of red Dymo tape used to individually identify the mussels. Photo from Ross (2005).

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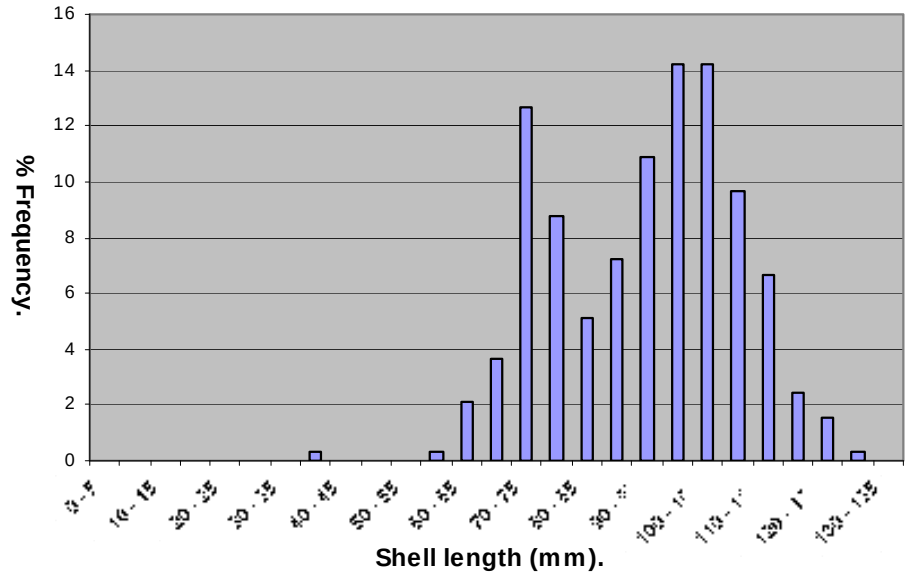

Figure 3.3 Shell length frequency distribution of a sample of *Margaritifera margaritifera* (L.) (n=331) removed from a 220m stretch of the Bandon River immediately upstream of the Long Bridge in Dunmanway, County Cork (from Ross, 2000).

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Ross (2005) noted, from repeated monitoring of transects, that a low level of mortality was observed among the 10 marked mussels previously resident at the relocation site, and the 30 marked mussels transplanted into the area, and concluded that significant unnatural levels of mortality had not occurred since the relocation process was undertaken during June 2000.

In the Caha, mussels occur from approximately five kilometres upstream of the confluence of the Caha and Bandon, to that confluence. A size profile of the Caha River population has not been carried out, but some mussels visible at the surface were removed and measured (McMahon, 2003). Only size classes rather than lengths were noted, the majority being between 50-100mm and some at 100-150mm and 150-200mm. The surveyors considered that the individuals of the population were likely to be all over 30 years of age.

3.3 CURRENT WATER QUALITY IN THE BANDON CATCHMENT

Table 3.1 summarises EPA water quality information (Q-values) from the Bandon system recorded intermittently over the past 37 years. Figure 3.4 illustrates the most recent water quality, as indicated by Q-values, in the Bandon catchment.

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Table 3.1 Q-values at EPA monitoring sites in the Bandon catchment 1971 to 2006
(SMN and OMN specify sites on the WFD surveillance and operational monitoring networks respectively)

RIVER	Site name	EPA Code	SMN	OMN	X	Y	1971	1976	1978	1982	1986	1989	1994	1997	2000	2003	2006
Bandon	Keenrath Br	20B020050	N	N	118687	56660	~	~	~	~	~	4-5	4-5	4	4-5	4-5	4-5
Bandon	Ardcahan Br	20B020150	N	Y	124259	55684	~	~	~	~	4-5	4	4	4	4	4	4
Bandon	Bealboy Br	20B020300	Y	Y	125690	51288	5	4-5	4-5	4	4	4	4	4	3-4	3-4	4
Caha	Br N of Coolcaum	20C010100	N	Y	118397	61836	~	~	~	~	~	~	4-5	4-5	4-5	4	4-5
Caha	Poulnaberry Br	20C010400	N	Y	121926	59246	~	~	~	~	~	4	4	4-5	4	4	4
CAHA	Caha Br	20C010700	N	Y	124342	56018	~	~	~	~	~	4	4-5	4	4	4	4-5
Cullenagh Lake Stream	Farnanes Br	20C040100	N	Y	116621	55137	~	~	~	~	~	4	4	4	4	4-5	4
Dirty	Sillahertane Br	20D010005	N	N	117892	51163	~	~	~	~	~	4	4	4	4	4	4
Dirty	Br NW of Tonafora	20D010050	N	Y	121880	52220	~	~	~	3-4	3-4	3	4	4	4	3-4*	4
Dirty	Br u/s Bandon R confl	20D010100	N	N	123542	52544	~	~	3-4	3-4	3-4	3-4	4	4	3-4	4	4

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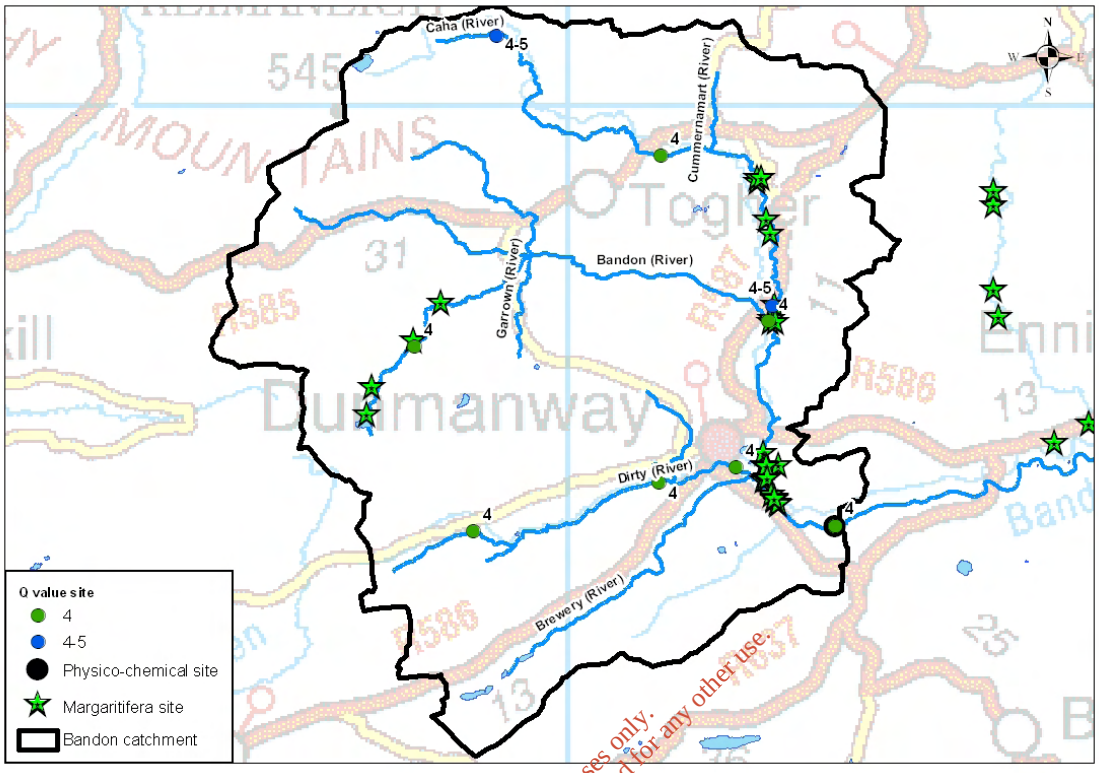

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Figure 3.4 Bandon catchment EPA Q value monitoring sites with most recent Q values, and location of Local Authority physico-chemical monitoring sites

Table 3.2 shows how the EPA interprets Q-values in terms of water quality and how this relates to WFD status. Based on Q-value alone, all sites in the Bandon catchment would considered to be at high or good status for the WFD.

Table 3.2 EPA Water Quality Status

Biotic Index	Quality Status	Water Quality	WFD Status Classes
Q5	Unpolluted	Good	High
Q4-5	Unpolluted	Fair-to-Good	High
Q4	Unpolluted	Fair	Good
Q3-4	Slightly Polluted	Doubtful-to Fair	Moderate
Q3	Moderately Polluted	Doubtful	Poor
Q2-3	Moderately Polluted	Poor-to-Doubtful	Poor
Q2	Seriously Polluted	Poor	Bad
Q1-2	Seriously Polluted	Bad-to-Poor	Bad
Q1	Seriously Polluted	Bad	Bad

In 2006 the EPA assessments (John Lucey, *pers comm*) were:

Bandon: Mostly satisfactory following some improvement at three locations, downstream of Dunmanway and Bandon, but reversion to slightly polluted conditions downstream of Enniskean.
Caha: Continuing satisfactory.

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Cullenagh Lake stream: Some siltation due to clearance and field drainage with loss of small pearl-mussel population.
Dirty: Satisfactory throughout following improvement at second location.

Figure 3.4 details the location of physico-chemical monitoring sites in the Bandon pearl mussel catchment. **Table 3.3** shows the data on Molybdate Reactive Phosphorus (MRP) concentrations (mg P/l) between 2005 and 2007, which were compiled for the determination of WFD status. The Environmental Quality Standards for MRP are stated in the Consultation Paper 'Draft European Communities Environmental Objectives (Surface Waters) Regulations 2009, and are;

For High status ≤0.025 (mean) or ≤0.045 (95%ile)
Good Status ≤0.035 (mean) or ≤0.075 (95%ile)

The supporting physico-chemical quality elements define three status levels – High, Good or less than Good. In the interim status assessments produced to date only two levels have been defined Good or Better and Less than Good. Based on these standards, the site in the Bandon catchment for which data is available, achieve the EQS for Good or better however due to the high maximum value. The sources of these nutrients should be investigated further.

Table 3.3 Ortho-P levels at stations in the Bandon catchment

EPA Code	River	Location	No of samples	Mean PO4-P	StdDev PO4-P	Max PO4-P	Min PO4-P	95%ILE PO4	EQS Good or better/Less than Good
20B020300	Bandon	Bealboy Br	16	0.0155	0.0078	0.038	0.003	0.0268	Good or better

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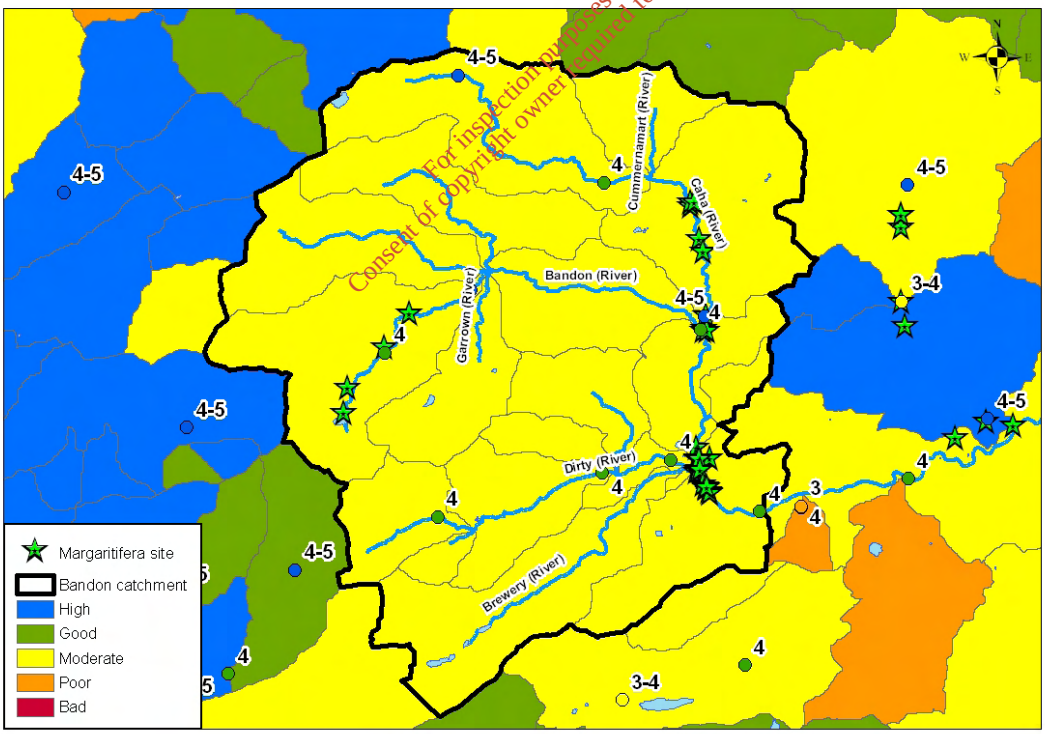

Figure 3.5 WFD status classification for the Bandon catchment

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Figure 3.5 above shows the final WFD status classification for the Bandon catchment. The lowest status defined by the individual quality elements available is used to define final WFD status for a water body. Not all quality elements permit a full five-category status definition from High to Bad but all available information is used at the best available resolution by the EPA. If a river water body (RWB) has more than one monitoring site within it the site with the lowest status is used to define the status of that RWB as a whole. Where the monitoring point represents an insignificant proportion of the length of the river channel (less than 100m), e.g. as a mixing zone, however, it can be ignored but in general all monitoring points are assessed and the lowest status is the one that defines the overall status for the RWB. The assessment of macroinvertebrates, includes a special consideration of the conservation status of pearl mussel in SACs protected for the species. In such areas where pearl mussel are at unfavourable conservation status (i.e. not recruiting), the status reported cannot be better than moderate. In the case of the Bandon catchment, Q values within the catchment vary between high and good status. The EQSs set for MRP were met at one site that was monitored. The pearl mussel population is at unfavourable conservation status. Therefore all 19 RWBs within the catchment have been made moderate. However, further fieldwork in 2009 will confirm whether those RWBs not containing mussels should have high or good status and this will be detailed in the final plan for the Bandon catchment.

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4 IDENTIFICATION OF KEY PRESSURES AFFECTING THE STATUS OF THE FRESHWATER PEARL MUSSEL *MARGARITIFERA MARGARITIFERA* IN THE BANDON CATCHMENT

4.1 Introduction

The main causes of the current unfavourable conservation status of the Bandon pearl mussel population are described below. The key improvements needed for the Bandon Catchment are to restore juvenile habitats to appropriate condition by simultaneously reducing nutrient and silt inputs to the river.

The order with which the pressures are described does not reflect their magnitude or their significance for the decline in pearl mussel populations in the Bandon catchment.

