

**Rose Energy Project: Assessment of impacts on the aquatic ecology of the Glenavy River and Lough Neagh**

**By:**

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## **1.0 REPORT AUTHOR**

Dr Chris Harrod has 20 years scientific experience, the last ten years of which has focussed on the ecology of fish and aquatic ecosystems. Prior to his appointment as Lecturer in Fish and Aquatic Ecology at Queen's University Belfast in 2007, he ran his own laboratory at the internationally-renowned Max Planck Institute for Limnology, in Plön, Germany. Previous to this he worked as an aquatic biologist for the Environment Agency of England and Wales, and for a private consultancy where he led the aquatic ecology section. His ongoing interest in the ecology of the Lough Neagh system stems from his doctoral studies (1997-2001) of the Lough Neagh pollan stock, and he has published a number of studies detailing the biology of pollan and the threats they face.

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## 2.0 TERMS OF REFERENCE

- 2.1 The School of Biological Sciences, Queen's University Belfast (QUB) were requested to conduct an assessment (based upon current knowledge) of the impacts to ecology of the Glenavy River and Lough Neagh of the proposed development of a power-station, with particular regard to a discharge of heated effluent at 2°C above ambient temperatures at a flow of 0.018m<sup>3</sup>·S<sup>-1</sup> into the Glenavy River. Furthermore, QUB was requested to provide text for an Environmental Statement.
- 2.2 This report has been prepared by Dr Chris Harrod, Lecturer in fish and Aquatic Ecology, and involves collection and analysis of literature and web-based information on the Glenavy River and Lough Neagh. Where possible, relevant data have been gathered and analysed in order to assess the likely impacts on the aquatic ecology of the proposed development with reference to the information provided by Rose Energy.

## 3.0 GLENAVY RIVER

- 3.1 The Glenavy River is a short (ca. 23 km) 3<sup>rd</sup> order river formed by the convergence of the Rushyhill and the Stonyford Rivers. At 44.3 km<sup>2</sup>, the Glenavy catchment is relatively small (Environment Agency, 2006), initially draining upland areas to W of Belfast (White hill) and then improved agricultural areas. Approximately 18 km from the river's source, the Glenavy River passes through Glenavy, a village with a population of ca. 1070 individuals ([www.nisra.gov.uk](http://www.nisra.gov.uk)), and finally flows into Lough Neagh. The proposed development site is located ca. 2 km above the point where the river enters the Lough, and is situated downstream of a large natural waterfall (Fig. 1), known locally as the leap (Watson, 1892).
- 3.2 There is little information available on the aquatic ecology of the Glenavy River, but the river supports populations of eel (*Anguilla anguilla*), brown trout (*Salmo trutta*) and stone loach (*Barbatula barbatula*) above the Leap waterfall (Crozier and Ferguson, 1986; Winfield and Wood, 1988). The river is designated as a salmonid river under the terms of the EC Freshwater Fish Directive (78/659/EEC), and a walkover survey conducted on 8 March 2008 revealed the existence of habitat suitable for adult and juvenile salmonids (brown trout and Atlantic salmon (*Salmo salar*), see Fig. 2) (Crisp, 1993; 1996). Lough Neagh supports an unusual freshwater-feeding population of river lampreys (*Lampetra fluviatilis*) (Harrod, 2001; Goodwin *et al.*, 2006) which is currently subject to considerable research activity (Harrod *et al.* in prep), and it is extremely likely that adjacent to the proposed development site, the Glenavy River provides suitable spawning habitats for adults (Jang and Lucas, 2005) and ammocoete (larval) lampreys.
- 3.3 The Glenavy River is routinely monitored by the Environment and Heritage Service for both biotic and abiotic indicators of water quality at a series of locations along its length, including the Leap Bridge (Irish Grid Reference: J139725), ca. 1 km upstream from the proposed development site. Table 1 details the results of recent assessments under the General Quality Assessment (GQA) scheme (Environment and Heritage Service, 2001). Recent biological and chemical results indicate that water quality at the Leap Bridge is slightly impacted by pollution (Table 1), but that it currently complies with the requirements for salmonid fishes under the EC Freshwater Fish Directive ([http://www.ehsni.gov.uk/water/quality/rivers/river\\_results.htm](http://www.ehsni.gov.uk/water/quality/rivers/river_results.htm)).

**Table 1:** Results of recent General Quality Assessments of water quality at the Leap Bridge ([http://www.ehsni.gov.uk/water/quality/rivers/river\\_results.htm](http://www.ehsni.gov.uk/water/quality/rivers/river_results.htm))

Assessment scheme	2003	2004	2005	2006
Biological GQA	C (fairly good)	C (fairly good)	B (good)	C (fairly good)
Chemistry GQA	D (fair)	C (fairly good)	C (fairly good)	C (fairly good)



**Figure 1:** The Leap waterfall upstream of the proposed development site. The pool directly downstream of the waterfall could potentially be used by river lamprey in spring during spawning.



**Figure 2:** The Glenavy River adjacent to the proposed development site showing several habitat features reflecting suitability for salmonid fishes.

## 4.0 ASSESSMENT OF IMPACTS OF PROPOSED DISCHARGE OF THERMAL EFFLUENT:

### 4.1 Methods

4.1.1 Gauged river flows are recorded at the Leap Bridge, and MARENCO supplied QUB with daily mean discharge data for the period 2001-2008. Dr Bob Foy (AFBI) kindly supplied various physicochemical data including water temperatures collected approximately monthly at the Leap Bridge between 2001 and 2007. The combination of these data permits some basic assessment of the likely effects of the proposed thermal discharge. An existing thermal discharge is located upstream of the proposed development site and may result in elevated river temperatures relative to those measured at the Leap Bridge. However, reliable data were not available for river temperatures directly adjacent to the proposed development site.

