Lakes: a new concept for wildlife conservation on Irish cutaway peatlands

H. Lally[1], T. Higgins[2], E. Colleran[1] and M. Gormally[3]

[1] Environmental Microbiology Research Unit, Department of Microbiology, National University of Ireland, Galway

[2] Freshwater Ecology Unit, Department of Zoology, National University of Ireland, Galway

[3] Applied Ecology Unit, Centre for Environmental Science, National University of Ireland, Galway

Summary

By 2030, Ireland will have more than 80,000ha of cutaway peatlands. Since the early 1990s, lake creation has emerged as a novel post-harvesting land use option for industrial peatlands. It is probable that up to half of all emerging cutaway peatlands in Ireland will be flooded and revegetated for conservation and public amenity uses, in one of the largest wildlife habitat creation projects in Europe in modern times. Here we review the Irish experience of creating lakes and wetlands on cutaway peatlands and describe some of the lessons learned. Baseline water chemistry data are presented for 13 lakes created in the pilot Lough Boora Parklands project in County Offaly. Physicochemically, the cutaway waterbodies lie along a gradient from acidic, dystrophic, humic lakes to alkaline, minerotrophic, clear water lakes. Data suggested that the hydrologic regime and type and depth of the residual peat sediment, both of which are determined by the construction approaches adopted, were the main determinants of water chemistry. In terms of trophic status, most cutaway lakes were slightly eutrophic-mesotrophic although certain sites were eutrophic-hypereutrophic, indicating elevated nutrient enrichment. Nutrient concentrations in the artificial lakes appeared to be influenced primarily by catchment land uses. Collectively, the research findings will help to provide guidelines aimed at maximising the conservation value and biodiversity potential of future cutaway lake creation projects.

Key index words: cutaway peatlands, lake creation, trophic status, conservation potential, biodiversity.

Introduction

Since its foundation in 1946, Bord na Móna (the Irish Peat Development Board), has extensively harvested Ireland's peatlands for fuel. As a result, Ireland is expected to have in excess of 80,000ha of redundant, worked out bogland, commonly know as cutaway peatlands, by the year 2030 (Egan, 1998). In recent years, lake creation has emerged as a major post-harvesting land use option for cutaway peatlands. Bord na Móna is now focused on rehabilitating at least half of all emerging cutaway peatlands for wildlife conservation and public amenity use. Consequently, 40,000ha of cutaway peatlands will be flooded and revegetated to form semi-natural wilderness extending throughout the Irish Midlands (Egan, 1998). This represents one of the largest habitat creation opportunities to emerge in Europe in modern times (Feehan and Kaye, 1998).

A blueprint of what is to come is seen in the Lough Boora Parklands in Co. Offaly. This is the oldest area of commercial peat production and was the first area in Ireland in which large tracts of cutaway peatlands emerged. The Lough Boora Parklands consist of a 2,000ha site in which Bord na Móna, since 1991, has created some 400ha of experimental waterbodies, as well as vast areas of naturally regenerating grassland and scrub woodland. The Parklands have become an important refuge for flora and fauna alike. Some 130 species of birds have been recorded within the Parklands, of which half breed there. The Parklands are also home to the last remaining native breeding population of Grey Partridge (*Perdix perdix*) and a dedicated conservation project: an estimated 200 of these native birds have been recorded. Over the last decade, extensive research has been undertaken on the macroinvertebrate fauna, microalgal populations, aquatic vegetation and water quality of the Lough Boora Parklands lakes, in order to better understand the ecology and conservation potential of these unique pioneering ecosystems as they evolve (O'Connor, 2000; Rowlands, 2000; Trodd, 2004; Higgins, 2005).

Three broad approaches are used in Ireland to construct lakes on cutaway peatlands, involving varying levels of residual peat removal, hydrological manipulation and post-flooding management (Egan, 1998; Higgins and Colleran, 2006). Bord na Móna aim to create moderately deep (>1 m) stands of open water designed for conservation and amenity purposes. This approach differs fundamentally from cutaway peatland rehabilitation projects in the UK, Northern Europe and North America where the main focus is on shallow re-wetting to promote *Sphagnum* re-growth (Meade, 1992; Sliva and Pfadenhauer, 1999; Smolders *et al.*, 2003; Rochefort *et al.*, 2003). In this review, we describe the three different approaches used by Bord na Móna in Ireland to construct lakes on cutaway peatlands and assess their implications for baseline water chemistry and trophic status in the resultant artificial lakes.