Table 6.3 contains a toolbox of measures, a selection of which will be implemented at those sites where investigations and risk assessment show that specific pressures need to be remediated to restore pearl mussel to favourable conservation status. Throughout 2009, a series of field investigations and further risk assessments will be conducted in order to verify the pressures identified below, as well as to locate other pressures within the Bandon catchment. Field investigations will include biological surveys (pearl mussels, fish, invertebrates and plants), as well as physico-chemical, morphological and siltation surveys. Further details of these field surveys can be obtained from Chapter 5 and the monitoring methods report (www.wfdireland.ie).

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 cost benefit analysis to ensure that the most cost-effective measures are used to solve particular problems.

The final pearl mussel plans which are due for publication in December 2009 will contain a list of the precise measures which will only be applied to those areas or sites within the catchment which have been identified as requiring them.

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4.2 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.

4.2.1 Morphological Pressures

Field investigation is required to confirm locations where morphological pressures, such as channelization, peat cutting, deforestation and over-grazing pose a significant risk or have had significant negative impacts on the pearl mussel population. Measures will be applied to those areas identified as potentially significant sources.

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), helps us to identify and locate the areas where pressures exist. By using detailed aerial imagery we can further refine these assessments and identify more localised issues. Through identification of these pressures using a desk-based approach we can then focus our field-work element within these areas. This enables 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

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future guidance produced by DEHLG. These measures encompass the concepts of reducing the pressure itself, and remediation where necessary. Regulation of future pressures may also apply to engineering type pressures near waters.

Table 4.1 shows the national GIS pressure datasets that have been used in the assessment of pearl mussel catchments from a morphological perspective.

Table 4.1 National GIS Based Pressure Datasets for Morphology

Pressure	National GIS Pressure Dataset	Present in Bandon Catchment
Overgrazing	National dataset developed by CFB using expert judgement	No
	Damaged areas depicted by Commonage Framework Plans through the Rural Environmental Schemes and Programmes (REPS 3) in 1999	Yes, but areas are relatively small.
Channelisation	OPW Drainage Scheme	Yes, just upstream of Pearl Mussel Populations
	OPW Drainage District	No
Barriers To Migration	Barriers to Migration (located using expert judgement by CFB but not yet qualified using fish data)	No

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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 4.1**, 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 4.1 illustrates the spatial extent of commonage areas and indicates the level of damage as recorded in 1999.

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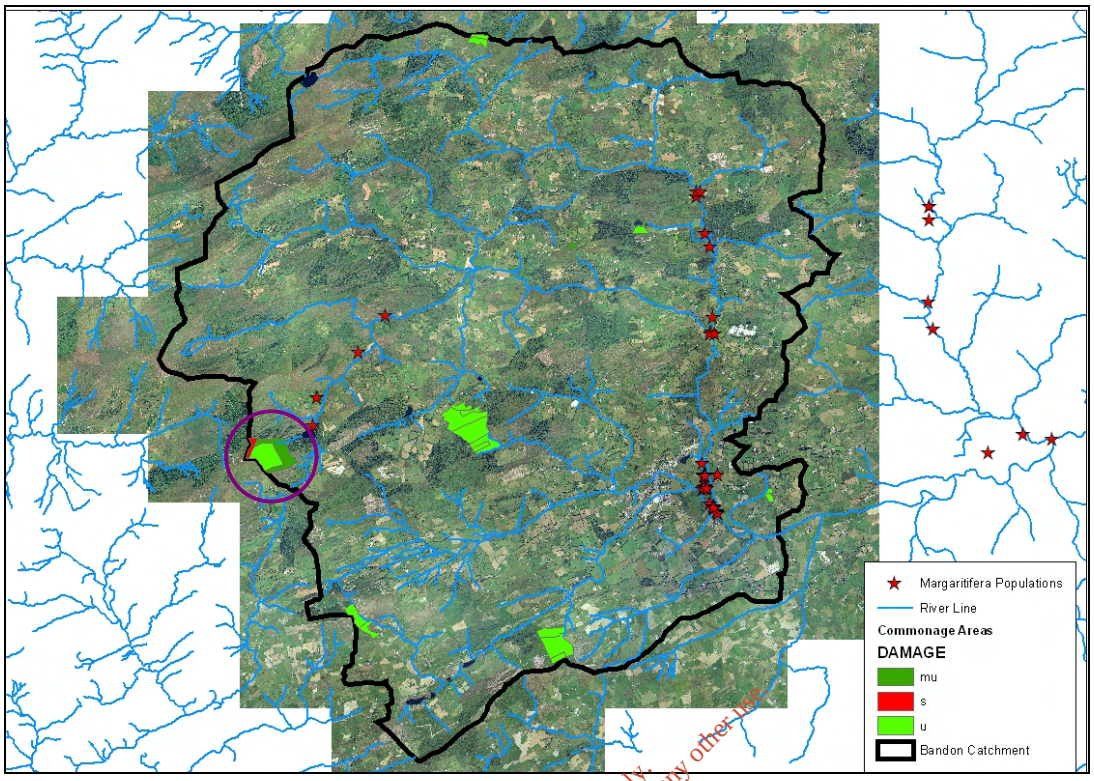

Notes:

U – Undamaged	MU - Moderately Undamaged
MM – Moderately Damaged	MS - Moderately to Severely Damaged
S - Severely Damaged	S* - Very Severely Damaged

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Figure 4.1 Areas of Commonage and Associated Damage

Figure 4.1 indicates that:

- The total area of the Bandon catchment is 15821ha
- 211ha of this area is Commonage land.
- 4ha of the Commonage land is severely damaged, this is located upstream of Pearl Mussel populations as circled on Figure 4.1. This is the significant focus in terms of applying measures.
- The remainder of commonage land is undamaged or moderately undamaged.

4.2.2 Direct Morphological Pressures

Channelisation

Arterial drainage was completed by OPW in 2001 as part of the Dunmanaway Flood Relief scheme. The location within the catchment is indicated by **Figure 4.2**.

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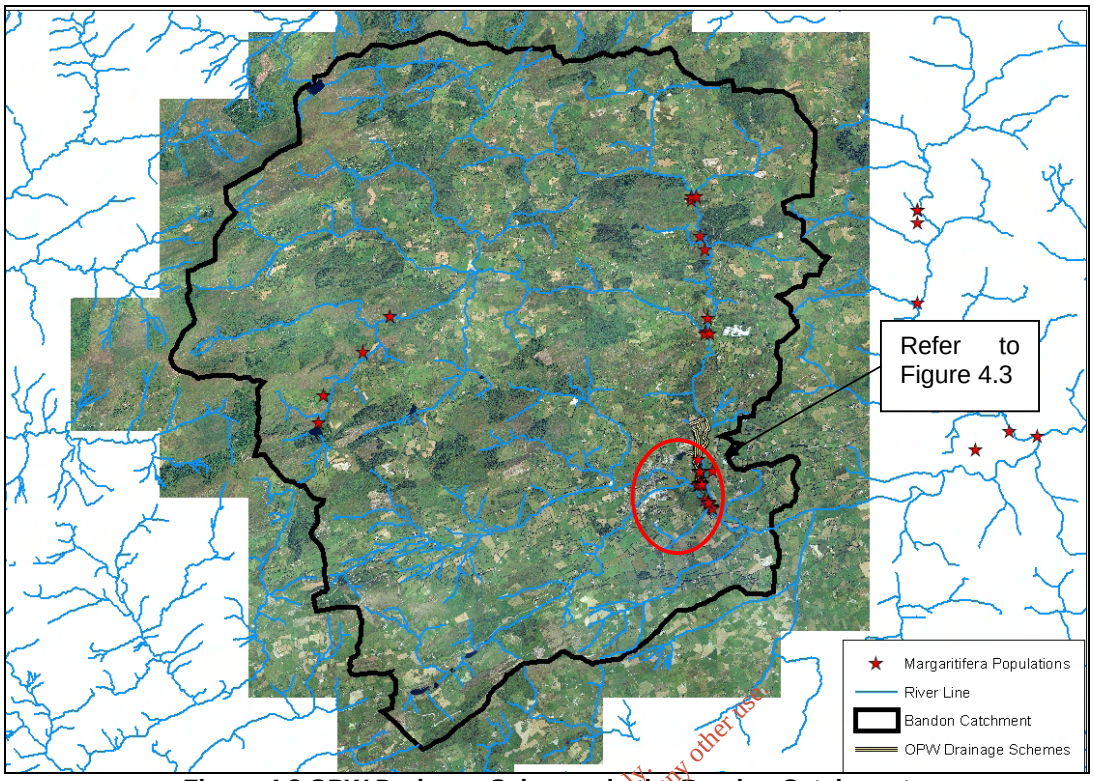

Figure 4.2 OPW Drainage Schemes in the Bandon Catchment

This scheme took place directly upstream of and also within the vicinity of Pearl Mussel populations, therefore the associated impacts are of significant concern.

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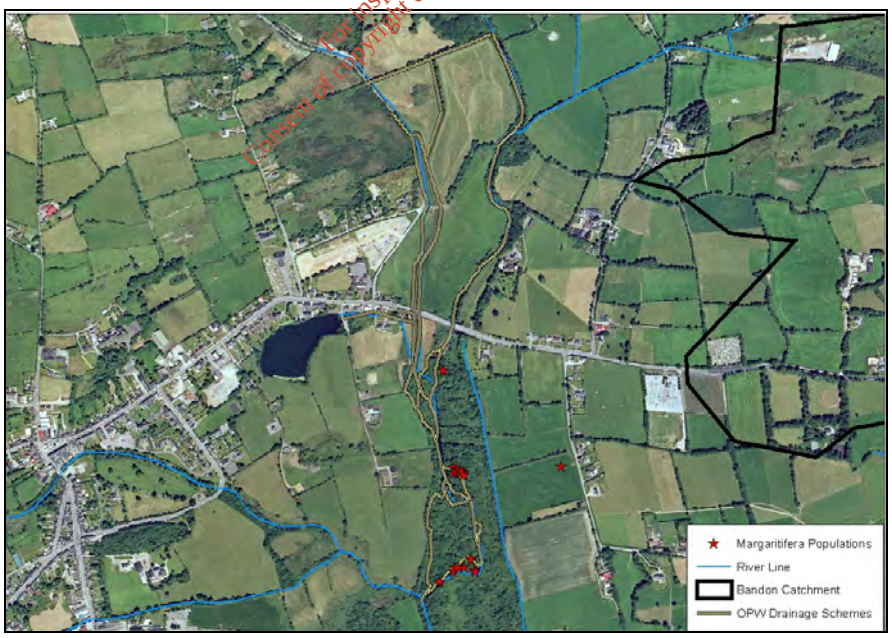

Figure 4.3 OPW Drainage Schemes in the Bandon Catchment

The arterial drainage scheme would have disturbed sediment regimes and habitats within the river since widening and/or deepening of the channel is likely to have taken place.

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Surveying and monitoring during implementation of the flood relief scheme was undertaken (refer to Chapter 3.0, Section 3.2). An Environmental Impact Assessment was undertaken and mitigation measures such as relocation of a portion of the Pearl Mussel populations.

However, OPW watercourse maintenance programmes for 2007 and 2008 indicate that stretches of the Bandon, just upstream of the Pearl Mussel populations were designated for maintenance. This involves works to reinstate the flood conveyance capacity and although it may be small scale, such as debris removal, it may also involve dredging. As such, watercourse maintenance is a repetitive pressure on the Pearl Mussels if it is not managed correctly.

Regulation of Future Engineering Activities

The draft River Basin Management Plans outline all of the required (or basic) measures currently in place in Ireland (Table 6.1). 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). The Department of the Environment, Heritage and Local Government is considering the introduction of new regulations to control physical modifications to surface waters. These may be risk-based with varying levels of authorisation depending on the extent of engineering activity proposed.

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.

Therefore structures within rivers will be subject to controls in future.

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4.2.3 Abstractions

Water abstraction from rivers can cause low flows, which can be directly damaging through drying out of existing previous 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 to identify areas at risk by the Eastern River Basin District Project (ERBD). Whilst this register indicates large scale schemes, smaller, more localised abstractions, such as for farm use or small scale water supplies are not identified. Data are currently not available on the location of smaller abstractions, therefore investigation shall be necessary.

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Large Scale Abstraction

This national register indicates two waterbodies within which abstractions take place in the Bandon Catchment – refer to **Figure 4.4**

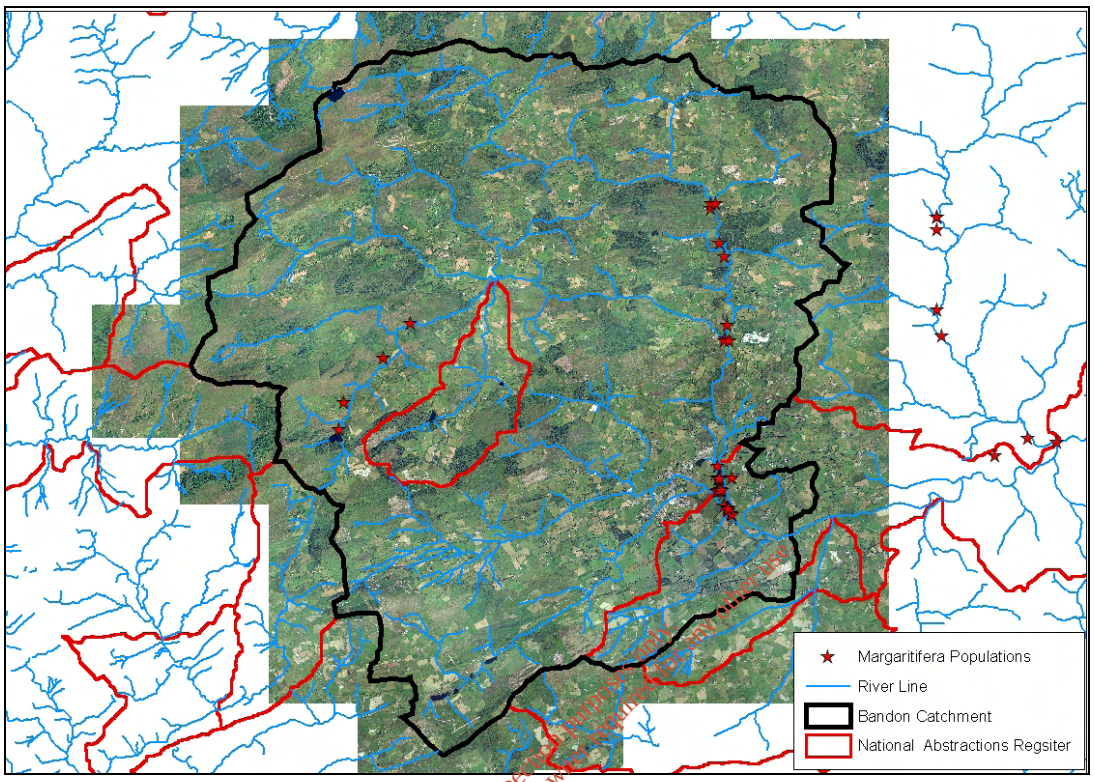

Figure 4.4 Location of Abstractions in the Bandon catchment from the National Abstraction Register

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4.3 Diffuse Pressures

4.3.1 Forestry

Forestry establishment (including drainage and ground preparation), thinning, roading, harvesting, replanting and all associated management practices are a major potential source of both silt and nutrients in pearl mussel catchments. Establishment of forests (afforestation) generally involves site preparation including drainage, which can give rise to erosion and release of silt into rivers or lakes. Afforsestation also occasionally use of herbicide. Fertilisation of forestry at establishment stage and subsequently (often aerial fertilisation) can potentially lead to release of nutrients into the watercourse. Fertilisation is generally a requirement for nutrient poor soils such as peat soils (raised bog, blanket bog, fen peat and cutaway peat). 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. A further significant contributing factor is the extent of the drainage network in the forested areas. 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. Recent research related to forestry operations, such as harvesting, indicates these forest stands, where planted on peat type soils, pose the greatest threat in terms of sedimentation and nutrient loss.