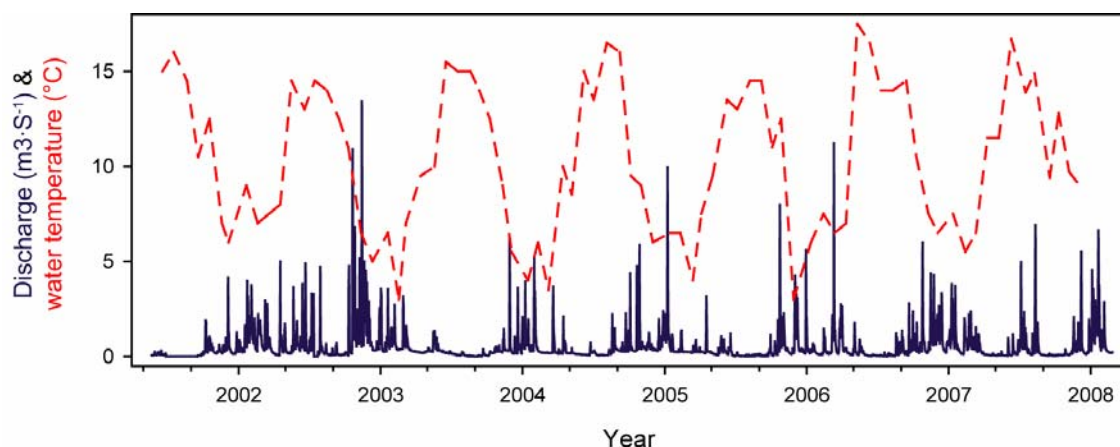
4.1.2 In order to estimate the consequences of the proposed thermal discharge, I used a simple linear mixing model (Clark, 2001) to examine river temperature immediately downstream of the discharge point following mixing of river water with effluent discharges at  $0.018 \text{ m}^3 \cdot \text{s}^{-1}$  at  $2^\circ$  above ambient water temperatures at the Leap Bridge, where:

$$\text{Temperature after dilution} = \frac{(\text{river flow} \times \text{river temperature}) + (\text{effluent flow} \times \text{effluent temperature})}{(\text{river flow} + \text{effluent discharge})}$$

4.1.3 In order to examine the possible thermal impacts of the proposed discharge, I estimated post-dilution river temperatures under a range of flow and temperature conditions.

### 4.2 Results

4.2.1 Both river discharge and water temperatures showed clear seasonal variation (Figure 3). Summary statistics for both discharge and water temperature are presented in Table 2. In the period 2001-2008, discharge values at the Leap Bridge ranged between 0 (91 separate days) and  $13.4 \text{ m}^3 \cdot \text{s}^{-1}$  (11 November 2002). Median discharge was  $0.25 \text{ m}^3 \cdot \text{s}^{-1}$ , with normal flows (Q25-Q75) ranging between  $0.11$  and  $0.52 \text{ m}^3 \cdot \text{s}^{-1}$ . Discharge values less than or equal to the proposed discharge were recorded on a total of 118 days, in June – September 2001, July 2002 and September 2003. Between 2001 and 2007, water temperatures varied between  $3$  and  $17.5^\circ \text{C}$ , with a median ( $\pm$  interquartile range) of  $10$  ( $\pm 7$ )  $^\circ \text{C}$ .

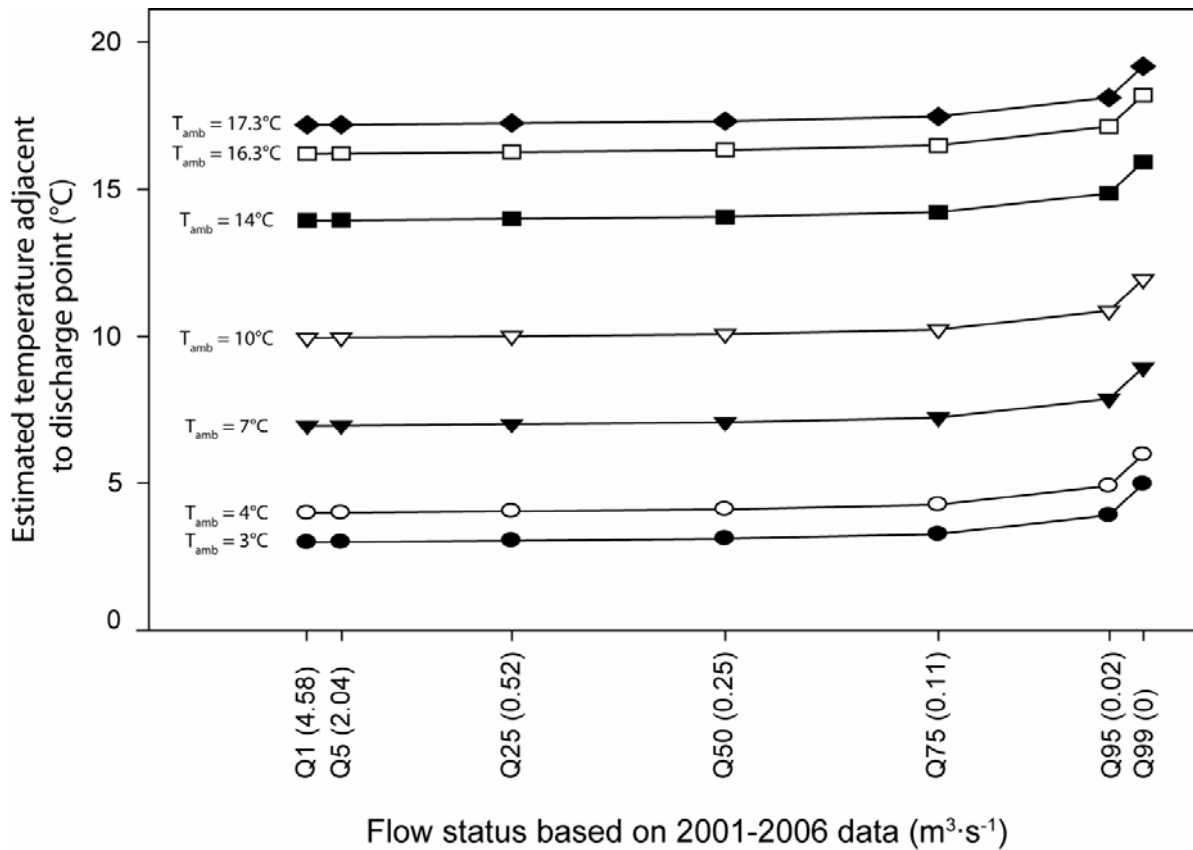


**Figure 3:** Variation in discharge (daily) and water temperature (monthly) for the Glenavy River at Leap Bridge 2001-2007/8. (Data from MARENCO & Dr B. Foy, AFBI).

