SEASONAL VARIATIONS IN NUTRIENT LEVELS IN BEMERSYDE MOSS, BORDERS REGION, SCOTLAND

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SUMMARY

Nutrient levels were monitored over a twelve month period in Bemersyde Moss, a shallow wetland in southern Scotland. The Moss is used by a variety of waterfowl, both as a winter roost by approximately 100-250 greylag geese (*Anser anser*) and in summer as a breeding colony for over 14,000 pairs of black-headed gulls (*Laws ridibundus*). It is surrounded by agricultural land, which along with the birds has an effect on nutrient levels. Phosphate phosphorus (PO_4-P) and combined inorganic nitrogen (NH_4-N, NO_3-N and NO_2-N) concentrations were analysed at fortnightly intervals, both in the drains flowing into the wetland and in the wetland itself. Abiotic parameters including pH, conductivity, temperature, depth, dissolved oxygen were also recorded. P and NH_4-N showed high concentration in summer due to the influx of birds and use by livestock. Although some of the NO_3-N could be attributed to the oxidation of NH_4-N, increased levels in the spring and late autumn/early winter were measured in the field drains, suggesting an input from the surrounding arable fields. It was concluded that birds and livestock were making a major contribution to P and N levels within the wetland.

INTRODUCTION

Shallow wetlands face a variety of problems. They frequently suffer from a reduced freshwater input, large water loss from evaporation, low flow (or even static water) and may show wide seasonal variations in depth with summer droughts and winter flooding. Although this may encourage the growth of certain plant species, providing ideal habitats for wetland breeding birds, it may also lead to eutrophication due to nutrient input from waterfowl and agricultural sources (Bailey-Watts, 1994; Balla & Davis, 1995; Eriksson & Weisner, 1997; Manny *et al.*, 1994; Mundie *et al.*, 1991; Rader & Richardson, 1994). This paper describes the nutrient inputs from avian and agricultural sources into Bemersyde Moss, Scotland, an important habitat for blackheaded gulls (*Laws ridibundus*).

Wetlands are an important habitat for wildlife and in Europe are decreasing in numbers. This paper presents preliminary results from an ongoing study which began in January 1997.

The aims of the study were to:
1) identify the sources of nutrients entering the wetland;
2) assess the various factors contributing to this nutrient enrichment.

Background to Site

Bemersyde Moss is located four miles east of Melrose, Borders Region (Figure 1; grid reference NT 612 330). It is owned by Earl Haig, managed by the Scottish Wildlife Trust (SWT) and Scottish Natural Heritage (SNH), and designated as a Site of Special Scientific Interest (SSSI) in 1987. The wetland lies in a shallow depression of Upper Old Red Sandstone (Greig, 1971), and is fed only by rainwater and field drains in the surrounding catchment. Although the water level now varies from 0.4 m to 1.2 m, prior to the 19th century it was known as Mertoun Loch and was used for eel fishing, cutting reeds for matting and to power local water mills (Russell, 1881). It was later drained and used for hay; the 1802 map shows a meadow with a single drain running through the middle. However, the main drain gradually silted up, creating the present wetland which continues to increase in size (Gaskell, 1995).