Study sites

A total of 13 cutaway peatland lakes were examined within the Lough Boora Parklands in Co. Offaly, Ireland. Four of the lakes were sampled intensively from February 2006 to February 2008 at bi-weekly intervals for the first year and monthly thereafter (Lally *et al.* in press). The remaining nine lakes were sampled at 3-month intervals between July 2007 and January 2008.

Three different approaches were used by Bord na Móna in the construction of the study lakes. In the first approach (A1), all residual peat is removed from the cutaway using land-moving machinery to form a deep lake basin where the underlying mineral sub soil is typically exposed. A piped inflow is introduced from a nearby stream or river and the lake is allowed to flood to a depth of 1–2m. This approach involves the introduction of aquatic plants and macroinvertebrate fauna to help expedite natural recolonisation. In addition, the surrounding landscape is reseeded to help stabilise the peat substratum. This approach is the most labour-intensive, costing €20,000 to 25,000 per ha.

In the second approach to lake creation (A2), the residual peat is partially excavated and used to form embankments and island regions within the lake basin. The area is allowed to flood to a depth of 1m by precipitation and groundwater seepage, or a supplemental piped inflow may be introduced (McNally, 1999), and natural recolonisation of the lake environs ensues. Constructing lakes using Approach 2 costs approximately €500 per ha.

In the simplest approach to lake construction (A3), lakes are created on low-lying sites by infilling the network of artificial drainage canals that were constructed prior to peat harvesting. Being lower than the regional water table, these sites then spontaneously flood. These lakes are shallow with a depth of 0.5–1m. Little on-site disturbance occurs using this approach, which is favoured by Bord na Móna because it enables large sized waterbodies to be created at minimal financial expenditure (c. €200 per ha). Of the 13 lakes studied, three lakes (Finnamore's, Cloghan, Loch Dochais) were constructed using total peat removal (A1), eight lakes (Drinagh, Turraun, Tumduff Mor, Blackwater, Mesolithic, Boora, Tumduff Beag, Turraun lagoon) were constructed using partial peat removal (A2) while two lakes (Clongawny, Derries) were constructed from simple flooding (A3).

Materials and methods

Near-surface (0.2m) water samples were taken at two opposite sampling stations at each lake and on site analyses of pH, conductivity, dissolved oxygen and temperature were conducted using the WTW Multiline field kit. Dissolved colour was determined spectrophotometrically (Hach DR4000 UV/Vis) at 465 nm on filtered (GF/C) water samples, while turbidity was measured nephelometrically using a HANNA. Total phosphorus was analysed by the ascorbic acid reduction method (Murphy and Riley, 1962). Ammonium was determined on filtered samples according to the indophenol blue method (Solórzano, 1969). Nitrite and nitrate were measured spectrophotometrically on filtered samples using the Hach low-range diazotization (precision ± 0.6 µg NO_2^--N L^{-1}) and cadmium reduction methods (precision ± 0.01 mg NO_3^--N L^{-1}). Chlorophyll-a was extracted using 90% acetone and measured spectrophotometrically with correction for phaeopigments (Lorenzen, 1967).

Results and discussion

Results indicate that the physico-chemical properties of the study lakes varied considerably according to the lake construction approach used (Fig. 1). Approach 1 produced alkaline (pH 8.04) lakes with high ionic conductivities (428.22 µS cm^{-1}) and low levels of colour (12.17 Pt-Co) and moderate levels of turbidity (3.59 NTU). Approach 2 lakes were circumneutral (pH 7.36), with moderate levels of ionic conductivity, colour and turbidity (384.77 µS cm^{-1}, 18.37 Pt-Co and 2.43 NTU, respectively). Approach 3, by contrast, produced lakes there were slightly acidic (pH 6.72) and ion poor (81.20 µS cm^{-1}), with very high levels of dissolved colour and turbidity (38.57 Pt-Co and 4.84 NTU, respectively). These data suggest that approach 1 and approach 2 produced physico-chemically similar alkaline, minerotrophic lakes, while approach 3 produced more acidic dystrophic, humic rich waterbodies. Peat removal during approaches 1 and 2 means that these lakes contain exposed calcareous marl and blue silty clay sediments. Together with the introduction at some sites of supplemental piped inflows from nearby natural streams, these factors increase the hardness of the water and reduce turbidity and colour levels associated with peat resuspension. The third approach to lake creation results in unconsolidated peat sediments that are prone to erosion and resuspension, resulting in darkly stained lakes with high levels of turbidity and suspended solids. A lack of mineral sediments and ground or surface hardwater inflows means that Approach 3 lakes are acidic and humic rich (dystrophic) leaving approach 3 lakes at high risk from erosion and run off due to the absence of buffering macrophytes.