**Table 2:** Summary statistics for Glenavy River discharge (2001-2008) and water temperature (2001-2007) recorded at the Leap Bridge.

Percentile	Discharge (m <sup>3</sup> ·S <sup>-1</sup> )	Water temperature (°C)
1	0	3
5	0.02	4
25	0.11	7
50	0.25	10
75	0.52	14
95	2.04	16.3
99	4.58	17.3
n	2 471	79

- 4.2.2 Figure 4 (estimated values detailed in Table 3) shows variation in estimated river water temperature immediately downstream of the proposed thermal effluent discharge point at a range of ambient water temperatures and discharge values (1, 5, 25, 50, 75, 95 & 99 percentiles of temperature and flow values recorded from 2001-2007/8). Assuming that data for temperature and flow of river and effluent water are reliable, it is apparent that under most flows, the dilution capacity of the river leads to rapid loss of heat. The discharge of heated effluent is only likely to have a detrimental ecological effect at extremely low flow rates (e.g. between Q95-Q99).
- 4.2.3 If there are extended periods of low flow (as have occurred in the past, see above), it is likely that many sensitive taxa (e.g. brown trout) will face considerable ecological stress and if capable, will attempt to move downstream. Other less mobile taxa, e.g. macroinvertebrates, lamprey ammocoetes (if present) may be unable to move and face the risk of desiccation and consequences of reduced dissolved oxygen concentrations under such low flow conditions. Heated effluent may therefore cause local problems under such low flow conditions.
- 4.2.4 These observations reflect a discharge of unpolluted (apart from elevated temperature) effluent. If the effluent contains any noxious waste, or is of low water quality (e.g. reduced dissolved oxygen concentrations, high suspended sediments), there is clearly the potential for ecological impacts. There is also scope for further impacts on the aquatic ecology of the Glenavy River during the construction and operation of the site and the operators should ensure that they develop a suitable environmental management plan, including control of fine sediments that could infiltrate salmonid redds (nests) in spawning gravels (Crisp, 2000). It is difficult to assess the probability of emergency discharges into the Glenavy River both during construction and operations at the site, but clearly these could be hazardous in terms of their impact both on the ecology of the river and Lough Neagh.



**Figure 4:** Graphical representation of variation in river temperatures following proposed discharge ( $2^\circ\text{C}$  above ambient at  $0.018 \text{ m}^3\cdot\text{S}^{-1}$ ) into Glenavy River at a range of ambient water temperatures and discharge values (1, 5, 25, 50, 75, 95 & 99 percentiles of temperature and flow values recorded from 2001-2006). Note that an effect of the heated effluent is only notable at extremely low discharges (Q95-Q99).

**Table 3:** Estimates of river temperatures following proposed thermal discharge ( $2^\circ\text{C}$  above ambient at  $0.018 \text{ m}^3\cdot\text{S}^{-1}$ ) into Glenavy River at a range of ambient water temperatures and river discharge values (1, 5, 25, 50, 75, 95 & 99 percentiles of temperature and flow values recorded from 2001-2006). Note that an effect of the heated effluent is only notable at extremely low discharges (Q95-Q99).

River temperature							
River Discharge	QT1 ( $3^\circ\text{C}$ )	QT5 ( $4^\circ\text{C}$ )	QT25 ( $7^\circ\text{C}$ )	QT50 ( $10^\circ\text{C}$ )	QT75 ( $14^\circ\text{C}$ )	QT95 ( $16.3^\circ\text{C}$ )	QT99 ( $17.3^\circ\text{C}$ )
QF99 ( $0 \text{ m}^3\cdot\text{S}^{-1}$ )	5.0	6.0	9.0	12.0	16.0	18.3	19.3
QF95 ( $0.02 \text{ m}^3\cdot\text{S}^{-1}$ )	3.9	4.9	7.9	10.9	14.9	17.2	18.2
QF75 ( $0.11 \text{ m}^3\cdot\text{S}^{-1}$ )	3.3	4.3	7.3	10.3	14.3	16.6	17.6
QF50 ( $0.25 \text{ m}^3\cdot\text{S}^{-1}$ )	3.1	4.1	7.1	10.1	14.1	16.4	17.4
QF25 ( $0.50 \text{ m}^3\cdot\text{S}^{-1}$ )	3.1	4.1	7.1	10.1	14.1	16.3	17.3
QF5 ( $2.0 \text{ m}^3\cdot\text{S}^{-1}$ )	3.0	4.0	7.0	10.0	14.0	16.3	17.3
QF1 ( $4.6 \text{ m}^3\cdot\text{S}^{-1}$ )	3.0	4.0	7.0	10.0	14.0	16.3	17.3

- 4.2.5 Currently little is known regarding the status, abundance and distribution of aquatic taxa in the Glenavy River adjacent and downstream of the site of the proposed development, hence it is extremely difficult to assess the wider ecological impacts of the proposed development. It is extremely likely that brown trout and river lamprey utilise the lower section of the Glenavy River for spawning and larval/juvenile habitat. The river lamprey is a UK BAP priority species, and is protected under the EC Habitats Directive (Council Directive 92/43/EEC) which is locally enforced by the Conservation (Natural Habitats, etc.) Regulations (Northern Ireland) 1995. Although no Special Areas of Conservation have been assigned for river lampreys in Northern Ireland, their unusual non-anadromous ecology in the Lough Neagh catchment markedly increases their conservation status.
- 4.2.6 The Lough Neagh catchment also supports populations of unique forms of brown trout known locally as dollaghan (Crozier, 1983; Crozier and Ferguson, 1986; Crozier and Ferguson, 1993). Anecdotal evidence suggests that dollaghan spawn in the lower reaches of the Glenavy River. The Glenavy River may also support salmon (spawning adults and juveniles).