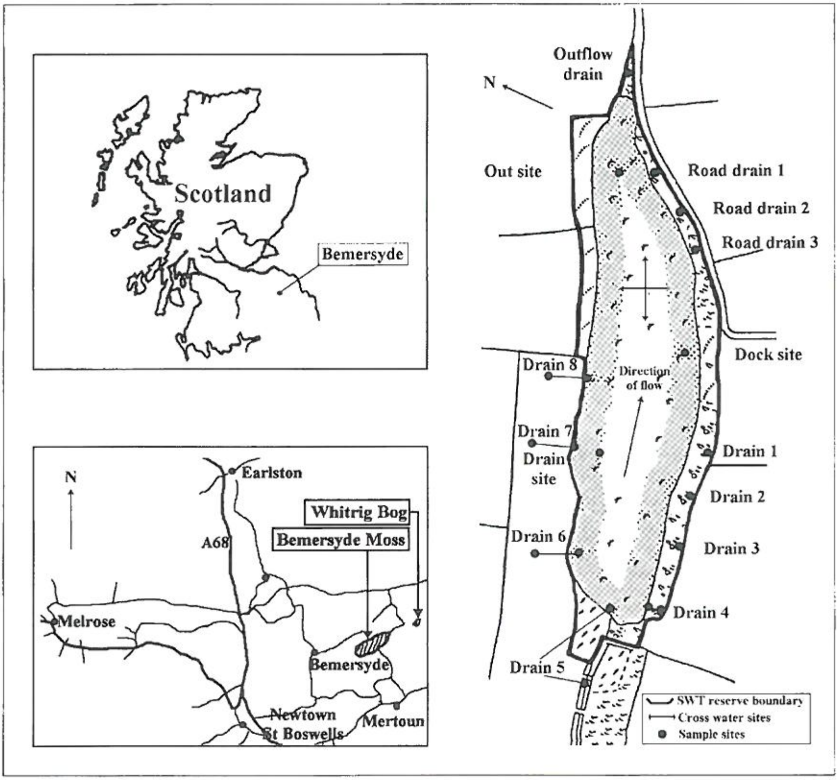

FIGURE 1
Location and site map of Bemersyde Moss, Scotland.

Description of Site

The main drain enters the wetland at the south west and leaves by the north east end, eventually flowing into Maidenhall Burn (Figure 1). No springs are known to be present. The depth and water quality of the wetland is therefore heavily dependent on the amount of precipitation, other local weather conditions (e.g. temperature and wind speed) and agricultural practices.

Bemersyde is a valuable site for plants, invertebrates and birds. It has over 136 species of flowering plants including several species of regional importance and numerous bird species. In the winter it has regionally important populations of wigeon (*Anas penelope*), teal (*Anas crecca*), whooper swans (*Cygnus cygnus*) and greylag geese (*Anser anser*) and smaller numbers of other migratory species. From mid-March to late July, it hosts approximately 14,000 pairs of black-headed gulls, three-quarters of the South Scotland population, along with several other duck species (mallard, *Anas platyrhynchos;* pochard, *Aythya ferina*; ruddy duck, *Oxyura jamaicensis*), black-necked grebes (*Podiceps nigricollis*), a pair of mute swans (*Cygnus olor*), coots (*Fulica atra)* and moorhens (*Gallinula chloropus*)). The various waterfowl have two obvious effects on the site. The first is nutrient enrichment through defecation which is exacerbated by the large number of black-headed gulls in the summer when the water levels are at their lowest, compounded by additional inputs by winter-roosting birds (mostly geese and ducks). Most of these species feed elsewhere (e.g. on surrounding arable ground and pasture or further afield), hence input into the wetland is additional loading. The second effect is the damage to vegetation by breeding birds trampling the reed beds, thereby inhibiting their growth and increasing the amount of open water (Gaskell, 1995; *pers. comm.*) In addition, the wetland is surrounded by arable fields (winter and spring barley, wheat, oats, oil seed rape, turnips), coniferous forestry (sitka spruce, *Picea sitchensis*, Norway spruce, *Picea abies*) and grazed pasture, all of which have drains feeding into the moss, each with their own input of nutrients from agricultural fertilisers and animal dung.

In this study a neighbouring site, Whitrig Bog, was used to compare water quality. Whitrig lies about 0.5 km to the east of Bemersyde and has similar geology and water conditions. It was drained around 1790 but, unlike Bemersyde, large amounts of clay were extracted between 1801 and 1900. It is also used by winter roosting geese and various duck species in the winter and summer. Livestock graze in the adjoining pastures from spring to autumn but, unlike Bemersyde, it does not have a large colony of nesting black-headed gulls.

METHODS

Water samples were taken from the drains flowing into and out of the wetland along with the areas of open water at fortnightly intervals for a 12-month period, although some drains dried up between late July and mid-November, making sampling impossible. A total of 12 drains, five water's edge sites and three open water sites were sampled and are described in detail in Table 1. A cross water transect was carried out by dinghy in mid-March and again in early August to assess uniformity of nutrient levels in the deeper parts of the wetland. The pH and conductivity were measured for all sites; in addition, dissolved oxygen (DO) and water temperature were recorded for the open water sites and Whitrig (Table 1), along with concentrations of phosphate phosphorus (PO_4-P), ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N) and nitrite nitrogen (NO_2-N) (APHA, 1996; Kirika, *pers. comm.*). Water samples were also taken from Whitrig Bog at fortnightly intervals.