In terms of nutrients, (Fig. 2) illustrates that the Approach 1 lakes had moderately high concentrations of total phosphorous (TP) and soluble reactive phosphate (SRP) (26.72 and 10 µg L^{-1}, respectively) and very high concentrations of ammonium and nitrate (246.06 µg L^{-1} and 4.82 mg L^{-1}, respectively). The Approach 2 lakes had high concentrations of TP and SRP (35.67 and 12.72 µg L^{-1} respectively) and moderately high concentrations of ammonium and nitrate (86.92 µg L^{-1} and 2.75 mg L^{-1} respectively). The Approach 3 lakes had similarly high TP and SRP concentrations to the Approach 2 lakes (36.09 µg L^{-1}, 12.06µg L^{-1}), and had moderately high ammonium concentrations (163.33 µg L^{-1}) but low nitrate concentrations (0.57 mg L^{-1}). Based on the current TP and chlorophyll-a data (Fig. 3) and using the OECD lake classification scheme (OECD 1982), Approach 1 lakes can be classified as oligotrophic-mesotrophic and Approach 2 and 3 lakes as eutrophic. Nitrate concentrations in the lakes are believed to reflect catchment landuses, particularly agriculture, the influence of which is greatest in Approach 1 lakes (Higgins and Colleran 2004, 2006). Approach 1 lakes are more likely to be susceptible to nutrient inputs from the catchment due the presence at some sites of introduced piped inflows from