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

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observed with coniferous forest stands on podsolic/lithosolic soils on granite and to a lesser extent on sedimentary rocks. The magnitude of the impact has been found to relate to the size of the forest stand with impacts being observed above 25% forest cover on the appropriate hydro-geological setting. Impacts may also be confined to the upper catchment areas, where forest stands are generally located and which provide important spawning and nursery areas for salmonids, and may not extend down the catchment due to increased buffering capacity.

The National Summary Characterisation Report identified forestry as a one of the main pressures 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 longer in the case of broadleaves.

The threat from forestry operations in pearl mussel catchments is significant. Appropriate mitigation measures must be put in place to ensure the restoration and future protection of the pearl mussel populations. Such measures may include initiatives to remove or restructure forestry in pearl mussel catchments. Even given such a commitment, major mitigation works will be necessary during the removal or restructuring process to protect pearl populations.

Forest stands in the Bandon-Caha Catchment are spread throughout the catchment and comprise both Coillte (State) and private forest stands (**Figure 4.5**). These forest areas are primarily coniferous type. The main forest areas are located above the pearl mussel populations.

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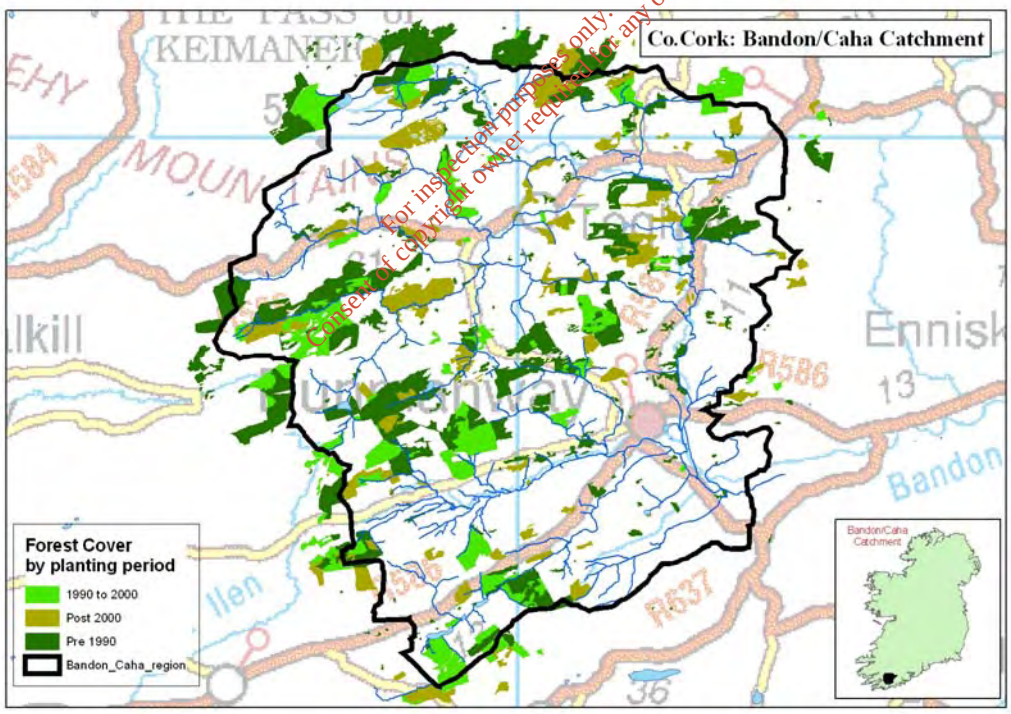

Figure 4.5 Bandon-Caha forestry by planting period.

Forest species are mainly of the coniferous type, largely Sitka Spruce and Lodgepole Pine with some Japanese Larch. The forest areas include some small areas of Broadleaf including pundunculate oak and Alder.

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An analysis of the age structure of the forest stands indicates that 1,300 hectares of the coniferous forestry was planted prior to 1990. Of the total forest stand, 43% of the existing plantation in the catchment is pre 1990.This is significant as forest planted prior to this date were largely planted without the benefit of the Forest Service guidance documents and codes of practice. In addition the national Irish Forest Service soils map indicates that this forestry was largely planted on podsolic-lithosolic soils wet type soils with some planting on acid mineral soils and also blanket peats. The afforestation technique used generally resulted in significant drainage of the area, direct connectivity of the drainage network to the main watercourses and planting right down to stream or lake edge. No buffer zones would have been provided.

Main pressures from forestry in the Bandon Caha catchment

The main pressures from forest stands identified in the Bandon-Caha catchment are

- Acidification impact from forest stands on acid geological settings.
- Nutrient enrichment from ground and aerial fertilisation: Conifer forest growing on nutrient poor soils like peat may require an application of phosphorous fertiliser to achieve the required yield class. Peat soils have poor P retention properties and aerial fertilisation poses a risk of nutrient loss to the receiving waters.
- Nutrient enrichment from brash decay post felling: Brash decay post clearfelling can potentially release nutrient, both N and P.
- Sediment loss: Forestry operations associated with harvesting, such as roading and clearfelling, can give rise to significant loss of sediment particularly on highly erodible soil types.
- Pesticide use. Both insecticides and herbicides are 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. Potential exists for losses of insecticide to the aquatic environment.

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The above pressures have the potential to impact significantly on the pearl mussel population in the Bandon-Caha catchment. The risk is increased due to the direct connectivity of the forest drainage network to the receiving water course, lack of vegetated buffer strips. There is some potential for P and N loss from harvesting operations due to the poor retention capacity of the peat type soils with forest stands.

4.3.2 Agriculture

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.

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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.

The Bandon-Caha rivers are dominated by peat gleys and peaty podsols type soils with areas of brown earths and podsolics (**Figure 4.6**). The Dirty and Brewery rivers are dominated by brown earths and podsolics. Soils have been grouped in accordance with their organic matter content based on the Irish Forest Service soils map (commonly referred to as the Teagasc/EPA soil map layer). Soils which are high in organic matter have low phosphorus retention properties. Grassland areas are largely associated with the brown earths and podsolics soil types in the catchment. Moderate livestock unit density is indicated by the national livestock unit density data provided by Teagasc (**Figure 4.7**), with densities ranging up to 1.41 lu/hectare, additionally soil P levels are high indicating that agriculture is a significant land use pressure in the catchment. 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. 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.

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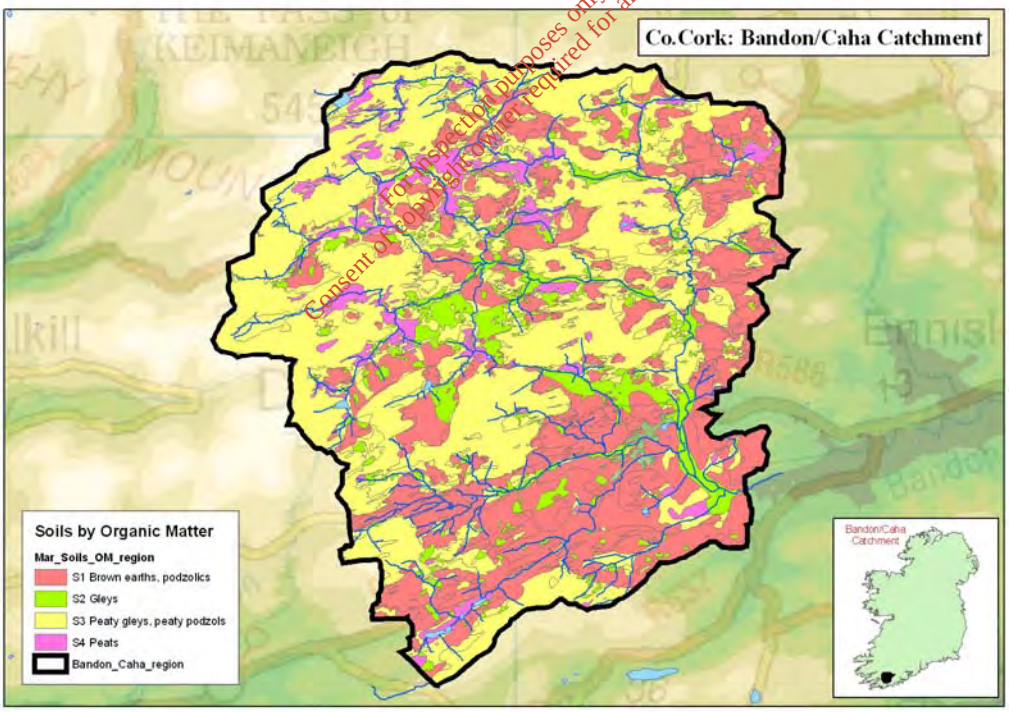

Figure 4.6 Bandon-Caha soil organic matter content

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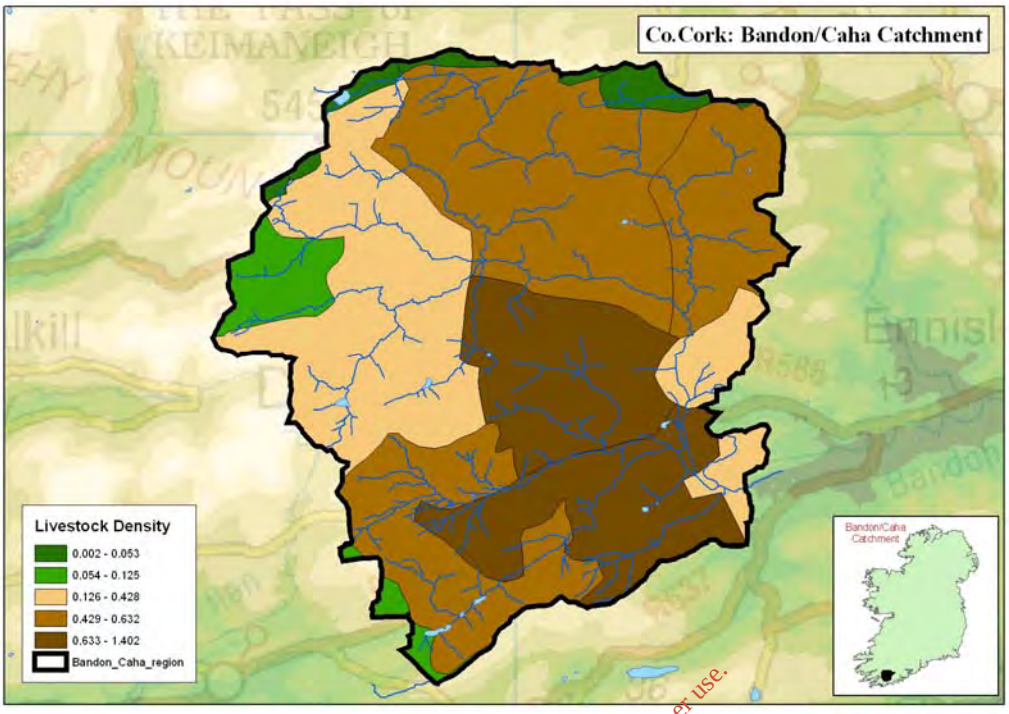

Figure 4.7 Bandon-Caha livestock unit density

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4.3.3 On-Site Wastewater Treatment Systems

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 as 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?

Simplified pathway risk maps (**Figures 4.8, 4.9 & 4.10**) of the Bandon-Caha catchment have 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. Parts of the catchment, the main Bandon and Caha rivers indicate areas of very high pathway risk from on-site systems within the catchment in terms of pathogens and phosphorous load to surface waters. 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 surveys of onsite systems in the catchment where there is a high likelihood of risk to surface waters, particularly from phosphorus.