### **4.3 Recommendations**

- 4.3.1 Routine sampling to assess water quality undertaken by the EHS on the Glenavy River is undertaken upstream at the Leap Bridge and is not representative of the sections of river below the Leap waterfall. Hence, in the light of the proposed development, there is a pressing need for a baseline assessment of the ecology and physicochemistry of the Glenavy River to allow an assessment of the current situation and any future environmental change associated with the development. An ecological assessment of the lower reaches of the Glenavy should be undertaken prior to the development of the site to examine fish community/population structure and abundance, including evidence of spawning by brown trout, salmon and river lamprey. Due to their utility as a means of assessing water quality and their importance as prey for higher trophic levels, the production and community structure of benthic macroinvertebrates should also be assessed. Routine monitoring of physicochemical characteristics should also be implemented in order to assess current and future water quality.
- 4.3.2 Due to the potential for power-generation plants to release persistent xenobiotic compounds (e.g. PCBs & PAHs) (Dyke *et al.*, 2003), baseline samples of biota from the Glenavy River should be collected prior to the development of the site to provide information on baseline concentrations of these pollutants.
- 4.3.3 The potential impacts of thermal effluents under low flow conditions could be minimised by the operators following a more restrictive discharge policy during periods of extreme low flow e.g. ensuring discharge temperatures were close or equivalent to ambient.
- 4.3.4 The production of large volumes of heated water by the proposed development potentially represents an opportunity rather than an ecological problem. The heated effluents produced could be utilised in the culture of a range of fishes or agricultural products. Of particular scope is the aquaculture of fish using recirculation aquaculture systems (RAS) (Zohar *et al.*, 2005). The RAS approach can be extended to eels (Heinsbroek and Kamstra, 1990), which is clearly of local interest, and even high-value marine species e.g. turbot (Olsen *et al.*, 2008). The availability of heated waters could even permit the culture of Mediterranean species, e.g. sea-bream (Blancheton, 2000).

## 5.0 LOUGH NEAGH

- 5.0.1 The proposed development is located close to the eastern shore of Lough Neagh, and by discharging emissions and heated effluent into the Glenavy River could potentially impact the aquatic ecology of this internationally and nationally important ecosystem
- 5.0.2 Lough Neagh is a strikingly large body of water, with a total area of 383 km<sup>2</sup> and comprises the largest area of freshwater in the British Isles. Although there is a current absence of routine monitoring of many key taxa, Lough Neagh remains one of the most researched bodies of freshwater in the British Isles (Wood and Smith, 1993; Wood, 1998).

### 5.1 Physico-chemical characteristics

#### Hydrology

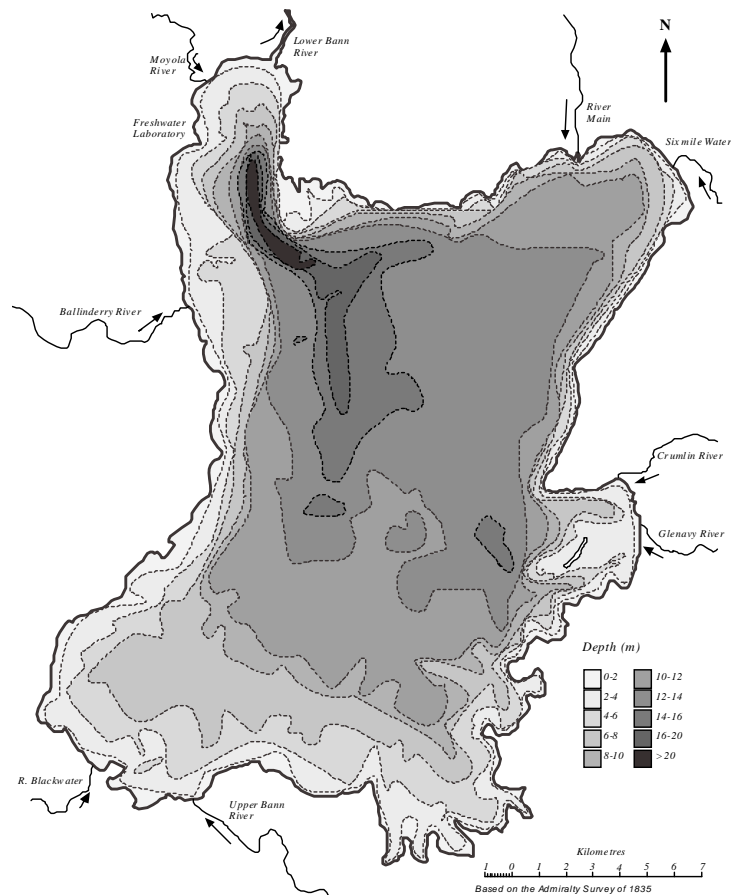
- 5.1.1 The Lough Neagh catchment drains an area of ca. 4 450 km, equivalent to approximately 43 % of Northern Ireland, and includes a small area of the republic of Ireland (Carter, 1993a). Six major afferent rivers flow into Lough Neagh (the R. Main, Balinderry R., Six Mile Water, Moyola R, R. Blackwater and the Upper Bann R.), and a single efferent river, the Lower Bann, drains to the north into the Atlantic Ocean, via the smaller Lough Beg. The catchment is partly delimited by upland areas; to the west the Sperrin Mountains, to the north-east, the Antrim Plateau, and to the south-east, the Mountains of Mourne (Carter, 1993a). The Lough Neagh catchment, like much of Northern Ireland is primarily agricultural, with large areas of improved grassland being given over to dairy and beef production (Carter, 1993a; Wood, 1998). The average annual precipitation in the catchment is 1 095 mm y<sup>-1</sup> (Betts, 1982 – in Carter, 1993a).