RESULTS

Table 1 summarises the site details, including location, classification, pH, conductivity, dissolved oxygen, temperature and a brief description of the site. The abiotic information is consistent with expected seasonal variations and responses to changes in water chemistry.

Nutrient levels

Sampling sites were classified according to their location and were amalgamated into the categories summarised in Table 1. The mean, maximum and minimum concentrations of the various nutrients for both Bemersyde Moss and Whitrig Bog are given in Table 2.

Phosphate-Phosphorus (PO_4-P)

Figure 2.1 shows the changes in phosphorus concentration in the water flowing into the wetland through the drains and out via the outflow. Also indicated is the duration of the presence of the black-headed gull breeding colony. Phosphorus remained at low concentrations throughout the winter and early spring. Peaks occurred in the open water sites (drain, dock and out) in April, early June and again in mid-July where concentrations stayed high until early December. They then decreased to previous winter levels. It should be noted that the drain site has reduced levels compared to the other open water sites, and that all of these have phosphorus-levels above the recommended levels set by environmental standards (Jarvie *et al.*, 1998).

Ammonium Nitrogen (NH_4-N)

It can be seen in Figure 2.2 that ammonium has a single peak in mid-June, then rose again

TABLE 1: Site descriptions.

Drain Sites	Source	pH	Conductivity (µS/cm)	temp (°C)	DO mg/l	Description
Drains 1-3	ploughed field	6.7-8.1	250-770			*Notes:* field planted with winter wheat 1996-7; sampled source only as impossible to find outlet into the wetland
Drain 4	pastures, arable land and forestry	6/6-7.6	300-1200			*Notes:* main inflow into the site from the west, sampled source and outlet into wetland
Drain 5-8	pasture	6.5-7.8	280-1670			*Notes:* sampled source and outlet into wetland
Road drains 1-3	ploughed field, road	6.5-7.8	410-2460			*Notes:* drains running under the road, which may be subject to road run-off in heavy rain
Outflow drain	wetland	6.6-7.9	280-570			*Notes:* outflow from Bemersyde
Open Water Sites						
Drain	pasture	6.7-8.1	300-720	2.6-20.8	1.21-10.67	*location:* at the west end of wetland, an open site with a large field drain (drain 6) running into it *sediment:* densely packed fine mud mixed with sand and grit *notes:* few macrophytes than the other sites, used by cattle and sheep for drinking; particularly heavily used in August/September/October when the cattle forage amongst the vegetation
Dock	no obvious inflow	6.9-7.8	300-610	1.8-21.1	1.68-10.87	*location:* in the middle of the southern edge of the wetland, a wooden jetty extending approximately 4 m into the mire *sediment:* large plant matter, including decaying leaves mixed with fine particulate mud *notes:* neighbouring vegetation includes a band of mixed woodland, bulrush (*Typha latifolia*), canary reed grass (*Phalaris arundiacea*) and sedges (*Carex sp.*); samples taken in the open water; the surrounding area is well vegatated
Out	Bemersyde	6.9-7.9	300-540	3.0-18.1	0.83-11.02	*location:* at east end of the wetland cut off from main body of water by reeds and bogbean (*Menyanthes trifoliata*), adjacent to outflow drain *sediment:* Very fine mud with some larger plant matter *notes:* north side includes corridor of pasture with arable field above it, west side conifer plantation, south side mixed woodland
Whitrig		7.2-8.6	210-480	1.8-16.8	2.82-12.26	*location:* 1 mile east of Bemersyde *sediment:* fine mud and sand *notes:* surrounded by permanent pasture grazed by cattle and sheep

TABLE 2
Mean, maximum and minimum concentrations of nutrients at Bemersyde and Whitrig.