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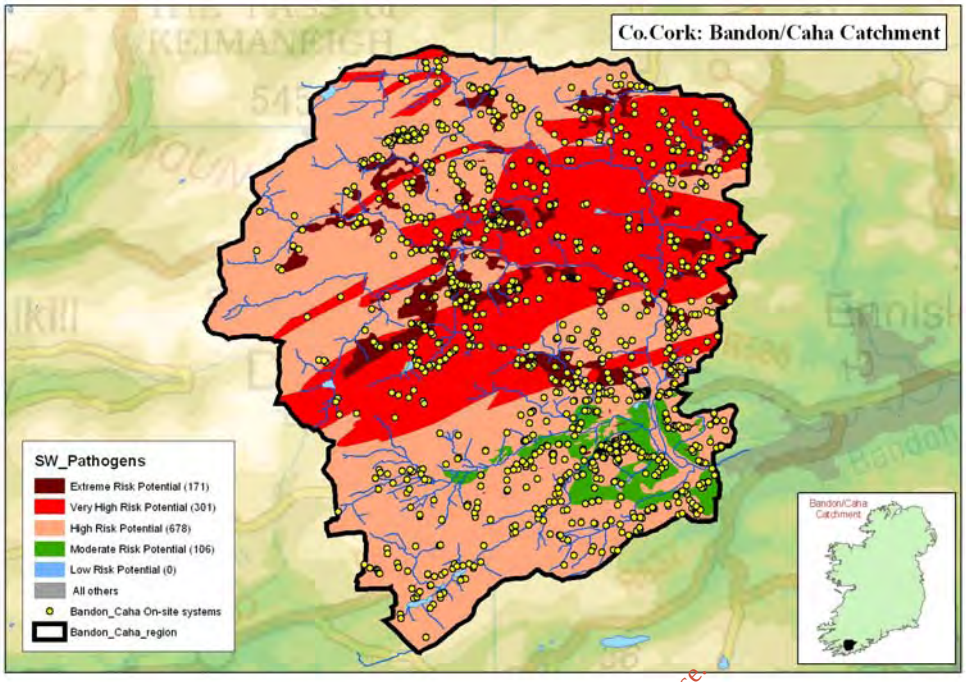

Figure 4.8 Surface water pathway pathogens risk map showing location of On-site wastewater treatment systems

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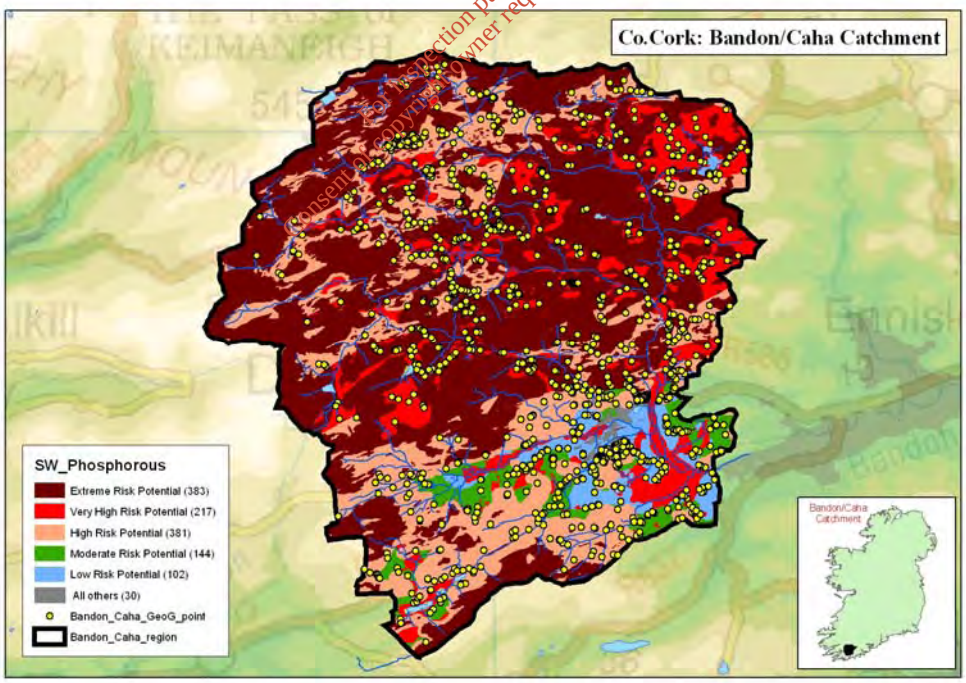

Figure 4.9 Surface water phosphorous pathway risk map showing location On-site wastewater treatment systems

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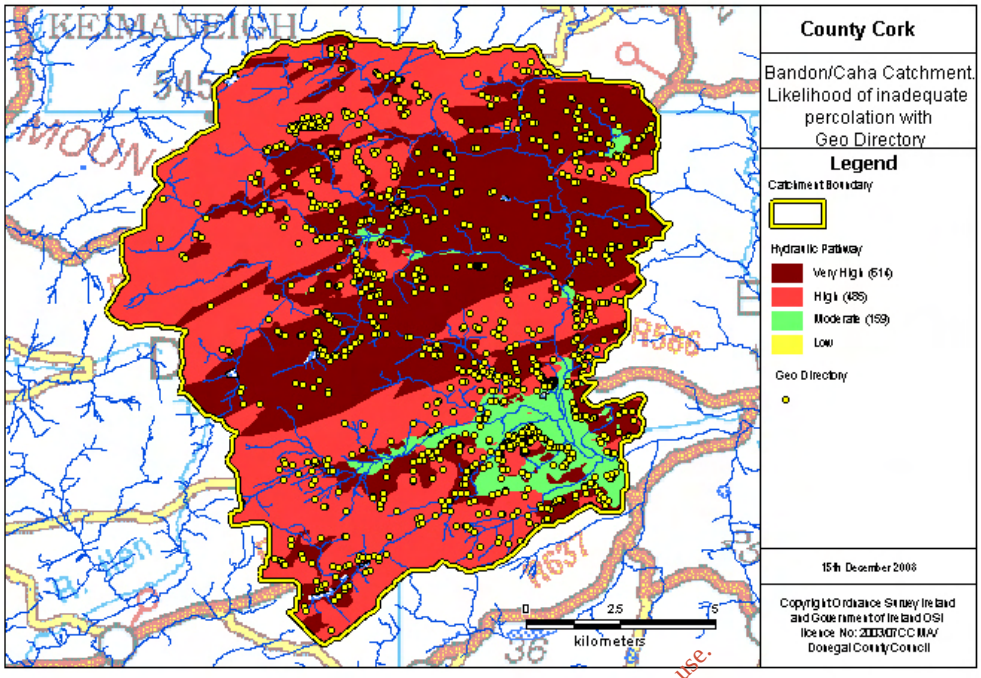

Figure 4.10 Surface water likelihood of inadequate percolation risk map showing

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4.4 Point Source Pressures

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.

A review was undertaken of the available information on municipal and industrial discharges by the South Western River Basin District Project (SWRBD) and an assessment carried out as to whether the river waterbody was considered to be at risk from point sources under a number of circumstances. Within the Bandon catchment no waterbodies were found to be at risk of failing to meet the objectives of the WFD due to municipal and industrial discharges.

The Bandon Catchment is not due to be included in the WFD surveillance monitoring programme till 2009.

The site which will be monitored is as follows:

- Br nr Desert Station (Gird Co-ords- 138063, 54062)

There is also a LA Dangerous Substances monitoring site located on the Bandon Catchment. This site is located at Innishannon Br (Grid Ref- 154155 57051). To date there has not been any exceedances at this site for the 14 substances monitoring under the LA Dangerous Substances Monitoring Programme**.**
Measures from Cork County Council LA Dangerous Substances Measures as per National Implementation Report 2005 (note overview of measures for the whole county not particularly the Badon/Caha Catchment)

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Current Measures

1. Regular sampling, monitoring and analysis of all WWTP final effluent for dangerous substances (except cyanide and arsenic);
2. Risk rating applied to each WWTP and ongoing monitoring for dangerous substances;
3. Identification of industrial point sources with licences to discharge dangerous substances;
4. Modification of farm surveys to include herbicides and monitor identified surface waters at risk;
5. Monitoring of high risk areas impacted from forestry and consultation with Coillte to agree on corrective actions where necessary;
6. Assessing levels of dangerous substances from waste facilities and introduction of corrective actions;
7. Biological assessment of tidal waters for TBT;
8. Consultation with neighbouring local authorities regarding shared water bodies;
9. Inform relevant stakeholders of the Dangerous Substances Measures report.

Proposed Measures

1. Develop plan of action based on the Biological Assessment of Tidal Waters;
2. Update database of monitoring for dangerous substances at landfills;
3. Assess risk of leachate from closed landfills by carrying out site visits and monitor surface waters if necessary;

A site at the Bandon catchment was also included in the EPA 99-00 dangerous substances monitoring programme. Only one substances Selenium slightly exceeded the proposed annual average standard at the time (note there has not been any EQSs developed for this particular metal under the WFD).

The Bandon catchment contains four quarries which are adjacent to river stretches which contain pearl mussel populations. The potential risk from quarry dust, effluent or pollution incidents will need to be investigated further within the catchment throughout the 2009 survey season.

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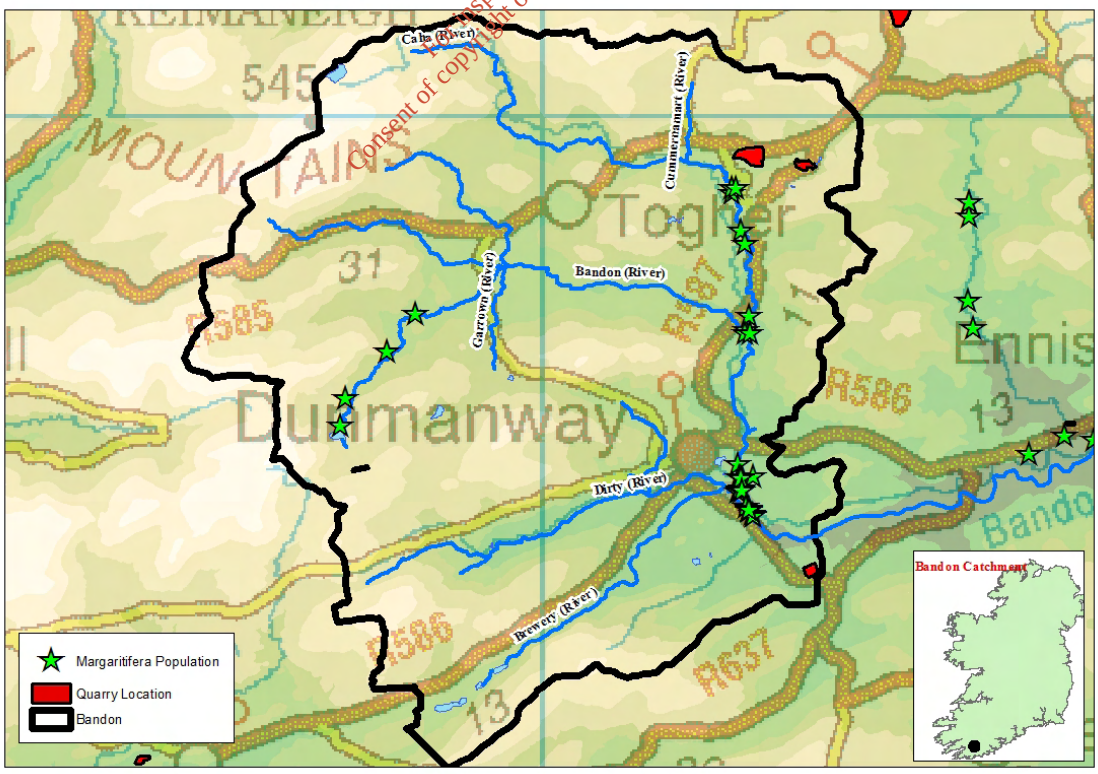

Figure 4.11 Location of Quarries within Bandon Catchment

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5 MONITORING

5.1 Overview

A detailed monitoring programme will be developed for the Bandon catchment during 2009, in order to evaluate the effectiveness of measures and progress made towards restoring favourable conservation status.

This programme shall comprise monitoring of:

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

Freshwater pearl mussels

For the purposes of examining the overall changes in the distribution and abundance of mussels, permanent mussel transects will be counted annually, completing a full cycle of transect monitoring once every three years. The locations of these permanent transects are chosen to cover both the geographical range of mussels within the catchment and their range of population density. 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.

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In order to monitor the conservation status of the mussel populations, in accordance with the criteria set out in the draft European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations, 2009, quadrat searches will be conducted. 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 them. This provides information on whether the population is recruiting or not and allows any changes in population age structure to be detected. Quadrat searches will also be conducted on a three year cycle, with quadrats being 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 will be supplemented by experimental kick sampling to look for one to two year-old mussels.

5.2 Other biological elements and general physico-chemical components

Restoration of the mussel population to favourable conservation status is the ultimate criterion for measuring the success of the sub-basin plan. However, as this may take some time to achieve, targets have been set for other more rapidly responding biological and physical elements under draft European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations, 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. Catchment-wide baseline surveys will be undertaken for these biological and physical elements during 2009.

In addition to this baseline survey, relevant biological and physico-chemical data will be provided by the on going WFD Monitoring Programme (2007-2009), which includes a number of monitoring sites in the Bandon catchment. The overall WFD monitoring programme will be revised during 2009 (for the 2010 – 2015 RBMP cycle) to include operational monitoring sites located to assess the effectiveness of both general, catchment-wide measures and targeted, site-specific measures. This operational

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monitoring programme will include all elements required for the pearl mussel sub-basin plan, as well as those standard WFD elements. These monitoring sites will be listed in full, along with the biological and physico-chemical components that are sampled at each in the final sub-basin plan. In addition, during 2009, a number of methods for monitoring siltation will be investigated, including the use of biological metrics, redox-potential, semi-quantitative methods and simple visual estimates.

5.3 Investigative monitoring

In addition to the above monitoring, which will provide information on the conservation status of the mussel population, the ecological status of the catchment and the effectiveness of any measures implemented, investigative monitoring will be conducted to identify the pressures and their sources, which have led to unfavourable conservation status of the pearl mussel. Investigative monitoring may include the following:

1. Macroinvertebrate and/or diatom sampling to identify point and diffuse sources of nutrients and silt
2. Fluvial audits to identify hot-spots of silt loss in the catchment
3. Morphological surveys to identify morphological pressures along the river corridor
4. River corridor surveys to identify pipes/drains that are delivering pollutants to the river
5. Chemical analysis to determine the nutrient load being delivered by point sources
6. Survey of juvenile salmonids to establish whether loss of host fish or failed glochidial attachment are significant concerns

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6 SUMMARY OF MEASURES

Under the WFD, each of the River Basin Management Plans (RBMP) must include a set of management measures (Programmes of Measures (POMs)) aimed at achieving the objective of good status by 2015. There are two types of POMs under the Draft RBMP.

- **Required** measures which are mandatory by law and affect all waters (Table 6.1).
- **Additional** measures which can be chosen to target problems in some or all waters if required measures don't achieve the objectives of the WFD (Table 6.2).

The measures listed in Tables 6.1 and 6.2 follow the WFD format and detailed information in relation to these measures can be obtained from the Draft RBMPs.

A suite of pearl mussel additional measures have also been developed (Table 6.3).

The suites of additional measures detailed in Tables 6.2 and 6.3 can be applied to target specific problem within pearl mussel catchments.