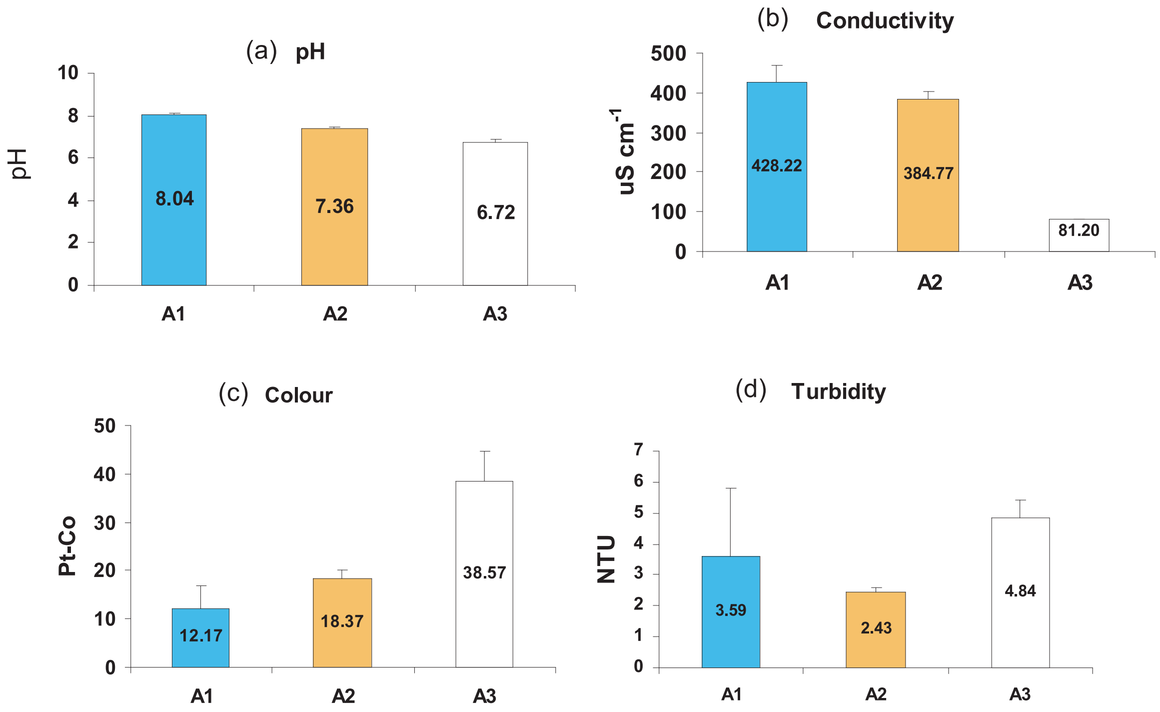

Figure 1. Effect of different construction (A1–A3) approaches on the physicochemical environment in 13 cutaway lakes: (a) pH, (b) conductivity, (c) dissolved colour and (d) turbidity. Values shown are means ± SEM (2006–2008; A1 n = 9, A2 n = 123 and A3 n= 39 sampling dates).

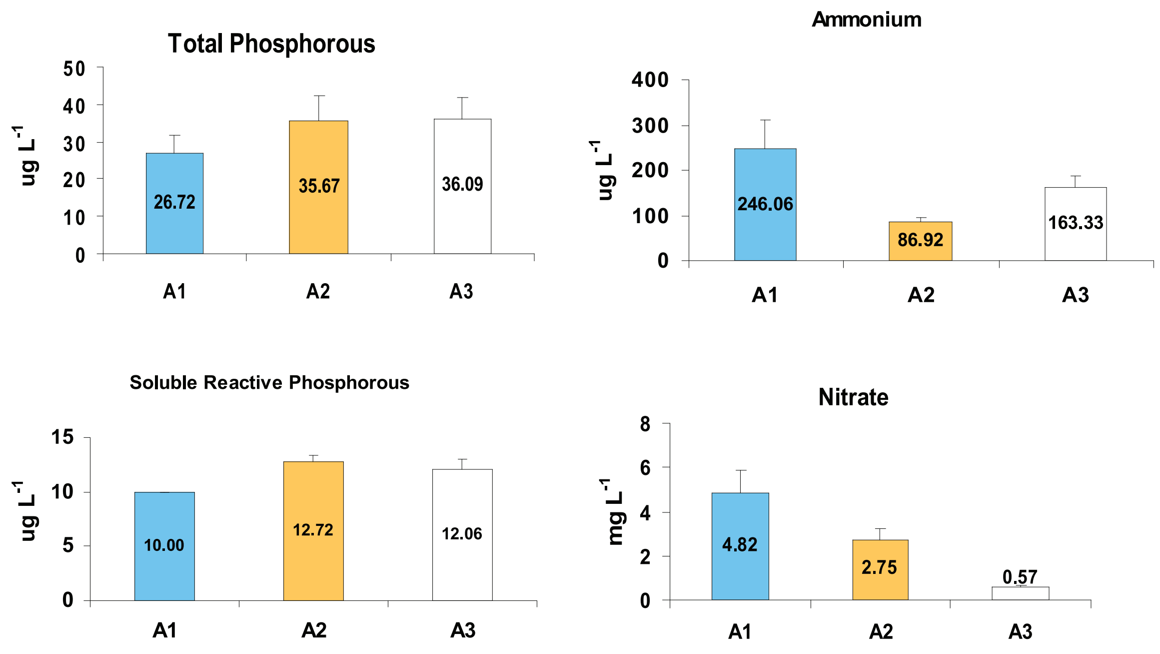

Figure 2. Effect of alternative construction approaches (A1–A3) on mean nutrient concentrations in 13 cutaway lakes: (a) total phosphorous, (b) ammonium, (c) soluble reactive phosphate and (d) nitrate. Values shown are means ± SEM (2006–2008; A1 n = 9, A2 n = 123 and A3 n= 39 sampling dates).).

local natural streams that drain a largely agricultural catchment. Approach 2 and 3 lakes, by contrast, may be more vulnerable to diffuse phosphorus enrichment. There is evidence from Clongawny (A3) that the absence of higher plants and the bare, unconsolidated peat sediments makes this site susceptible to erosion and phosphorus runoff from the afforested catchment (Higgins *et al.*, 2006). Collectively, these results emphasise the importance of incoming water quality and catchment land-uses on the nutrient status of the cutaway lakes.