#### Bathymetry

- 5.1.2 Although Lough Neagh is extremely large, it is relatively shallow (Fig. 5). The lough bed is flat, with a mean depth of only 9.8 m, and less than 3 % of the lough area is deeper than 16 m (Douglas, 1997). Only in the north-western area of the lough is there a significant deepwater area (maximum depth = 34 m). Lough water levels have been subject to various regulatory schemes over the past 150 years in order to reduce flooding and improve navigation (Harron and Rushton, 1986; Carter, 1993a). Water levels are currently regulated at +12.5 m O.D. Belfast through the operation of sluice gates at Toome.

#### Hydrodynamics

- 5.1.3 Although its catchment is largely bounded by upland areas, Lough Neagh itself is extremely exposed, with a maximum effective fetch of ca. 30 km (Douglas and Rippey, 2000). This, combined with its shallow nature and the strong south-westerly winds characteristic of the region (Hueston, 1993), ensures that the water column rarely stratifies and is typically isothermal and well oxygenated (Carter, 1993b; Hueston, 1993). However, biological activity is such that during periods of high temperature and low winds, water column dissolved oxygen concentrations can fall rapidly (Griffiths, 2007). Wind-driven circulation of the water column causes resuspension and mobilisation of the lough's sediments (Douglas and Rippey, 2000). Sediment resuspension can liberate phosphorous, which in turn can promote phytoplankton growth (Gibson and Stewart, 1993). However, Jewson (1976) demonstrated that light penetration could sometimes be so reduced by sediment resuspension as to limit phytoplankton growth.



**Figure 5:** The simplified bathymetry of Lough Neagh, including the afferent and efferent rivers.

## Sediments

- 5.1.4 Lough Neagh acts as a net sediment trap for materials transported from elsewhere in the catchment by the afferent rivers (Carter, 1993b; Douglas, 1997). The bottom sediments of Lough Neagh can be largely divided into two principal zones, the littoral (< ca. 6 m) and the profundal, which are divided by a transitional zone (Carter, 1993b). The sediments of the littoral zone are typically coarse-grained (e.g. sands, gravels, mixed sands and clays) whilst the larger profundal area is dominated by fine-grained biogenic muds (Carter, 1993b). The shoreline of Lough Neagh includes rocky, exposed bays and sheltered sandy bays, some of which support reed beds and stands of macrophytes. The Glenavy River flows into the largely sandy Lennymore Bay (Fig. 5), although it includes areas of rocky substrate (Winfield and Wood, 1988).

## Water temperature

- 5.1.5 The seasonal pattern of water temperature is less marked in Lough Neagh than would be predicted by its latitude (54°), which is similar to Labrador (Canada), and Moscow. Water temperatures can fall to ca. 1°C between January to March, but in most winters median monthly temperatures remain above 4°C (Table 4), and Lough Neagh very rarely freezes. Water temperatures increase through spring, reaching a peak during August in most years, (median August<sub>1969-99</sub> temperature =16.4°C). The water column generally remains isothermal, but can stratify during periods of relative calm (Gibson and Stewart, 1993; Harrod, unpublished data). Median annual temperature between 1968-1999 was 9.8°C (Table 4). There is a certain amount of interannual variation in

water temperature, and Griffiths (2007) reported that water temperatures rose significantly between 1994 and 2005, whilst the annual period during which temperatures exceeded 16 °C doubled during this period.

### Dissolved oxygen

- 5.1.6 As noted above, Lough Neagh is extremely exposed to winds, and hence is typically well mixed, with thermal stratification only occurring during rare periods of calm. However, when these events occur, the extreme productivity of the sediments and water column ensures that oxygen is rapidly stripped from the water column (Gibson and Stewart, 1993).

**Table 4:** Descriptive statistics summarising monthly variation in Lough Neagh surface temperature between 1968 – 1999 (Data source: Dr Bob Foy, AFBI & Dr David Griffiths, University of Ulster)

Month	Median	25th	75th
January	4.0	3.0	5.0
February	4.0	3.0	4.6
March	5.0	4.0	5.8
April	7.6	6.5	8.5
May	11.0	10.0	12.4
June	14.1	13.0	15.6
July	16.0	15.0	17.4
August	16.4	15.7	17.5
September	14.3	13.4	15.5
October	11.5	10.0	12.4
November	7.8	6.6	9.0
December	5.8	5.0	6.4
Annual	9.8	5.5	14.3

### Water chemistry

- 5.1.7 A large component of the scientific interest directed towards the lough has been focused towards describing, understanding and countering the effects of cultural eutrophication (Wood and Smith, 1986). Following detailed assessment of the nutrient budget of Lough Neagh, it was shown that the critical nutrient limiting was phosphorous (Smith, 1993). Water quality today is now indicative of a hypereutrophic lake system (OECD, 1982), with elevated concentrations of phosphorous, and chlorophyll *a* (Table 5).

**Table 5:** Some physico-chemical characteristics of Lough Neagh. Note: samples collected at ca. 11 m, from the open lough at Irish Grid reference J 02351 70705 between January 1998 and November 1999 (Carter and Griffiths, 2001).