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Table 6.1 Required measures under the Draft RBMPs

Bathing Waters Directive	Who leads	When and Where
Actions: Quality of Bathing Waters Regulations: o Identify bodies of water used as bathing areas. Undertake bathing water monitoring programmes. Adhere to bathing water quality standards. Classify Bathing Waters. Develop Bathing Water Profiles. Investigate causes of pollution potentially affecting Bathing Waters. Develop Bathing Waters Management Plans with active involvement from users of the bathing areas. Increase provision of information on quality and management of bathing areas to the public. Report annually to the EPA with respect to bathing water identification, monitoring and assessment. o Report annually to the Commission with respect to bathing water identification. Where necessary, provide advice, recommendations and directions with respect to bathing waters o Where necessary, provide general policy directions with respect to bathing waters. o Cooperate on cross border bathing waters including exchange of information and joint action.	Local Authorities EPA DEHLG Local Authorities, DEHLG, EPA	2009 – 2015 Designated Sites

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Birds and Habitats Directive	Who leads	When and Where
Actions: Natural Habitats Regulations o Include all water-dependant species and habitats in the WFD Register of Protected Areas. Ensure that appropriate assessment is carried out in relation to activities which are likely to impact on designated sites. Manage land use planning and development activities within and upstream of designated areas in such a way as to allow achievement of conservation objectives. Where necessary, enter into management agreements with owners, occupiers or lessees of land within or adjacent to designated sites e.g. Farm Plans. o Ensure that appropriate assessment is carried out before granting licenses to operations/planning permission to developments that are likely to have a significant impact on designated sites. o Implement freshwater pearl mussel sub-basin plans. Incorporate the protection of designated sites in all plans and programmes e.g. development plans. Where necessary, control damaging activities within and outside designated sites that are likely to impact on designated sites. o Designate sites hosting habitats and species of European importance for inclusion in the Natura 2000 network. Establish monitoring and surveillance programmes. Develop conservation measures within management plans to ensure that designated sites meet favourable conservation status. Where necessary, regulate damaging activities within and outside that are likely to impact on designated sites. Require owners, occupiers or users to restore land where an operation or activity has impacted on a designated site. License dealers of listed fauna. Prohibit purchase, sale or damage of listed flora. Introduce measures necessary to protect listed flora and fauna. Establish a system to monitor the incidental capture of listed fauna and undertake research and conservation measures as required. Introduce measures to ensure that the allowable taking of listed flora and fauna will allow the achievement of favourable conservation status. Where necessary, introduce derogations to allow non-compliance with the Regulations as long as favourable conservation status is maintained. Report on implementation to the Commission every 6 years. Introduce compensatory measures to ensure the coherence of the network of designated sites if damaging activities are allowed to go ahead. Promote research, education and information supply. Reintroduce native species where research shows it would benefit conservation status.	Local Authorities Local Authorities, EPA, An Bord Pleanála All public authorities NPWS, DEHLG	2009–2015 Designated Sites
Drinking Water Directive	**Who leads**	**When and Where**
Actions: Drinking Water Regulations: (see also Protection of Drinking Water Sources) o Ensure compliance with the Regulations. Issue guidelines on monitoring, implementation, enforcement and remedial actions if required. o Prohibit water supplies considered to pose a potential danger to human health.	EPA Local Authorities, HSE	2009 – 2015 Designated Sites

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o Monitor drinking water quality to ensure that drinking water meets the quality standards in the Regulations. Ensure that action is taken in relation to non-compliances due to water distribution systems in commercial or public premises. Ensure that action is taken in relation to non-compliances due to water distribution systems in private premises. Maintain a register of water supplies and records of monitoring. Facilitate public access to information. Audit water supplies. Immediately investigate non-compliances. Inform consumers of non-compliances and remedial actions. Introduce measures where water supplies pose a potential danger to human health having regard to the risks associated with interruption of supply or restriction of use. Prepare Action Programmes where the quality of water does not meet the required standards. Require persons responsible for pollution to prepare and implement Action Plans to prevent and mitigate pollution. Ensure that any measures introduced under the Regulations do not allow deterioration in drinking water quality.	Local Authorities	
Actions: Water Services Act:		
o Facilitate the provision of safe and efficient water services and water service infrastructure. Supervise and monitor the performance of water services authorities and issue guidelines where necessary. Plan and supervise the investment programme for water services under the Water Services Investment Programme. Issue compliance notices specifying corrective actions in the event of non-compliances with the Act. Develop detailed guidance on the preparation of Water Services Strategic Plans under the guidance of a technical sub-group of the Environmental Services National Training Group.	DEHLG	
o Take account of all other relevant principles, plans, programmes, strategies, guidelines, codes of practice and regulations.	DEHLG, Local Authorities, EPA	
o Provide water services for domestic and non-domestic requirements. Take measures necessary to adhere to drinking water standards. Ensure that no measure will have the effect of allowing any deterioration in drinking water quality or increase in pollution of waters used for the provision of drinking waters. Establish monitoring programmes and maintain water services records. Communicate derogations and non-compliances with drinking water standards to the population concerned along with reasons, actions and advice. Supervise provision of water services by other parties. Prohibit or restrict a water supply that poses a potential threat to human health or the environment. Require remedial actions to be taken where there is a potential threat to human health or the environment. Require owners of premises to undertake works on their internal distribution systems to ensure that drinking water standards are met. Prohibit or restrict certain water uses if there is a deficiency of supply. Monitor both public and private supplies to ensure compliance. Prepare and implement Water Services Strategic Plans with measures to meet the requirements of the Act while supporting proper planning and sustainable development. Review and revise Water Services Strategic Plans every 6 years. Implement the Rural Water Programme to ensure water supplies in rural areas.	Local Authorities	
o Implement licensing system for the Group Water Scheme sector.	Local Authorities	
o Monitor compliance with drinking water standards and enforce compliance. Issue advice, directions, guidance or recommendations to water services authorities as necessary.	EPA	

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Major Accidents and Emergency Directive	**Who leads**	**When and Where**
Actions: Control of Major Accident Hazards Involving Dangerous Substances Regulations:		2009 – 2015 Qualifying Sites
o Prepare on-site emergency plan identifying major accident hazards and specifying measures to be taken to prevent major accidents and to limit their potential consequences.	Manufacturers	
o On notification of activities prepare off-site Emergency Plans for action outside the establishment in relation to possible major accidents. Enter into agreements with operators to take action to inform the public in the event of an accident.	Local Authorities	
o Require written notification of activities involving the use or storage of specified dangerous substances at least 6 months before commencement of the activity. Require operators to demonstrate safe operation and storage at their establishments. Organize system of inspections or other measures of control for relevant establishments. Supply information on major accidents to public authorities. Require operators to investigate their operations in the event of major accidents.	DETE	
Actions: Planning and Development Act:		
o Ensure that adequate controls are in place for relevant new developments.	Local Authorities	
Environmental Impact Assessment Directive	**Who leads**	**Where and When**
Actions: Environmental Impact Assessment Regulations:		2009 – 2015 National
o Require certain developments, either by the private or public sector, to prepare Environmental Impact Assessments for consideration before planning permission is granted (taking account of WFD objectives). Notify authorities in Northern Ireland of any planning application which is likely to have significant effects on the environment in Northern Ireland. Make Environmental Impact Assessments available.	Local Authorities	
Provide guidance on the preparation of Environmental Impacts Statements.	EPA	
Sewage Sludge Directive	**Who leads**	**When and Where**
Actions: Use of Sewage Sludge in Agriculture Regulations:		2009 – 2015 National
o Supervise the supply and use of 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 available to the public. Regularly provide users with the results of sludge analysis. Ensure adherence to the code of practice in relation to the use of biosolids in agriculture.	Local Authorities	
o Issue recommendations to Local Authorities regarding their duties under the Regulations.	DEHLG	

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Actions: Waste Management Act: o Ensure enforcement of the Act. o Prepare Sludge Management Plans for the management of wastewater sludge taking full account of the water quality objectives established in river basin management plans. Licence waste operators. 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. Request land owners to prepare nutrient management plans, where necessary.	DAFF Local Authorities	
Urban Wastewater Treatment Directive	**Who leads**	**When and Where**
Actions: Urban Wastewater Treatment Regulations: o Provide collection systems and treatments plants to meet the requirements in the Regulations. Meet more stringent requirements with respect to quality of receiving waters as specified in other Directives. Design, construct, operate and maintain treatment plants to ensure sufficient performance, taking seasonal variations of load into account. Choose discharge points so as to minimise impact on the environment. Monitor effluent discharges. Take all steps necessary to ensure compliance with the water quality objectives established in river basin management plans. Ensure that sewage sludge can be disposed of safely. Actions: Water Services Act: o Plan and supervise provision of wastewater services under the Water Services Investment Programme. Supervise and monitor the performance of water services authorities. Prepare and implement Water Services Strategic Plans to support sustainable provision of wastewater services.	Local Authorities Local Authorities	2009 – 2015 National
Plant Protection Products Directive	**Who leads**	**When and Where**
Actions: Authorisation, Placing on the Market, Use & Control of Plant Protection Products Regulations: o Authorise plant protection produces for use or sale subject to controls in relation to the nature of the products themselves, plus their packaging and labelling. Search, inspect, seize, retain and remove substances where non-compliances are found and cancel authorisations as required. o Prepare an annual list of plant protection products authorised in the State. o Notify the DEHLG of all new information on potentially dangerous effects of authorised plant protection products on human or animal health, the environment or groundwater. Provide notification of import and export of plant protection products.	Pesticide Control Service DEHLG Relevant persons	2009 – 2015 National

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Nitrates Directive	**Who leads**	**When and Where**
Actions: Good Agricultural Practice for the Protection of Waters:		2009 – 2015 National
o Develop a National Action Programme in consultation with all interested parties. Ensure implementation of the National Action Programme.	DEHLG	
o Undertake monitoring and evaluation programmes in relation to farm practices to determine the effectiveness of measures. Maintain a register of all farm holdings to be available to the EPA and Local Authorities.	DAFF	
o Issue reports on implementation to the DEHLG every four years. Carry out monitoring as necessary for the purposes of the Regulations. Provide recommendations and direction to Local Authorities with respect to monitoring, inspections and measures to be introduced for the purposes of the Regulations.	EPA	
o 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 as necessary for the purposes of enforcing the Regulations and coordinate with other farm inspection programmes. Maintain a register of farm inspections.	Local Authorities	
o Grant derogation from nitrogen application limit (170 kg/ha/yr) up to a maximum of 250 (kg/ha/yr) to applicant land owners where strict specified conditions are met. Carry out mini-catchments studies to demonstrate the effectiveness of the National Action Programme.	DAFF, EPA	
Integrated Pollution Prevention Control Directive	**Who leads**	**When and Where**
Actions: EPA Acts and Licensing Regulations:		2009 – 2015 National
o Ensure that operators of certain industrial and agricultural installations obtain IPPC licenses in relation to their activities. Set license conditions based on BAT. Take account of all relevant plans, policies, objections, EIAs and submissions when considering a licence application. Enforce licence conditions including monitoring. Maintain a register of licences and make available to the Commission and to the public. Undertake reporting as necessary. Undertake reviews of existing licences periodically (taking account of WFD objectives).	EPA	
o Ensure cross border consultation where necessary.	DEHLG	
o Give consent to discharges from IPPC operations to sewers.	Local Authorities, EPA	

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Cost Recovery for Water Use and Promotion of Efficient and Sustainable Water Use	Who leads	When and Where
Actions: National Water Pricing Policy Framework:		2009 – 2015 National
o Charge non-domestic customers for water and wastewater services. Ensure that all non-domestic supplies are metered by the end of 2008.	Local Authorities	
o Cover domestic capital costs from the Exchequer. Cover domestic operational costs through the Local Government Fund.	Local Authorities, DEHLG	
Actions: National Water Conservation (Leakage Reduction) Programme:		
o 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.	Local Authorities	
o Provide project-specific funding designed to meet specific leakage reduction targets.	DEHLG	
Actions: Water Services Act:		
o Facilitate the provision of efficient water services.	DEHLG	
o Meter and charge non-domestic customers for water services. Rehabilitate and repair water works. Develop Water Services Strategic Plans to achieve the objectives of the Act and support proper planning and sustainable development.	Local Authorities	
o Ensure that water distribution systems are in a fit state and free from leaks.	Premise owner/occupier	

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Protection of Drinking Water Sources	**Who leads**	**When and Where**
Actions required: (see also Drinking Waters Directive o 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 > 10m3 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. Adopt a water safety plan approach i.e. risk assessment, effective operational monitoring and effective management. Consider the designation of safeguard zones around current and future abstractions under the Drinking Water Regulations.	DEHLG	2009 – 2015 Proposed Designated Sites
Abstraction and Impoundments	**Who leads**	**When and Where**
Actions required: abstractions and impoundments o Develop new abstraction regulations to update and extend existing abstraction legislation creating a registration and authorisation system for abstractions and impoundments. Actions: Water Pollution Acts: o Maintain registers of abstractions and make available to the public.	DEHLG Local Authorities	2012 – 2015 National
Point Sources & Diffuse Sources Discharges	**Who leads**	**When and Where**
Actions: Water Pollution Acts and regulations: o 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. o Serve notices or directions on persons requiring measures to be taken in order to prevent or control pollution of waters, where necessary. o Notify Local Authorities of accidental discharges and spillages of polluting materials which enter, or are likely to enter, waters. Other actions: Urban Wastewater Treatment Plants: o Measures for improved management: keep register of plant capacity and update annually; install facilities to	Local Authorities Local Authorities, Fisheries Boards, NPWS Relevant persons Local Authorities	2009 – 2015 National

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monitor influent loads and effluent discharges in accordance with Environmental Protection Agency 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.		
o Optimise treatment plant performance by the implementation of a performance management system	Local Authorities	
o Revise existing Water Pollution Act industrial licence conditions and reduce allowable pollution loading.	Local Authorities	
o Review existing Industrial Pollution Prevention Control licence conditions and reduce allowable pollution load.	Local Authorities, EPA	
o Investigate contributions to the collection system from unlicensed discharges.	Local Authorities	
o Investigate contributions to the collection system of specific substances known to impact ecological status resulting from licensed and unlicensed discharges and issue or revise licenses to reduce or remove such specific substances in the discharge.	Local Authorities	
o Upgrade plant to increase capacity where necessary.	Local Authorities	
o Upgrade plant to provide nutrient removal treatment where necessary.	Local Authorities	
Actions: Wastewater Discharge Authorisation Regulations:		
o License large Local Authority WWTPs and certify smaller WWTPs as specified in the Regulations (taking account of WFD objectives). Review licenses at intervals not less than 3 years. Enforce compliance with WWTP licensing conditions. Maintain a register of WWTP licences and certificates and make available on request. Inform other relevant public authorises when an application or review is received.	EPA	
Actions: Water Services Act:		
o Prepare and implement Water Services Strategic Plans.	Local Authorities	
o Duty of care on owners of premises to ensure that treatment systems for wastewater are kept in good condition.	Premise owner/occupier	
Actions: Minerals Development Act:		
o 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. Grant Preservation of support orders to the purpose of securing sufficient support for buildings, may impose	DETE	