Nutrient	Site	Mean	Minimum	Maximum
PO_4-P	Bemersyde	7.610	1.288	16.909
	Whitrig	0.098	0.000	0.340
NH_4-N	Bemersyde	7.617	0.322	30.483
	Whitrig	0.304	0.000	0.913
NO_3-N	Bemersyde	4.208	0.080	35.398
	Whitrig	0.460	0.004	3.162

in early August in the three open water sites and outflow drain. The levels gradually decreased in all open water sites except the drain site, maintaining low levels from October onwards. In contrast, the drain site showed a gradual decrease until early October, rising until mid-November and dropping in early December.

Nitrate Nitrogen (NO_3-N)
In contrast to the phosphorus and ammonium, nitrate was found mainly in the input drains at source and at the water's edge (Figure 2.3). Increased levels occurred in May-June and again in mid-November through to early January. However, in the second period the drain site also had an extremely high level of nitrate, which was not replicated in any other open water site.

Nitrite Nitrogen (NO_2-N)
Nitrite levels were low at Bemersyde and added little to the nitrogen budget of the site.

Cross water samples
The cross water samples showed the concentrations of the phosphorus, ammonium and nitrate were similar throughout the area surveyed and consistent with the samples taken from the open water sites (Figure 3). All results were significantly different ($p<0.001$): phosphorus and ammonium were higher in August, while nitrate had increased levels in March.

Nutrient levels recorded in 1994-96
The wetland was sampled for free and saline ammonium, nitric nitrogen and PO_4-P soluble phosphate in 1994-96 by SEPA, Melrose, Scotland (Table 3). When the results from this study were compared with similar measurements taken by SEPA for SWT in 1994-96, they showed similar trends, although magnitudes differed. The latter may reflect true values, or be attributable to differences in sampling methods and analytical procedures employed.

Discussion

Bemersyde is a unique habitat that has altered considerably over the last 300 years. Although anthropogenic factors were responsible for the initial changes, the subsequent use by wildlife has had a major effect. The black-headed gulls are of particular interest mainly due to their enormous increase in numbers since 1967: 1500 pairs, (Meikle, 1967) to 9050 in 1984, 14,320 in 1991 and 15,000 pairs in the summer of 1999 (Murray, Recorder, British Trust for Ornithology, Borders Region, *pers. comm.*).

Nutrient Inputs
Examination of the main nutrient inputs shows that phosphorus and ammonium levels are much higher in the open water sites, with very little nitrogen and phosphorus input via the

TABLE 3
Results from water analysis 1994-96 carried out by SEPA, Borders Region*.

Date	pH	PO_4P (mg/l)	NH_4 (mg/l)	NO_3-N (mg/l)
20/3/94	7.4	0.33	0.16	2.00
21/6/94	7.4	4.67	25.70	0.31
19/9/94	7.25	1.02	0.26	0.5
31/1/95	7.3	0.43	0.39	2.45
22/3/95	7.4	0.64	0.30	2.20
19/6/95	7.25	4.15	11.30	0.40
25/9/95	7.5	0.22	0.49	0.35
4/2/96	7.0	1.31	2.90	1.55

* Results courtesy of L. Gaskell, Chairman of Bemersyde Management Committee, SWT.

drains. Since the high phosphorus levels occurred during the prime gull breeding period, it can be inferred that the gulls are the cause. This is in agreement with other studies on bird related phosphorus inputs to lakes and rivers (Downing & McCauley, 1992; Manny *et al.*, 1994; Marion, *et al.*, 1994).

Gould and Fletcher (1978) recorded amounts and main components of black-headed gull faeces under captive conditions and found that gulls on average produced 38 mg total (30 mg of soluble) phosphorus per 24 hour period. Studies comparing free living with captive gulls of other species suggested that captive studies may underestimate the actual amount of faeces produced by a free-living bird by as much as 50% (Portnoy 1990), hence the total amount could be twice that given above. Even though the gulls did not spend all of their time on or above the water, over 14,000 pairs of gulls along with their offspring would have a considerable effect on phosphorus loading of the wetland.