Variable (unit)	Median value	25 <sup>th</sup> quartile	75 <sup>th</sup> quartile	Max	n
Secchi depth (m)	1.5	1.20	1.86	2.1	14
Dissolved O <sub>2</sub> (% saturation)	90	88	99.5	128	14
Total suspended solids (mg l <sup>-1</sup> )	6.25	4	10	12	14
pH	8.08	7.01	8.57	9.2	14
BOD (mg l <sup>-1</sup> )	1.14	0.39	2.98	4.6	14
COD (mg l <sup>-1</sup> )	36.3	24.8	53.3	82.3	12
Total Phosphorous (mg l <sup>-1</sup> )	0.17	0.12	0.23	0.40	14
Soluble Reactive Phosphorous (mg l <sup>-1</sup> )	0.05	0.03	0.10	0.26	14
Ammonium (mg l <sup>-1</sup> )	0.04	0.01	0.10	0.14	14
Nitrate (mg l <sup>-1</sup> )	0.61	0.23	1.30	3.1	14
Nitrite (mg l <sup>-1</sup> )	0.08	0.02	0.26	0.82	14
Chloride (mg l <sup>-1</sup> )	20	20	21.25	36	14
Hardness (mg l <sup>-1</sup> Ca CO <sub>3</sub> )	113.7	111.1	125.5	163.3	13
Conductivity (μS cm <sup>-1</sup> )	290.5	279	300.5	483	14
Chlorophyll a (mg l <sup>-1</sup> )	41.73	18.33	82.55	93	14

## 6.0 ECOLOGICAL CHARACTERISTICS

6.0.1 Although extremely eutrophic and isothermal (see above), Lough Neagh supports populations of several thermally sensitive taxa more characteristic of cold, oligotrophic systems – e.g. *Monodiamesa ekmani* (Carter and McLarnon, 1999), *Mysis relicta* (Griffiths, 2007), and the pollan, *Coregonus autumnalis* (Harrod *et al.*, 2001; 2002). The existence of these sensitive species reflects Ireland's recent glacial history, which limited colonisation by species more typical of temperate Europe, whilst the typically well-oxygenated waters of Lough Neagh have probably facilitated their continued survival in what now is a temperate, hypereutrophic lake (Wood *et al.*, 2000).

6.0.2 The Lough Neagh ecosystem has undergone marked shifts in both its structure and productivity following lake enrichment, and the establishment of an array of invasive species including fish – roach (*Rutilus rutilus*) and alien macroinvertebrates – *Gammarus tigrinus*, *G. pulex*, *Crangonyx pseudogracilis*, (Battarbee and Carter, 1993; Fitzsimons and Andrew, 1993; Dick, 1996a; b). A notable recent invader is the zebra mussel (*Dreissena polymorpha*) which was recently (2005) identified in Lough Neagh. Where invasive, this bivalve has had marked ecological consequences (Ward and Ricciardi, 2007), including Northern Ireland (Maguire and Grey, 2006), and settlement densities have been such to interrupted power plant operations through reduced water flows (Kovalak *et al.*, 1993).

### 6.1 Primary Producers

6.1.1 Primary production in Lough Neagh (> 500 g C m<sup>-2</sup> y<sup>-1</sup>) is dominated by phytoplankton (Jewson, 1993b). The phytoplankton community is dominated for much of the annual cycle by blue-green algae (mostly *Oscillatoria redekei* and *O. agardhii*), although diatoms (e.g. *Stephanodiscus astraea* and *Aulacoseira italica* subsp. *sub-artica*) form a major peak in the spring, but which become limited by the availability of silica (Gibson, 1993). Phytoplankton primary productivity is ultimately controlled by the availability of nutrients, but in the turbid, well mixed water column of Lough Neagh, the availability of light acts as

a further regulatory factor (Jewson, 1976; 1993b). Jewson (1993a) detailed the benthic algae of Lough Neagh, which due to the turbid nature of the lough (Jewson, 1977) are restricted to a relatively limited coastal strip where water depths do not exceed 3 m. Included in the benthic algae is an abundant population of the rare diatom *Cymbellonitzschia diluviana* (Jewson, 1993a).

- 6.1.2 The turbulent nature of Lough Neagh restricts the distribution of macrophytes to sheltered bays (Harron and Rushton, 1986; Davidson, 1993). The distribution of submerged vegetation, which includes various *Potamogeton* spp., spiked water milfoil (*Myriophyllum spicatum*), and Canadian pondweed (*Elodea Canadensis*), is further limited by the restrictive euphotic zone (ca. 3 m during summer, (Jewson, 1977). Although much reduced following the successive lowering of lake levels, areas of reedswamp are still apparent. These include stands of the reed canary grass (*Phalaris arundinacea*) and common spike grass (*Eleocharis palustris*) both of which are relatively resistant to wave action (Davidson, 1993). In more sheltered areas, there are considerable stands of other emergent macrophytes, including the common reed (*Phragmites australis*). During summer months large populations of free-floating plants (e.g. *Lemna* spp.) can develop in sheltered bays (Harrod pers. obs.).

## 6.2 Zooplankton

- 6.2.1 The zooplankton of Lough Neagh underwent marked shifts in community structure between their first description in 1913 (Dakin and Latarche, 1913) and the late 20<sup>th</sup> century (Fitzsimons and Andrew, 1993; Kirkwood, 1996). In 1913 the zooplankton community included abundant populations of the small-bodied cladocerans *Bosmina longirostris* and *B. coregonid* but currently *Cyclops abyssorum* dominates the zooplankton, followed by *Eudiaptomus gracilis*, with *Daphnia hyalina* occurring at elevated densities between May and October.

## 6.3 Invertebrates

- 6.3.1 The aquatic macroinvertebrates of Lough Neagh have been researched to varying degrees, but the greatest focus has been on population studies of chironomid larvae (Carter, 1973; 1976; 1977; 1978; Carter and Murphy, 1993; McLarnon, 1997), whilst the more diverse macroinvertebrate community of the littoral zone has been less well-studied (Hynes, 1958b; Murphy and Carter, 1984; Carter and Murphy, 1997). The chironomid larvae (known locally as Lough Neagh flies) are extremely abundant (e.g. several thousand individuals m<sup>-2</sup>), and on emergence as adults, they form large breeding swarms which can cause considerable local nuisance. Bigsby (2000) conducted a detailed examination of the distribution and abundance of the benthic fauna in the context of their availability to overwintering diving ducks and fish. He demonstrated that chironomid larvae dominated the benthic fauna, and that species diversity was inversely related with increased depth. Dick (1996b) detailed the distribution and interactions between native and introduced gammarid species.