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restrictions on mining. Securely fence off abandoned State owned mines to prevent accidents.		
Actions: Energy Act:		
o 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	
Actions: Planning and Development Act (unsewered systems):		
o Permit on-site wastewater treatment systems subject to site suitability assessment.	Local Authorities.	
Other actions: Unsewered Systems:		
o Amend Building Regulations to give effect to new codes of practice for single houses and large systems.	DEHLG	
Actions: Forestry Act, grant support system and Aerial Fertilisation Regulations:		
o Regulate forestry. Promote forestry with financial incentives. License forestry activity and where necessary, attach additional conditions in sensitive areas.	Forest Service	
o Encourage sustainable, commercial, afforestation. Ensure that participants comply with guidance and codes of practice.	Forest Service	
o Grant aerial fertilisation licences with conditions, insert new conditions, revoke licences or refuse an application. Inform the appropriate local authority, fisheries board and River Basin District if it appears that a proposed application might have significant effects in relation to water quality. Carry out investigation to enable granting, refusal or to revoke an aerial fertilisation licence. Carry out investigation to ascertain adherence to an aerial fertilization licence, guidelines and good forest practice.	Forest Service	
Actions: Strategic Plan for the Development of Forestry:		
o Adhere to Forest Management Plans and ensure that Irish forestry practice conforms to the principles of sustainable forest management	All stakeholders	
o Ensure implementation of the National Forestry Standard. Ensure adherence to the code of best forest practice.	Forest Service	
Actions: Shellfish Regulations:		
o Ensure that designated shellfish areas conform with quality standards. Undertake monitoring programmes and maintain records in relation to shellfish waters. Establish Action Programmes to ensure conformity with quality standards including all necessary steps.	Local Authorities	

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o Investigate the reasons for non-conformity with the quality standards.	Local Authorities, DEHLG	
Actions: Environmental Objectives (Surface Water) Regulations:		
o Ensure surface water bodies comply with the Environmental quality standards set out in the regulations. Establish appropriate measures to achieve the environmental objectives and quality standards set out. Consult, co-operate and liaise with other public authorities within the river basin district and with relevant competent authorities in Northern Ireland, where appropriate to co-ordinate compliance.	Public Authorities	
o Set out emission limits when authorising discharges to water that aim to achieve the environmental objectives taking account of emissions controls based on BAT and best environmental practice. Review existing licenses to take into account the new environmental quality standards.	Local Authorities , EPA	
o Prepare programmes for the examination and review of authorisation under relevant Acts. Prepare programmes for the monitoring and inspection of farmyard installations to verify compliance.	DEHLG	
o Classify waters based on the results of a monitoring programme and make it available in GIS. Assign a status of less than good where environmental objectives for a protected area are not met.	EPA	
o Establish an inventory of emissions discharges and losses of priority substances, priority hazardous substances and other pollutants and publish a summary of the inventory. Direct other public authorities to collect and transfer data required. Prepare guidance on the development of inventories. 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 for the RBD	
o Establish a National Implementation Committee to provide oversight of the preparation of the inventories and the pollution reduction plans.	DEHLG	

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Authorisation of discharges to Groundwater	**Who leads**	**When and Where**
Actions required: groundwater discharges		2009 – 2015 National
o Transposition of the Groundwater Directive including a general prohibition on direct discharges of pollutants into groundwater except where they are subject to a specified system of prior authorisation and provided the discharges don't compromise the achievement of the objectives established for that body of groundwater.	DEHLG	
Actions: Wastewater Discharge Authorisation Regulations:		
o Authorisation of Local Authority WWTPs effluent discharges discharging to groundwater.	EPA, Local Authorities	
Priority Substances	**Who leads**	**When and Where**
Actions: Chemicals Act:		2009 – 2015 National
o Administration and enforcement of the European Registration, Evaluation and Authorisation of Chemicals regulations (REACH).	Health and Safety Authority	
o Identify and manage risks linked to the chemicals manufactured or imported and registration of chemicals produced or imported in quantities > 1 tonne.	Manufacturers or importers of chemicals	
Actions: European Pollutant Release and Transfer Register Regulations:		
o Submit required data in relation to releases of pollutants and off-site transfers of pollutants and waste.	Operators	
o 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	
Actions: Environmental Objectives (Surface Water) Regulations:		
o 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. Establish and inventory of emissions discharges and losses of priority substances, priority hazardous substances and other pollutants and publish a summary of the inventory. Direct other public authorities to collect and transfer data required.	Coordinating Local Authority for the RBD	
o Prepare guidance on the development of inventories.	EPA	
o Establish a National Implementation Committee to provide oversight of the preparation of the inventories and the pollution reduction plans.	DEHLG	

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Physical Modifications	**Who leads**	**When and where**
Actions required: physical modifications: o Develop new morphology regulations creating a registration and authorisation system. Actions: Planning and Development Act: o Consider the morphological implications of developments as part of the planning process.	 DEHLG Local Authorities	2009 – 2015 National
Other activities impacting on water status	**Who leads**	**When and Where**
Actions required: alien species: o 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.	 These actions are under consideration by DEHLG	2009 – 2015 National
Prevention or Reduction of the Impact of accidental pollution incidents	**Who leads**	**When and Where**
Actions: Framework of Major Emergency Management o Prepare Major Emergency Plans with supporting plans, procedures, arrangements and initiate major emergency development programme for the implementation of the Major Emergency Plans. Carry out risk assessments, mitigate risk, promote resilience and review annually in respect to major emergencies. Co-ordinate the inter-agency aspects of major emergency preparedness and management in assigned regions. Review site and event specific emergency plans. o 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

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Table 6.2 RBMP Additional Measures. These measures could be used to target specific pressures within the sub-basin.

Point and Diffuse Sources: Wastewater	Who leads	When and Where
Measures intended to reduce loading to the treatment plant: • Limit or cease the direct importation of polluting matter (e.g. liquid wastes, landfill leachate, sludges). • Investigate the extent of use and impact of under-sink food waste disintegrators and take appropriate actions. • Investigate fats/oils/grease influent concentrations and take actions to reduce FOG entering the collection system.	Local authorities	2009 – 2015 Prioritised Sites
Impose development controls where there is, or is likely to be in the future, insufficient capacity at treatment plants.	Local authorities	2009 – 2015 Prioritised Sites
Initiate investigations into characteristics of treated wastewater for parameters not presently required to be monitored under the urban wastewater treatment directive.	Local authorities	2009 – 2015 Prioritised Sites
Initiate research to verify risk assessment results and determine the impact of the discharge.	Local authorities	2009 – 2015 Prioritised Sites
Use decision making tools in point source discharge management.	Local authorities	2009 – 2015 Prioritised Sites
Where necessary to achieve water quality objectives install secondary treatment at smaller plants where this level of treatment would not otherwise be required under the urban wastewater treatment regulations.	Local authorities	2009 – 2015 Prioritised Sites
Apply a higher standard of treatment (stricter emission controls) where necessary.	Local authorities	2009 – 2015 Prioritised Sites
Upgrade the plant to remove specific substances known to impact on water quality status	Local authorities	2009 – 2015 Prioritised Sites
Install ultra-violet or similar type treatment.	Local authorities	2009 – 2015 Prioritised Sites
Relocate the point of discharge.	Local authorities	2009 – 2015 Prioritised Sites
Additional measures to be determined following assessment of urban areas	Local authorities, EPA	2009 – 2015 Prioritised Sites

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Point and Diffuse Sources: Industrial Discharges	**Who leads**	**When and Where**
To be determined following review of industrial licenses.	Local authorities, EPA	2012 – 2015 Prioritised Sites
Point and Diffuse Sources: Landfills, Quarries, Mines & Contaminated Lands.	**Who leads**	**When and where**
Further investigation of quarries and landfills and assessment of remediation schemes for mines and contaminated/urban sites	Local authorities, GSI, EPA	2009 – 2015 Prioritised Sites
Point and Diffuse Sources: Agriculture	**Who leads**	**When and Where**
To be determined following review of the Nitrates Action Plan	DEHLG in consultation with DAFF and other parties	2009 – 2015 National
Point and Diffuse Sources: Wastewater from Un- Sewered Properties	**Who leads**	**When and Where**
Amend Building Regulations • Code of Practice for single houses • Code of Practice for large systems	DEHLG, Local Authorities	2009 – 2012 National
Establish: • Certified national panel of experts for site investigation and certification of installed systems. A second panel of hydrogeologists is required for clusters and large systems. • National group for formulating polices and coordination of consistent approach. • A technical advice section or advisory group to coordinate and give advice on emerging and innovative technologies. • Installation and maintenance training by FAS	Local authorities	2009 – 2015 National
For new developments: • At planning assessment stage, apply the GIS risk mapping / decision support system and codes of practice • Notice to planning authority required immediately prior to the installation of on-site effluent treatment systems including percolation areas and polishing filters.	Local authorities	2009 – 2015 National
Inspect existing systems in prioritised locations: • Use the GIS risk mapping / decision support system to prioritise locations to be targeted in a programme	Local authorities	2009 – 2015 National

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of inspections and maintenance • Use a database and action tracking system		
Enforce requirements for percolation	Local authorities	2009 – 2015 National
Enforce requirements for de-sludging	Local authorities	2009 – 2015 National
Consider connection to municipal systems	Local authorities	2009 – 2015 National
Point and diffuse Sources: Forestry	**Who leads**	**When and Where**
Management Instruments - Ensure regulations and guidance are cross referenced and revised to incorporate proposed measures.	Forest Service	2009 – 2012 National
Acidification - Avoid or limit (to below critical thresholds) afforestation on 1st and 2nd order stream catchments in acid sensitive catchments	Forest Service	2009 – 2015 Prioritised Sites
Acidification - Restructure existing forests to include open space and structural diversity through age classes and species mix, including broadleaves	Forest Service	2009 – 2015 Prioritised Sites
Acidification - Revise the Acidification Protocol to ensure actual minimum alkalinities are detected (that is ensure sampling under high flow conditions) and revise boundary conditions for afforestation in acid sensitive areas.	Forest Service	2009 – 2015 Prioritised Sites
Eutrophication and Sedimentation - Avoid or limit forest cover on peat sites	Forest Service	2009 – 2015 Prioritised Sites
Eutrophication and Sedimentation –Change the tree species mix (for example broadleaves) on replanting	Forest Service	2009 – 2015 Prioritised Sites
Eutrophication and Sedimentation - Limiting felling coup size	Forest Service	2009 – 2015 Prioritised Sites
Eutrophication and Sedimentation - Establish new forest structures on older plantation sites (including riparian zones, drainage layouts, species mix, open areas)	Forest Service	2009 – 2015 Prioritised Sites
Hydromorphology - Audit existing drainage networks in forest catchments	Forest Service	2009 – 2015 Prioritised Sites
Pesticide Use - Reduce pesticide usage	Forest Service, Pesticide Control Service	2009 – 2015 Prioritised Sites
Pesticide Use - Pre-dip trees in nurseries prior to planting out	Forest Service	2009 – 2015 National
Pesticide Use - Maintain registers of pesticide use	Forest Service, Pesticide Control Service	2009 – 2015 Prioritised Sites

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Acidification - Mitigate acid impacts symptomatically using basic material (e.g. limestone or sand liming)	Forest Service	2009 – 2015 Prioritised Sites
Acidification - Manage catchment drainage to increase residence times and soil wetting, including no drainage installation in some areas	Forest Service	2009 – 2015 Prioritised Sites
Acidification - Implement measures to increase stream production – for example with native woodland in riparian zones.	Forest Service	2009 – 2015 Prioritised Sites
Eutrophication and Sedimentation - Establish riparian zone management prior to clearfelling	Forest Service	2009 – 2015 Prioritised Sites
Eutrophication and Sedimentation - Enhance sediment control	Forest Service	2009 – 2015 Prioritised Sites
Eutrophication and Sedimentation - Manage catchment drainage to increase residence times and soil wetting, including no drainage in some locations	Forest Service	2009 – 2015 Prioritised Sites
Hydromorphology - Enhance drainage network management – minimise drainage in peat soils	Forest Service	2009 – 2015 Prioritised Sites
Pesticide Use - Develop biological control methods	Forest Service	2009 – 2015 National
Point and Diffuse Sources: Dangerous Substances & Chemical Pollution	**Who leads**	**When and Where**
To be determined following review of wastewater and industrial licenses	Local authorities, EPA	2009 – 2015 Prioritised Sites
Physical Modifications	**Who leads**	**When and Where**
Code of Practice	Competent authority to be designated	2009 – 2015 National
Support voluntary initiatives	Local Authorities	2009 – 2015 Prioritised Sites
Chanelisation impact remediation schemes	Office of Public Works, Drainage Authorities	2009 – 2015 Prioritised Sites
Channelisation investigation	Central Fisheries Board	2009 – 2015 Prioritised Sites
Over-grazing remediation	DAFF	2009 – 2015 Prioritised Sites
Impassable barriers remediation schemes	Local Authorities	2009 – 2015 Prioritised Sites
Impassable barriers investigation	Local Authorities, Central Fisheries Board	2009 – 2015 Prioritised Sites

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Abstractions	Who leads	When and Where
To be determined following further investigation enabling review or setting of compensation flow requirements and selection of the appropriate supplementary measures on a site specific basis	DEHLG	2009 – 2015 Prioritised Sites

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Table 6.3 Freshwater pearl mussel additional measures.

The following is a list of measures, a selection of which will be implemented at those sites where investigations and risk assessment show that specific pressures need to be remediated to restore pearl mussels to favourable conservation status. Priorities and specific timelines for implementation of the selected measures will be detailed in the final plan. The policy or regulatory framework for the implementation of some of these measures does not currently exist and will need to be developed. 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 cost benefit analysis to ensure that the most cost-effective measures are used to solve particular problems.