Phosphorus lodged in sediments is another potential source of contamination (Mayer *et al.*, 1999). Although living plant material has a negligible effect on phosphorus levels, fallen dead material can make a major contribution (Granéli & Solander, 1988). Furthermore the amount released may vary with season (Mason & Bryant, 1975; Morris & Lajtha, 1986) and the disturbance to substrate caused by waterfowl and livestock using the wetland. It is notable that the drain site, although an open water site, showed lower concentrations of P than the other two open water sites or the outflow drain. The substrate here had a higher proportion of sand which would remain more oxidised, hence less release of P would occur. Moore *et al.*, (1998) measured phosphorus flux from various sediment types and suggested that the flux was lower from sandy sediments than the other zones tested. Preliminary work is being carried out on the amount of phosphorus in the substrate, and early indications are that the sediment is acting as a net sink for phosphorus.

The peaks in ammonium may be attributed to several factors. Since there is very little ammonium in the drain samples, the main sources must be gull dung (in the form of uric acid broken down by biological processes), urine and faeces from the livestock and/or released from pore water into the sediments (Mayer *et al.*, 1999). An additional factor is that the first major peak in ammonium occurred after a period of unusually heavy rainfall (150.5 mm recorded for month of June 1997 compared to an average of 57.59 mm for the previous 18 years, Scottish Agricultural College Veterinary Station (SAC), St. Boswells, Roxburghshire). This would facilitate the direct run-off of dung and urine from the surrounding pastures. Cooke and Prepas (1998) reported higher amounts of ammonium in run-off from agriculture with cow-calf units. This is particularly evident at the drain site, which shows an extra peak in mid-October to mid-November. It is believed that this peak is entirely due to the activity of cattle at this site in the late autumn. The site showed evidence

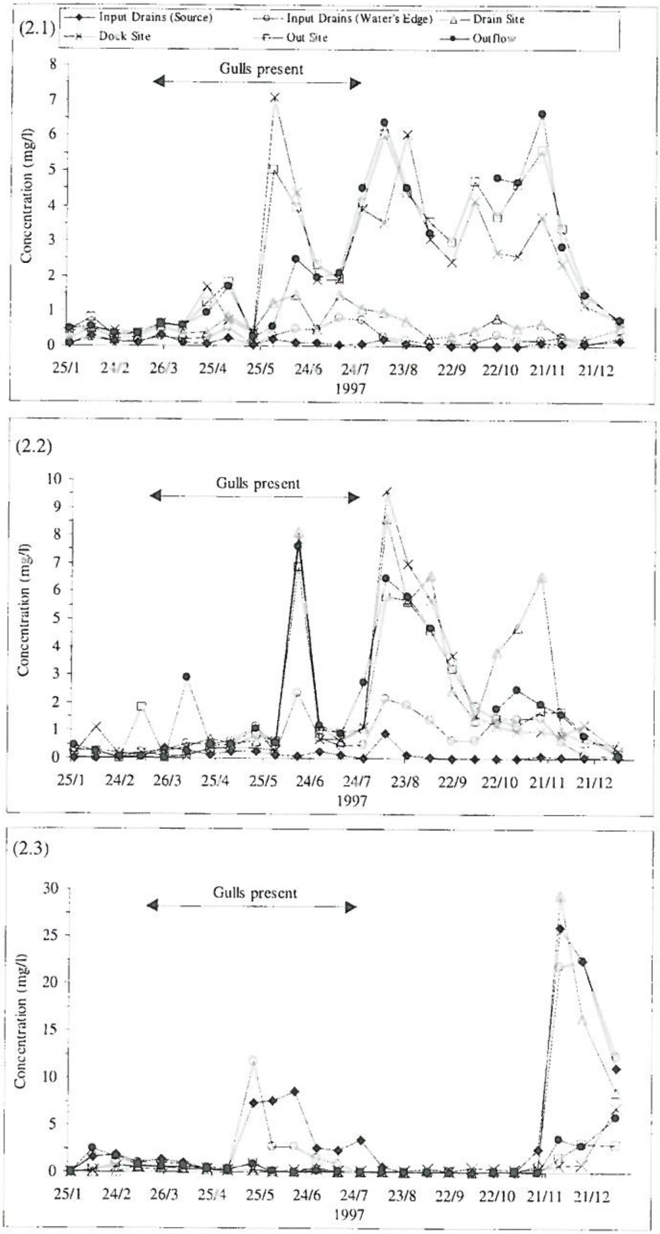

FIGURE 2
Phosphate phosphorus (2.1), ammonium nitrogen (2.2) and nitrate nitrogen (2.3) concentrations January 1997 to January 1998.