6.3.2 Lough Neagh supports one of only four extant populations of the thermally-sensitive epibenthic shrimp, *Mysis relicta*, in the British Isles (Väinölä, 1994). The life cycle and behaviour of the Lough Neagh population was detailed by Andrew & Woodward (1993). Griffiths (2007) noted that *Mysis* year-class strength declined by a factor of 10 between 1995-2005, and he showed that this decline was associated with recent increases in lough temperature. *Mysis* plays an important ecological role in the lough both as a predator of zooplankton and as an important trophic resource for pollan, eels, perch and brown trout populations (Anon, 1967; Bigsby, 2000; Harrod, 2001).

## 6.4 Fish

- 6.4.1 In reflection of their historical and current importance to human populations, the fishes of Lough Neagh have been well researched, although little is known of the ecology of the commercially important European eel (*Anguilla anguilla*) population (Winfield *et al.*, 1993; Kennedy, 2000; Rosell *et al.*, 2005). It was not until the 1970s that ecologists began to study the fish of Lough Neagh in detail. Cragg-Hine (1973) provided an early warning of the arrival of the invasive roach into the Lough Neagh catchment. The majority of the research conducted during the 1970s was focussed on the pollan. Ferguson examined the genetics of pollan during the 1970s (Ferguson, 1974; 1975), and in a joint study with Himberg and Svårdson was finally able to establish its taxonomic position as *Coregonus autumnalis* (Ferguson, 1974; 1975; Ferguson *et al.*, 1978), a fish more typically distributed in Arctic Russia and North America (McPhail, 1966). Wilson and Pitcher studied the ecology of the pollan in detail in the 1970s (Wilson, 1983; Wilson and Pitcher, 1983; Wilson, 1984b; a; Wilson and Pitcher, 1984a; b; 1985). More recently, Harrod and co-authors have examined the population ecology, conservation status, reproductive ecology and parasitism of the pollan stock (Harrod, 2001; Harrod *et al.*, 2001; 2002; Harrod and Griffiths, 2004; 2005a; 2005b). Other studies have examined the autecology of brown trout (Crozier, 1983), perch (Montgomery, 1990), and roach (Tobin, 1990). The monograph by Wood and Smith (1993) contained detailed summaries of the studies conducted on Lough Neagh fishes up to the late 1980s including a first examination of the fishes of Lough Neagh at a community level (Winfield *et al.*, 1993). Lough Neagh supports the largest freshwater fishery in the British Isles, and one of the largest and most important eel fisheries in Western Europe (Rosell *et al.*, 2005). Although commercially important, recent quantitative sampling indicates that the eel is the third most abundant fish in Lough Neagh (Table 6).
- 6.4.2 Following the decline of pollan from other Irish lakes (Harrod *et al.*, 2001; Harrod *et al.*, 2002), Lough Neagh supports the last viable population in Europe, enhancing its conservation status. Although currently abundant (Table 6), pollan are subject to a range of threats including invasive species, parasites and largely unregulated exploitation. Like many fishes, the early life stages are particularly sensitive. Pollan spawn in late November/December over shallow hard-bottomed areas in the sub-littoral (Dabrowski, 1981; Harrod and Griffiths, 2004), including areas close to the mouth of the Glenavy River (Winfield and Wood, 1988). Pollan require water temperatures < 5°C before spawning can occur (Dabrowski, 1981), and once spawned, eggs develop over the winter and hatch in early March. Any changes in thermal conditions, e.g. an increase in water temperature, could modify spawning behaviour or even egg development (Crisp, 1981), potentially resulting in a mismatch with the zooplankton food resources required by pollan larvae (Cushing and Horwood, 1994). Coregonid eggs are extremely susceptible to siltation of spawning grounds (Büttiker, 1986).
- 6.4.3 Lough Neagh is probably most famous for its eels, but apart from some early attempts to assess the stock and to examine the trophic ecology of eels during the late 1950s and 1960s (Hynes, 1958a; c; 1959; Anon, 1967), there is little relatively little known about the ecology of the eel in the Lough. AFBI biologists are currently generating the basic biological information required to support the eel fishery (Rosell *et al.*, 2005). Although eels are in decline throughout their distribution (Dekker *et al.*, 2003), the Lough Neagh eel population remains relative abundant through stocking by glass eels from other locations .

- 6.4.4 Although the pollan population is the principal species of conservation concern, the lough also supports genetically isolated ecotypes of brown trout, the dollaghan (Crozier, 1983), and an unusual freshwater-feeding population river lamprey, both of which are of considerable conservation importance. The fish community has recently undergone considerable shifts with regard to its structure and recent surveys by Queen's University, Belfast have revealed that the lough is dominated by roach (Table 6).

**Table 6:** Relative abundance of Lough Neagh fishes assessed during lough-wide 2006 purse-seine survey (n hauls = 122).

Species	Mean numerical contribution % (n = 12 589)
Roach ( <i>Rutilus rutilus</i> )	41.1
Pollan ( <i>Coregonus autumnalis</i> )	35.6
Eel ( <i>Anguilla anguilla</i> )	11.1
Perch ( <i>Perca fluviatilis</i> )	6.7
Bream ( <i>Abramis brama</i> )	1.8
Brown trout ( <i>Salmo trutta</i> )	1.4
3-spined stickleback ( <i>Gasterosteus aculeatus</i> )	0.8
Gudgeon ( <i>Gobio gobio</i> )	1.2
River Lamprey ( <i>Lampetra fluviatilis</i> )	0.3
Roach x Bream hybrid	0.1