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Unnatural flows – Implementation of these measures will only occur at the specific sites where they are required.	**Who Leads**	**When and where**
An analysis of the flow of regulated rivers will be undertaken. Where necessary, a plan shall be made and implemented to control flows in a manner that is suitable for the sustainable reproduction of the pearl mussel. Monitoring of the success of changes implemented shall be carried out.	Operator	
Remediation of morphological pressures - Implementation of these measures will only occur at the specific sites where they are required.		
Investigation shall be conducted to identify areas where morphological remediation measures are required within the channel. Undertake required remedial measures	NS2 – pearl mussel project National Parks and Wildlife Service, Central and Regional Fisheries Boards, DAFF (Marine)	
Peat Cutting - Implementation of these measures will only occur at the specific sites where they are required.		
A review of turf-cutting and associated drainage shall be undertaken to identify significant silt sources. Where necessary, drains from such peatland will be filled or effectively silt trapped, and an effective buffer zone established to trap any overland peat silt before it reaches the rivers. Where impacts from peat cutting (i.e. hydrological & siltation) are identified and cannot be mitigated along the pathway, reduction and/or cessation of peat cutting will be required.	Ns2 – pearl mussel project, National Parks and Wildlife Service, Environmental Protection Agency, Local Authorities.	
Road and Bridge Construction Adjacent to River - Implementation of these measures will only occur at the specific sites where they are required.		
All planned future roads or bridges of any size shall be assessed for potential negative impacts to mussel populations during construction and operation. Future roads or bridges of any size should be subject to the	Local Authorities National Road Authority	

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forthcoming River Basin Management Plan Programmes of Measures for morphology including new regulations to control future engineering activities near rivers. A guidance document for road crossings in pearl mussel catchments will be produced.	National Parks and Wildlife Service	
A survey of ongoing damage caused by temporary or permanent roads and bridges shall be carried out and recommendations made for retrofitting construction through silt trapping, resurfacing and other remediation works. Undertake required remedial actions	NS2 – pearl mussel project Local Authorities/NRA	
During the above surveys, the road- and path- surfacing material shall be examined. Where necessary, any hardcore or surfacing that includes substantial limestone content will be remediated. These works will require an impact assessment.	NS2 – pearl mussel project	
Abstractions - Implementation of these measures will only occur at the specific sites where they are required.		
Review and conduct risk assessments of current abstractions to identify possible impacts on pearl mussels and introduce reduction and remediation measures as appropriate. Conduct risk assessments of all proposed abstractions to avoid possible impacts on pearl mussels. Prioritise the installation/up-grade of hydrometric stations. Consult with NS2 project in relation to installations within the NS2 project area.	DEHLG NS2 – pearl mussel project	
Forestry - Implementation of these measures will only occur at the specific sites where they are required.		
Develop specific Forestry Management Plans with key stakeholders to address the significant pressures identified through an appropriate assessment for each catchment. The plan will include a suite of measures adopted from the following which can be implemented where appropriate:	DAFF	
• The option of not felling to be considered in sensitive areas • Coniferous plantations within sensitive areas of the catchment shall be subject to final felling and replacement with either continuous-cover native woodland or semi-natural bog/moor		
• Establish riparian zone management prior to clearfelling with sufficient time to allow vegetative cover to develop		
• Change the tree species mix (e.g. broadleaves) on replanting		
• Limit felling coupe size to reduce potential sediment and nutrient load pressure		
• Felling shall be carried out in small coupes, using best practice according to the Forestry and *Margaritifera* requirements, felling away from the river • Following felling of existing forest-stands, restore blanket bog and wet heath through drain blocking and appropriate site management		
• Remove bankside trees by hand as whole trees where feasible		
• Enhance sediment control through increased numbers and locations of sediment traps.		

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• Main silt traps will be large enough for *Margaritifera* conservation purposes (Altmüller & Dettmer, 2006)		
• Prohibition of fertilisation on sensitive sites		
• No replanting or afforestation on certain hydro geological settings (peat soils) on sensitive sites.		
• Auditing of existing drainage networks prior to clearfelling		
• Enhanced drainage network management – minimise drainage in peat soils		
• Reduction/cessation of pesticide use – allow clearfelled areas to lay fallow for prolonged periods		
• Pre-dipping of trees in nurseries prior to planting out		
• Maintaining registers of pesticide use in the catchment		
• Establish native riparian woodland as a buffer where appropriate		
• Strict adherence to the Forestry and *Margaritifera* requirements and any other appropriate requirements/guidance		
• Any associated roading should be subject to risk assessment		
• Establishment of continuous-cover, native bankside trees at mussel habitat locations to produce dappled shade with no tunnelling of the river. • 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 qualified and experienced tree surgeons at mussel locations and, where necessary, be replaced by appropriate native species. • Research into buffer zones to identify optimum buffer zone design and establishment methods to enhance nutrient and sediment interception • Remove immature forestry from peat and peaty soils through felling-to-waste; and block drains • Leave immature forestry on peat and peaty soils in-situ and block drains, i.e. abandon crop		
A monitoring programme to assess the effectiveness of the forestry measures will be developed		
Agriculture - Implementation of these measures will only occur at the specific sites where they are required.		
Prioritise cross-compliance monitoring for the 27 pearl mussel catchments. Within the pearl mussel catchments, target farms in sensitive areas.	Local Authorities/DAFF	
Inspect sheep-dip stores and survey pesticide use on farms through cross-compliance checks	Local Authorities/DAFF	
Provide improved information and higher resolution maps of agricultural land-use, including livestock density, fertiliser use, slurry spread grounds and application rates, etc.	DAFF	
A field survey shall be undertaken to verify that the areas identified as overgrazed during the desk-study are a significant risk to the pearl mussel population. The field survey will also attempt to identify additional overgrazed areas. Where investigation confirms over-grazing pressure, reduction measures will be applied at source, i.e. de-stocking/ stock-control measures, and/or mitigation measures along the pathway.	NS2 – pearl mussel project DAFF	
Undertake desk and field-based surveys (including catchment walk-overs, physical, chemical and biological sampling) to identify agricultural areas that are significant sources of nutrients, silt, hydrological pressures and/or dangerous substances.	NS2 – pearl mussel project	
Targeted measures shall be adopted for agricultural areas identified as significant sources (critical source areas) for nutrients, silt, hydrological pressures and/or dangerous substances, and may include one or more of the	Local Authorities/DAFF	

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following: 1. Measures to reduce pressures at source These may include: • Reductions/cessation of fertiliser use • Reductions/cessation of slurry application • Implementation of nutrient management plans • Reductions/cessation of ploughing • Reductions/cessation of drainage and drainage maintenance • Reductions in grazing intensity/livestock units • Other reductions in land use intensity, e.g. conversion to native woodland • No liming of land in sensitive areas • Fencing off drains, streams or rivers where there is significant bed or bank erosion 2. Measures to remediate pressures along the pathway Such remediation measures can be designed to stop the pollutants reaching the aquatic environment (e.g. buffer zones) or to halt the pollutants progress through the aquatic environment (e.g. sediment traps). This suite of measures includes the following: • Establishment of an appropriate, site-specific buffer zones of native woodland or semi-natural vegetation around drains, streams, rivers and lakes • Floodplain restoration • Wetland restoration • Creation of artificial wetlands or filter beds • Installation of appropriately-sized sediment traps • Other measures to increase infiltration or slow/divert surface run-off, or flow in drains Emergency response measures may be employed in specific, highly sensitive areas in advance of establishment of these more tailored measures, e.g. a fenced 10m buffer zone.		
Modification of voluntary agri-environmental schemes, REPS and NPWS farm plan scheme, to include freshwater pearl mussel measures.	DAFF and DEHLG	
Review agri-environmental schemes and existing farm plans within the catchment to ensure there is no conflict with pearl mussel requirements	DAFF and DEHLG	
Water abstraction by farmers using tankers shall not be carried out within pearl mussel habitat in order to avoid bank erosion and direct damage to the mussels.	Local Authorities/DAFF	
Rivers and lakes shall not be used for the washing of tankers in pearl mussel catchments.	Local Authorities/DAFF	

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Grazing animals should be fenced away from pearl mussel habitat to prevent direct trampling of mussels. Suitable watering troughs should be provided.	Local Authorities/DAFF	
Catchment Modelling - Implementation of these measures will only occur at the specific sites where they are required.		
Calculate/model total nutrient, sediment and dangerous substance loads to pearl mussel catchments to assist in developing and targeting measures	Local Authorities/ Environmental Protection Agency /DAFF/National Parks and Wildlife Service /DEHLG	
On-site Wastewater treatment Systems - Implementation of these measures will only occur at the specific sites where they are required.		
A survey of septic tanks and small effluent systems, and data basing of results, shall be undertaken.	Local Authorities	
Each system will be graded as to its age, suitability and effectiveness. Systems that are releasing excessive nutrients shall be upgraded.	Local Authorities	
Use constructed wetlands for treating/polishing household effluent from unsewered properties. Where no alternatives exists remove by tanker as a temporary measure until system is up-graded/connected to municipal systems.	Local Authorities	
Municipal and Industrial Discharges - Implementation of these measures will only occur at the specific sites where they are required.		
The surveys of municipal and industrial discharges and CSOs carried out as part of the River Basin Management Plan shall be prioritized for pearl mussel catchments.	Local Authorities	
Reviewing and issuing of discharge licences shall be prioritised for pearl mussel catchments and shall comply with emission limits that aim to achieve the objectives set out in the pearl mussel Regulations.	Local Authorities/ Environmental Protection Agency	
Catchment Awareness Campaign		
An education and awareness campaign shall include talks through schools, public meetings and distribution of leaflets. Topics covered will include the biology and ecology of pearl mussels and damage caused by pearl fishing, in-stream activities, silt 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. This catchment awareness campaign will be tied in with the River Basin Management Plan programme of awareness. Establish an education and awareness programme on outline design, operation and maintenance of on-site wastewater treatment systems (septic tanks, etc.).	National Parks and Wildlife Service/Local Authorities	
RBD Pearl Mussel Technical Group		
A committee of stakeholders interests shall be facilitated, in order to promote the conservation of the pearl mussel population and to provide a forum by which progress on all measures can be discussed. Local authority staff, NPWS, fisheries, forestry and DAFF staff should all be represented where possible. National guidance on	National Parks and Wildlife Service RBDs	

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the implementation of measures will be issued by the national conservation working group, to ensure consistency across all sub-basins.	Local Authorities	
Leisure management - Implementation of these measures will only occur at the specific sites where they are required.		
Angling rights holders and angling clubs shall provide appropriate managed walkways and control access to unstable river banks. Angling should only take place from the bank to avoid trampling on pearl mussel populations. Implement any guidelines which are produced in relation to *Margaritifera* and fisheries enhancement works to ensure that any improvements are beneficial to both.	Local Authorities Fisheries Boards	
Morphological Alterations - Implementation of these measures will only occur at the specific sites where they are required.		
All river morphological alterations should be subject to a project level appropriate assessment; this includes all fisheries enhancements measures.	Lead will depend on the source of the morphological alteration	
Sand and gravel extraction - Implementation of these measures will only occur at the specific sites where they are required.		
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 mussels.	Local Authorities	
Other sources of silt – Implementation of these measures will only occur at specific sites where they are required.		
Where further investigation identifies other sources of silt, such as quarries or land clearance for development, appropriate mitigation measures will be implemented. Mitigation measures will be designed to reduce silt loss at source and/or intercept silt along the pathway. to the river.	Local Authorities	
Dangerous Substances - Implementation of these measures will only occur at the specific sites where they are required.		
Incorporate findings of a review of *Margaritifera* toxicity research into review of licences, conditions for new licences and up-grading of effluent treatment	NS project, Local Authorities, DAFF	
Housing and other Development - Implementation of these measures will only occur at the specific sites where they are required.		
Identify areas where further development represents a significant risk to pearl mussel conservation and Implement development restrictions as necessary Implement any guidance document/code of practice for the protection of *Margaritifera* populations and habitat during development works Provide necessary data to planning authorities, including mussel locations	Local Authorities Local Authorities National Parks and Wildlife Service	

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Pearl fishing - Implementation of these measures will only occur at the specific sites where they are required.		
Liaise with Gardaí with regard to early detection of pearl fishing incidents and prosecution of pearl fishing crimes	Gardaí, DEHLG	
Breeding Programmes - Implementation of these measures will only occur at the specific sites where they are required.		
Augment populations through breeding and release programmes when and where juvenile habitat has been restored	National Parks and Wildlife Service	

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APPENDIX A

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Literature Review

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INTRODUCTION TO THE FRESHWATER PEARL MUSSEL *MARGARITIFERA MARGARITIFERA*

Background

1.0 Current status

1.1 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).

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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).

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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.

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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.

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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.

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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.

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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.

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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.

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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.

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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.

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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.

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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).

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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.

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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.

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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).

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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

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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).

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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.

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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).

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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

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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.

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Appendix 4

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APPENDIX 4: FRESHWATER MUSSEL SURVEY

An investigation of the status of *Margaritifera margaritifera* (L.) in the side channel of the Bandon River receiving effluent from the Dunmanway Sewage Treatment Plant.

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Carried out on behalf of:

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Submitted: June, 2004.

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Introduction

The sewage treatment plant in Dunmanway, Co. Cork is to be upgraded. The existing treatment plant is located east of the town within 100m of the Bandon River. Effluent from the treatment plant is discharged by pipe (Photograph 1) into the Bandon River at a point where a small side channel diverges from the western side of the river (Photograph 2). This part of the Bandon River and adjacent lands have been designated as a Special Area of Conservation. The area contains good examples of two habitats listed on Annex I of the E.U. Habitats Directive - alluvial forest and floating river vegetation - and supports populations of four Annex II species - Otter, Salmon, Brook Lamprey and Freshwater Pearl Mussel.

The pearl mussel is one of three species of large Unionacean bivalves found in Irish freshwaters. The species may occur in fast-flowing, oligotrophic, calcium deficient streams and rivers, where it can grow to lengths of 159mm (Jackson 1925) and live to ages well in excess of 100 years (Ross 1984). ***Margaritifera*** has been recorded in most parts of Ireland with the exception of the central limestone plain but several studies have confirmed that a significant decline has occurred in some Irish populations, notably in northern and eastern areas (Ross 1988, Moorkens and Costello 1994, Beasley and Roberts 1996). Such declining populations are usually characterised by a predominance of older mussels and an absence of juvenile recruitment (Bauer 1983).