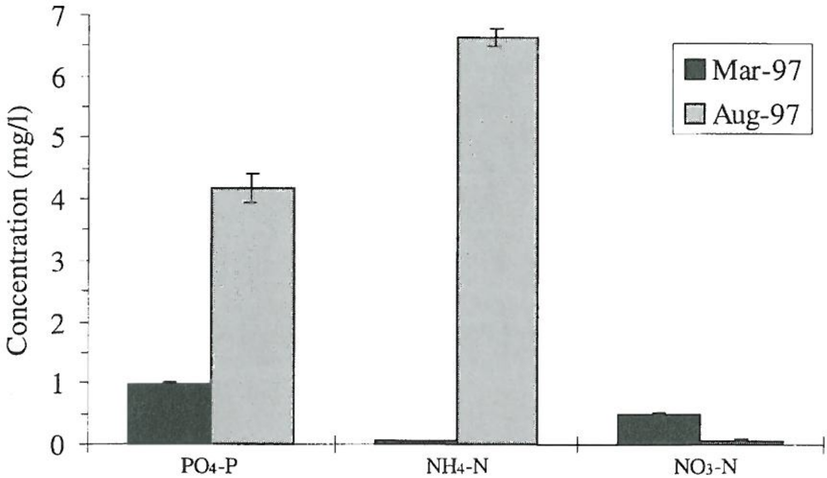

FIGURE 3
Cross water sample concentrations of PO_4-P, NH_4-N, NO_3-N.

of cattle wading into the area, presumably to drink but also to graze on the *Juncus* spp. that surrounds the site. Cattle frequently defecate and urinate while grazing, thereby contributing to the overall concentration of ammonium. A final factor relevant to the high concentrations in the summer and early autumn is the reduced availability of dissolved oxygen which would limit the process of nitrification.

In contrast, both combined oxidised inorganic N levels are higher in the input drains, suggesting that these compounds are entering the wetland via the drains in the adjoining fields and production on site. The peak in nitrate in the field drains in mid-May relate to local seasonal applications of nitrogen (with appropriate time lag) in the form of fertiliser to arable crops and in November from leaching due to ploughing and possible pre-ploughing slurry applications. Nitrate is highly mobile and thus has a tendency to leach from disturbed soil (Marston, 1989; Cooke & Prepas, 1998). The autumn peaks might also reflect the renewed flow of water from the drains bringing with it a flush of nitrate along with the bacterial oxidation of ammonium to nitrate and nitrite.

The ratio of N : P was calculated for all samples. The ratio of N : P was less than 16 : 1 in all samples taken at the open water sites. Hence nitrogen may be a limiting factor (Vollenweider, 1968).

Conclusions

This preliminary study shows that the birds and agricultural practices are having an effect on Bemersyde Moss. However, the information derived so far leaves many questions unanswered. Further work is being undertaken on the amount of phosphorus in the sediments, potential disturbance to the sediment/water interface, the role of the vegetation in buffering the nutrient input and most importantly the management of the site for the gulls. They are a valuable asset and one that makes this site unique.

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BOTANICAL REPORT FOR 1999
FLOWERING PLANTS AND FERNS

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The recorders thank all those who have sent records: Nomenclature is according to Kent, D. H. (1992) *List of Vascular Plants of the British Isles* and Stace, C. A. (1991) *Flora of the British Isles.*

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EAST YORKSHIRE (VC61) (P. J. Cook)

Equisetum x *litorale* Hoddy Cows, Buckton TA17; YNU Excursion.
Polypodium interjectum On mortar, central Withersea TA32; P.J.C. conf. R.H.R.
Chenopodium polyspermum On waste ground, Withernsea TA32; P.J.C.
Malva neglecta On farmyard waste, Easington TA41; P.J.C.
Juncus ambiguns Near Humber at Easington, on sand with *Glaux maritima* TA31, P.J.C.
Elytrigia x *oliveri* West Hull dockland TA02; B.B.G. Excursion 1998, conf. T.A.C., Spurn TA41; B.B.G Excursion 1999 conf. T.A.C.