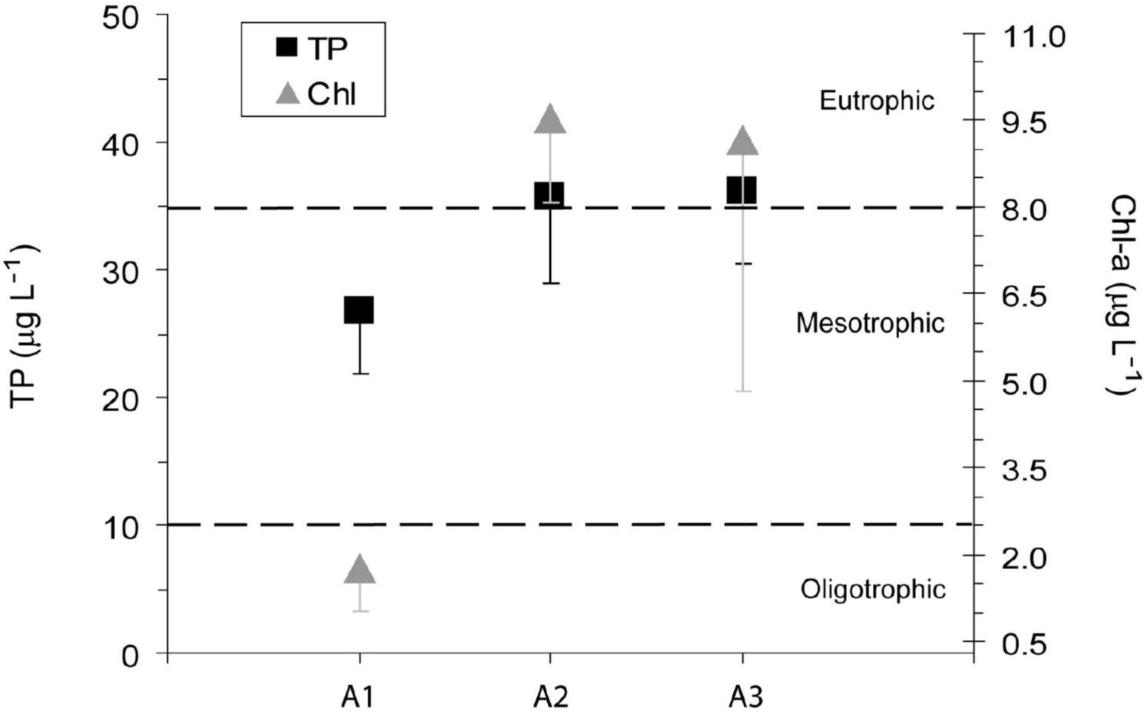

Figure 3. Trophic status of lakes created using three alternative construction approaches (A1–A3). (Left y-axis are mean ± SEM TP (white) (2006-2008; A1 n = 9, A2 n = 123 and A3 n= 39) and right y-axis are mean ± SEM Chlorophyll-a (black) (2006–2008; A1 n = 9, A2 n = 123 and A3 n= 39 sampling dates)).

Conclusion

Collective data on artificial cutaway lakes within the Lough Boora Parklands suggest that Approach 1 (total peat removal) and Approach 2 (partial peat removal) produce lakes that are physicochemically similar (hard, clear water lakes) but differ in their nutrient status (with Approach 1 lakes being oligo-mesotrophic and Approach 2 lakes being eutrophic, in terms of phosphorus and chlorophyll concentrations). By contrast, Approach 3 (simple flooding) produces lakes that are acidic, highly coloured and eutrophic. The similarity in water chemistry of Approach 1 and 2 lakes is somewhat surprising considering the differences between the two construction approaches in terms of the extent of peat removal, hydrological manipulation, post-flooding management, and subsequently, the construction costs involved. The data suggest that stable, hardwater lakes can be created using Approach 2 at much lower expenditure than the earlier, labour intensive Approach 1. In the future peat removal estimates may need to be considered when creating lakes on cutaway peatlands. However, in view of the considerable timescales involved in ecosystem establishment, continued monitoring is also required to evaluate whether younger lakes created using Approach 3 stabilise as they evolve and become recolonised.