Although very widely distributed across northern Europe, Eurasia and North America, ***Margaritifera*** is declining throughout its range and is extinct or seriously threatened in many parts of Europe (Wells et al. 1983). The main cause of this decline is deteriorating river water quality although a variety of other factors are also implicated (Moorkens 1999). The species is on the IUCN Invertebrate Red Data List and is protected under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention). ***Margaritifera*** is also listed in Annex II and Annex V of the Habitats Directive (92/43/EEC) and is protected by law in Ireland under the 1976 Wildlife Act (Statutory Instrument No. 112, 1990).

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The objectives of this investigation were to determine if ***Margaritifera*** was present in the side channel receiving the effluent from the Dunmanway sewage treatment plant, and if so, to quantify the number of mussels present, and to advise on the best means of minimising the impact of the proposed work on the ***Margaritifera*** population in that part of the Bandon River.

Study area and methods

The existing sewage effluent discharge point is located on the western bank of the Bandon River, at the downstream end of “The Captains Hole”. Eight metres downstream from the discharge point a small side channel, hereafter referred to as “Channel A”, diverges from the main channel (Figure 1, Photograph 2) having received the sewage effluent. “Channel A” then flows in a southerly direction before rejoining the main river channel at “The Meeting of the Waters”(Photograph 3). The site was visited on three occasions (April 23rd, May 18th and May 25th, 2004) and observed under normal and low water flow conditions. The entire length of “Channel A” was carefully searched for ***Margaritifera margaritifera*** by visual examination, and by examining the stream substrate using a viewing device while wading. Due to significant health and safety considerations relating to the highly contaminated nature of the effluent present, no attempt was made to search “Channel A” for mussels by snorkelling. Representative photographs of “Channel A” habitat were taken

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and its length was measured using a surveying tape. The work was carried out under licence issued by the National Parks and Wildlife Service.

Results

On each of the three days that the site was examined, weather conditions were ideal, with generally bright sunlight and excellent underwater visibility in the main river channel. All the sewage effluent emanating from the discharge pipe appeared to be flowing into "Channel A", which diverged from the main channel just below the effluent discharge point. "Channel A" was 310m in length and generally 3-5m in width, reaching a maximum of 8m. Water depth in "Channel A" was generally shallow and varied from a few centimetres in riffle areas to a maximum observed depth of 54cm.

The substrate of the upstream section of "Channel A" was covered in a layer of sewage fungus (Photograph 4), and in non-riffle areas a deep layer of foul smelling sediment had accumulated. In the downstream half of "Channel A" the non-riffle areas of substrate also had a deep layer of sediment, which was often covered with a layer of filamentous green algae (Photographs 5 and 9). A pronounced smell of sewage was evident all along "Channel A" and this increased as one approached the effluent discharge point.

On April 23rd, the water level was normal, and underwater visibility was poor in "Channel A" close to the sewage outfall, with pronounced turbidity and very high levels of suspended solids due to the sewage effluent (Photograph 6). However, conditions were adequate for searching the substrate for ***Margaritifera*** along most of the length of "Channel A". No mussels were observed.

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On May 18th the water level had dropped significantly after a prolonged dry spell and visibility was very poor in the 50-80m stretch of "Channel A" immediately downstream of the effluent discharge point. No mussels were observed in "Channel A", although mussels were observed in the main river channel within 30m of the effluent discharge point and within 30m of the point where "Channel A" rejoined the main river channel at "The Meeting of the Waters". It was noted that due to the low water levels, a low bank of gravel extended several metres upstream of the effluent discharge point, completely separating "Channel A" and the sewage effluent from adjacent channels (Photograph 7)

On May 25th the water level had risen slightly after overnight rain and visibility was again poor in the upper part of "Channel A", which seemed to be receiving an increased volume of sewage effluent than that observed on the previous two visits. Once again no mussels were observed in "Channel A".

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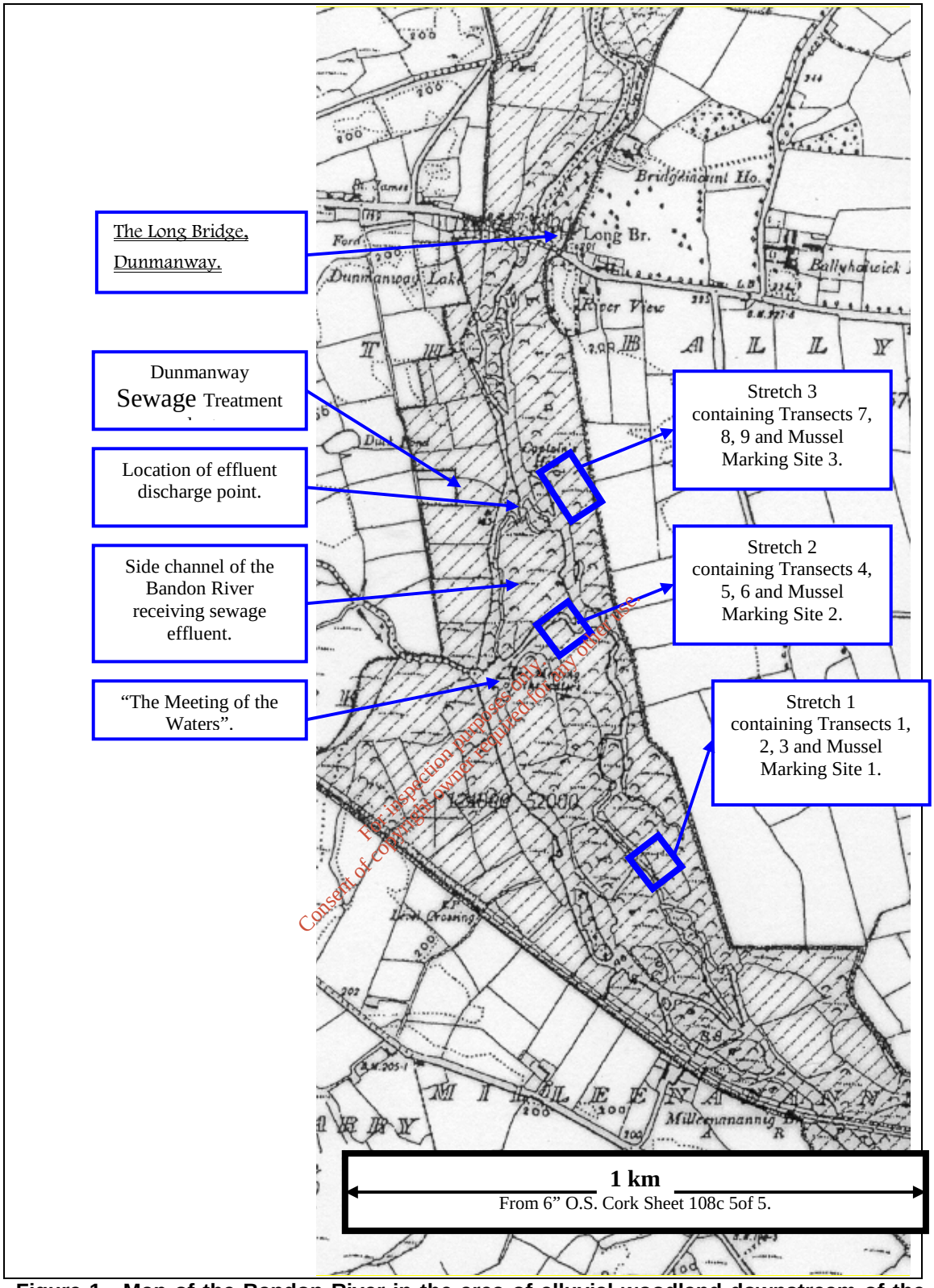

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Figure 1. Map of the Bandon River in the area of alluvial woodland downstream of the Long Bridge (Dunmanway, Co. Cork). The locations of the Dunmanway Sewage Treatment Plant, the sewage effluent discharge point, "Channel A" receiving the effluent, and the three river stretches where a long term monitoring program of the Bandon River population of *Margaritifera margaritifera* is ongoing, are also indicated.

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Discussion

The habitat conditions observed in “Channel A”, which receives the effluent from the Dunmanway sewage treatment plant were absolutely inimical to the presence of ***Margaritifera margaritifera***.

The species normally occurs in a narrow range of habitat types, with the main prerequisites being clean, oligotrophic, well-oxygenated waters with little sedimentation and a firm substrate of gravels and sand. Unfortunately none of these conditions were present in “Channel A” during the current investigation. The species is abundant in other side channels and in parts of the main channel of the Bandon River adjacent to “Channel A”, where suitable conditions do exist (Ross 2001).

Margaritifera uses its gills for respiration and filter feeding. The very high levels of suspended organic solids observed (Photograph 6) downstream of the effluent discharge pipe would very quickly clog up the gills of any mussels present, greatly reducing their ability to respire and feed. Prolonged exposure to such high levels of suspended solids would result in starvation of the mussels or respiratory stress leading to asphyxiation. During the warm summer months these problems would be further exacerbated because ***Margaritifera*** uses its outer gills as brood pouches for the developing Glochidia larvae, thereby further reducing their respiratory and feeding efficiency, at a time when oxygen levels can be at their lowest.

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Recolonisation of the habitat by juvenile mussels, that normally spend several years buried in coarse sand and gravel substrates, would also be prevented by the conditions observed in “Channel A”. The juveniles require a constant flow of oxygen down into the substrate interstices, and the observed accumulation of sediment (particularly organic sediment) and layers of filamentous algae on top of the substrate would prevent oxygen reaching the juveniles below, and result in their death.

The habitat conditions in “Channel A” render it impossible for pearl mussels to survive there for any significant period of time. The upgrading of the sewage treatment plant should result in an improvement in the habitat quality, both in “Channel A”, and further downstream in the main Bandon River channel where ***Margaritifera*** also occurs (F. McMahon, pers. comm.).

On the three occasions when the site was visited, all the sewage effluent appeared to be entering “Channel A”, with no apparent entry of effluent into the other channels. During the very low flow conditions observed on May 18th, 2004, the low bank of gravel (Photograph 7) exposed by the falling water levels acted as a physical barrier, preventing any possibility of effluent entering other adjacent channels. However, it is likely that this gravel bank is not a permanent feature and may change in height or extent, or even disappear after periods of high flow/spate. The site was observed only under normal and low flow conditions, and it is possible that under conditions of higher flow, some effluent could be carried into other channels adjacent to “Channel A” which do contain mussels. This possibility could be prevented by

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moving the discharge point downstream so that the effluent discharged directly into “Channel A” after it had diverged from the main channel, thus removing any risk to mussels in the adjacent channels. However this option should only be considered if the necessary works could be carried out without significant negative impact to the streambed, the bank or the adjacent riparian areas.

Recommendations

In order to minimise or avoid any negative impacts associated with the proposed upgrading of the Sewage Treatment Plant, the following measures should be adopted:

1. The discharge point could be moved downstream to ensure that all effluent enters directly into “Channel A”, thereby preventing the possibility of effluent entering other channels containing mussels, during high water flow conditions. This course of action should only be considered if the required works can be carried out without disturbance of the streambed, or significant negative impact on the bank or the adjacent riparian areas.
2. If the works required to complete option 1. above cannot be undertaken without significant negative impact, then the existing effluent discharge point should be retained.
3. Works involving any disturbance to the streambed or bank of “Channel A” should be avoided if possible, but if absolutely necessary, they should be carried out by hand in order to reduce disturbance or damage to “Channel A” and the riparian area.
4. Entry of machines into the riparian area or any river channel should be prevented.
5. Any activity resulting in the introduction of soil, sediment, fuel, hydraulic fluid, or other pollutants into the river as a result of the proposed works should be prevented.
6. Any disturbance of the riparian area should be minimised and made good immediately by removal of loose soil and replanting with suitable species.

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Photographs.

Photograph 1. The site of the sewage effluent discharge pipe into “Channel A” of the Bandon River at Dunmanway, Co. Cork.

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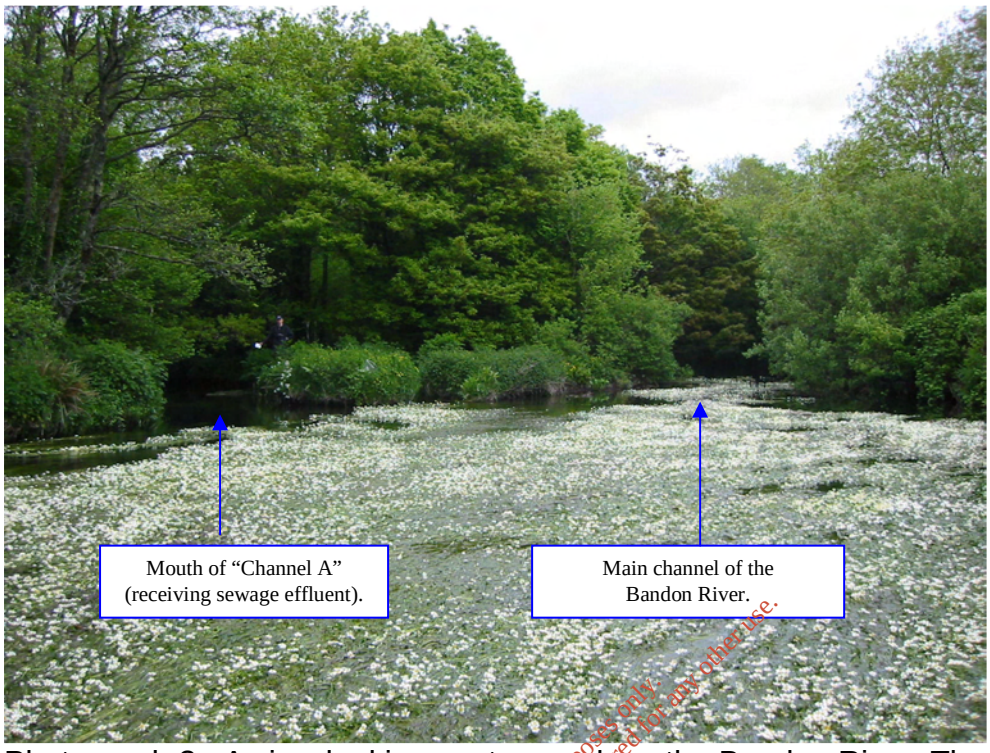
Photograph 2. A view upstream from the point where “Channel A” diverges from the main channel of the Bandon River. The sewage effluent discharge pipe is visible on the western bank.



Photograph 3. A view looking upstream along the Bandon River. The point where “Channel A” rejoins the main river channel is visible on the left hand side of the picture.

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Photograph 4. Sewage fungus present on the substrate in the upstream section of “Channel A”

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