## 6.5 Birds

- 6.5.1 The bulk of the conservation attention to date has been directed at the lough's bird community as with Lough Beg, the lough supports internationally important and extremely abundant populations of overwintering and resident wildfowl. In recognition of this importance to birdlife, they have been given statutory protection at an international, European and national level, being designated as a Ramsar site, a Special Protection Area (SPA) under the European Community's Birds directive, and an ASSI. The Lough Neagh and Lough Beg SPA represents the most important site for diving ducks in Britain and Ireland, hosting overwintering populations of ca. 40 000 pochard (*Aythya farina*), 30 000 tufted duck (*Aythya fuligula*), 14 000 goldeneye (*Bucephala clangula*) and 5 000 scaup (*Aythya marila*) during the early 1990s (Bigsby, 2000; Evans, 2000; Maclean *et al.*, 2006). However, since the early 1990s concern has been raised due to large, and significant declines in the numbers of three of these species (Allen and Mellon, 2006; Maclean *et al.*, 2006). For instance, over the winter of 2003/04, an estimated 9 000 tufted duck, 8 000 pochard, 4 000 goldeneye and 2 600 scaup overwintered in the SPA (Maclean *et al.*, 2006). Although scaup numbers have subsequently recovered, the declines in the other diving ducks were shown by Maclean *et al.* (2006) to be an order of magnitude larger than declines recorded from anywhere in Britain or Ireland over the same period, and were not associated with similar trends anywhere in Europe.
- 6.5.2 Lough Neagh also provides excellent foraging habitat for large numbers of cormorants (*Phalacrocorax carbo*), a predator of pollan (Warke *et al.*, 1994). Local wildfowling exploit both the migratory wildfowl and the abundant resident population of mallard (*Anas platyrhynchos*). Although conservationally important, there have been few studies of the ecology of the birds of Lough

Neagh. Evans (2000) examined diving duck behaviour and ecology, whilst trophic ecology was examined by both Winfield (1991) and Bigsby (2000).

## **6.6 Mammals**

- 6.6.1 Otters (*Lutra lutra*) are occasionally seen on the shoreline of Lough Neagh, and otter traffic mortalities have been recorded on roads adjacent to the lough (Harrod Pers. Obs.).

## **7.0 SOCIO-ECONOMIC CHARACTERISTICS**

### **7.1 Cultural heritage**

- 7.1.1 Lough Neagh has played a fundamental role in the history of Ireland (Bardon, 1992). Excavations at Ireland's first recorded settlement at Mount Sandel, on the banks of the Lower Bann River, demonstrated that Mesolithic settlers relied on fishes migrating between the lough and the Atlantic Ocean via the river (Woodman and Mitchel, 1993). Later in Ireland's history, native Irish peoples were displaced to the shores of Lough Neagh during the plantations of English and Scottish settlers in the 16<sup>th</sup> and 17<sup>th</sup> century, and represent the ancestors of today's fishing community (Donnelly, 1986). After over a century of legal wrangling, the fishing community finally gained control of the fishery in 1971, and today operates as a co-operative.

### **7.2 Fishery**

- 7.2.1 The commercial fishery currently employs ca. 300 people, (Kennedy, 2000); reliable figures regarding its worth are not available, but it is likely to be in the region of several million pounds a year. Although the cultural value of fishing is immense and probably undervalued, it also provides much-needed employment and income in what is one of the European Union's most deprived regions. The fishery principally exploits eels, taking immature brown eels from the lough using long lines and draft nets and mature silver eels are trapped during their downstream migration. The majority of eels are exported live to Holland. Pollan and other scale-fish also contribute to the fishery, but at a far reduced annual yield. Rosell et al. (2005) showed that although catches have declined recently, ca. 500 t of eels are still removed annually. Clearly the long-term sustainable management of eels is of paramount importance to many Lough Neagh stakeholders and any proposed development should consider the potential impacts to the eel fishery.

### **7.3 Other human uses of Lough Neagh**

- 7.3.1 Large volumes of Lough Neagh water are abstracted daily to supply Belfast and other population centres (ca.  $2 \times 10^5$  m<sup>3</sup> d<sup>-1</sup> - (1998), whilst the lough and its afferent rivers receive effluent from STWs. The sediments of Lough Neagh are also commercially exploited. Sand is extracted from the lough bed in considerable, but unquantified volumes using large suction dredges mounted on sand barges. Currently, recreational use of the open water of Lough Neagh is minimal. Some cruising and yachting takes place, but it is far less developed than in lakes of comparable size elsewhere (e.g. Lough Erne and Loch Lomond).

### **7.4 Possible impacts of the development on Lough Neagh:**

- 7.4.1 The proposed development is located only ca. 0.9 km from Lough Neagh, and although current specifications indicate that the development will be largely isolated from the Lough and that effects of thermal discharges on the lough will be negligible, there is still the potential to impact the aquatic ecology of the

lough. For instance, there is a direct connection to the Lough through the Glenavy River (see above) and any effluents introduced during the construction and operation of the site, or through discharges under emergency situations are likely to ultimately find their way into the lough.

- 7.4.2 As noted above, it is possible that both brown trout and river lamprey utilise the Glenavy River as spawning and nursery habitats and any impacts on these areas will have ongoing consequences to the wider Lough Neagh fish community.

## 7.5 Recommendations

- 7.5.1 Although Winfield and Wood (1988) sampled spawning pollan in Lennymore Bay, there is very little known about the aquatic ecology of this unusually shallow bay. There is a need to gather baseline information on fish, phytoplankton, zooplankton and benthic macroinvertebrate community structure, water and sediment chemistry in order to assess any possible environmental impacts of the proposed development.

- 7.5.2 Eels have been repeatedly shown to accumulate xenobiotic compounds partly due to their benthic foraging mode, and their elevated body lipid concentrations (Roche *et al.*, 2000; Mariottini *et al.*, 2006). Although emissions of harmful persistent organic compounds (dioxins, PCBs, PAHs) are much reduced in modern, well run power-generation plants, the potential for these compounds to be released into the Lough Neagh food web remains (Dyke *et al.*, 2003). Hence, it is recommended that baseline information on the concentrations of these compounds prior to the construction of the proposed development.

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