Acknowledgements

This study is being funded by Bord na Móna. Thanks to Owen Doherty for all his technical support.

References

Egan, T. (1998). A pilot project for the utilization of cutaway boglands in West Offaly. In G. O'Leary and F. Gormley (eds.), *Towards Conservation Strategy for the Bogs of Ireland,* 119-126. Irish Peatland Conservation Council, Dublin

Feehan, J. and Kaye, B. (1998). Creating the space for a new Irish wilderness. *The future use of cutaway bogs*, 7-11. Brosna Press Ltd., Co. Offaly.

Higgins, T. and Colleran, E. (2004). A comparative assessment of water quality in four artificial lakes created on Irish cutaway peatland. In J. Päivänen (ed.), *Wise Use of Peatlands*, 372-378. International Peat Society, Jyväskylä, Finland.

Higgins, T. (2005). *Lake creation on cutaway peatland in Ireland: Evolving trophic status of experimental lakes and implications for future design.* Unpublished Ph.D. thesis, National University of Ireland, Galway.

Higgins, T. and Colleran, E. (2006). Trophic status of experimental cutaway peatland lakes in Ireland and implications for future lake creation. *Journal of Environmental Science and Health*, Part A, **41**, 849-863.

Higgins, T., Colleran, E. and Raine, R. (2006). Transition from P- to N-limited phytoplankton growth in an artificial lake on flooded cutaway peatland in Ireland. *Journal of Applied Vegetation Science* **9**, 223-230.

Lally, H., Higgins, T., Colleran, E and Gormally, M. (in press). A new Irish wilderness? Trophic status and conservation potential of cutaway peatland lakes in Ireland. *Redefining Theoretical and Applied Limnology for the 21st Century.* Proceedings of the 30th Congress of the International Association of Theoretical and Applied Limnology.

Lorenzen, C.J. (1967). Determination of chlorophyll and phaeopigments: spectrophotometric equations. *Limnology and Oceanography* **12**, 343-346.

McNally, G. (1999). Peatlands, power and post-industrial use. In L. Parkyn, R.E. Stoneman, and H.A.P. Ingram (eds.), *Conserving Peatlands*, 245-251. CAB International, Wallingford, UK.

Meade, R. (1992) Some early changes following the rewetting of a vegetated cutover peatland surface at Danes Moss, Cheshire, UK, and their relevance to conservation management. *Biol. Conserv.* **61**, 31-40.

Murphy, J. and Riley, J.P. (1962). A modified single solution method for the determination of phosphate in natural waters. *Anaytica Chimica Acta* **27**, 31-36.

O'Connor, A. (2000). *The development of aquatic macroinvertebrate communities in two artificial ponds on Irish cutaway bog, with particular reference to Corixidae (Hemiptera Heteroptera).* Unpublished Ph.D. thesis, University of Dublin, Trinity College.

O.E.C.D. (1982). *Euthrophication of Waters: Monitoring, Assessment and Control.* Organization for Economic Co-Operation and Development (OECD), Paris.

Rochefort, L., Quinty, F., Campeau, S., Johnson, K. and Malterer, T. (2003). North American approach to the restoration of *Sphagnum* dominated peatlands. *Wetlands Ecology and Management* **11**, 3–20.

Rowlands, R. and Feehan, J. (2000). The ecological future of industrially milled cutaway peatlands in Ireland. *Aspects of Applied Biology* **58**, 263-270.

Sliva, J. and Pfadenhauer, J. (1991). Restoration of cut-over raised bogs in southern Germany – a comparison of methods. *Applied Vegetation Science* **2**, 137-148.

Smolders, A.J.P., Tomassen, H.B.M., van Mullekom, M., Lamers, L.P.M. and Roelofs, J.G.M. (2003). Mechanisms involved in the re-establishment of *Sphagnum*-dominated vegetation in rewetted bog remnants. *Wetlands Ecology and Management* **11**, 403-418.

Solórzano, L. (1969). Determination of ammonia in natural waters by phenol-hypochlorite methods. *Limnology and. Oceanography* **14**, 799-801.

Trodd, W. (2004). *Assessment of aquatic habitats in Turraun Nature Reserve for restoration management and use of Chironomidae (Diptera; Insecta) as bioindicators of water quality.* Unpublished Ph.D. thesis, University College Dublin.