Biodiversity Benefits of Coal Mine Water Remediation Schemes for Bird Life

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Abstract

Lagoons and reedbeds are established components of mine water treatment systems for iron-rich coal mine drainage. This study coupled modified British Trust for Ornithology (BTO) Breeding Bird Survey monitoring with habitat survey to assess the presence and usage of two UK coal mine water treatment systems by bird species. Over thirty species were documented at the two sites including four red listed, eight amber listed and eighteen green listed species (under the BTO Birds of Conservation Concern designation). There were statistically significant associations of bird group with specific habitat types suggesting that a mosaic of habitats at coal mine treatment systems benefits bird diversity and that these sites may have conservation potential at the landscape level.

Keywords: Mine Water, Remediation, Bird Survey, Ecology, Constructed Wetlands

Introduction

The legacy of coal mine water pollution in the United Kingdom has led to an extensive management programme run by the UK Government's Coal Authority addressing predominantly iron (Fe)-rich coal mine waters (Johnston *et al*. 2008). This programme consists of over 80 schemes which protect ≈350 km of streams from mine drainage (Coal Authority, 2021). A large proportion of these treatment systems incorporate lagoons and aerobic reedbeds to aid settlement of Fe as the chief pollutant of concern. These systems are engineered to maximise Fe removal within the available land area (e.g., Sapsford and Watson, 2011). However, the creation of a mosaic of open water, marginal and reedbed habitats associated with the treatment may provide benefits for local biodiversity.

Reedbed habitats have seen severe global declines in the last 150 years (Mitsch and Gosselink, 2015) and are considered a priority habitat type in the UK under biodiversity action plans and in the European Union. There is extensive literature on the importance of such habitats for bird life, notably declining passerine (perching bird) species such as Bearded Tit (*Panurus biarmicus*) as well as the Eurasian Bittern (*Botaurus stellaris*) for which considerable conservation efforts have been developed in the EU in recent decades (RSPB, 2013). Indeed, there have been major efforts in modern extractive industries to incorporate reedbed habitats as part of site restoration (Jarvis and Walton, 2010).

Across the treatment schemes within the current portfolio, the Coal Authority manage over 35 hectares of reedbed across the UK coalfields. The potential biodiversity benefits of these mine treatment wetlands have, however, received relatively little attention. Batty *et al*. (2005) demonstrated that although macroinvertebrate diversity and abundance was lower in coal mine water treatment systems than natural wetlands, the communities present were sufficient to potentially support higher organisms. More recent research which looked at a variety of constructed wetlands, including some used for mine water treatment, suggested that artificial reedbeds are just as diverse as natural systems for a number of different taxa, however, such as small mammals, moths and stem-dwelling invertebrates (Athorn, 2017)

This preliminary study aimed to undertake a baseline survey of bird species and their associated habitat usage at two coal mine water treatment systems in South Yorkshire, UK.

Methods

The study sites at Woolley and Strafford (South Yorkshire, UK) both treat circumneutral pH, ferruginous pumped coal mine water from Carboniferous Coal Measures strata. Treatment systems at both sites comprise aeration cascades, lagoons, and polishing reedbed cells. Reedbed cells are dominated by common reed (*Phragmites australis*) with marginal vegetation consisting of sedges and rushes with additional planting along the banks in some areas. These are typical in configuration of treatment systems adopted in the UK for coal mine water (and ironstone mine water) remediation (Coal Authority, 2021).

Habitat surveys at each site were undertaken during initial site visits using the Joint Nature Conservation Committee Phase 1 Survey procedure (JNCC, 2010). Bird surveys were undertaken using a modified British Trust for Ornithology (BTO) Breeding Bird Survey (BTO, 2021a), which is a long-established technique for the monitoring of bird populations during the UK breeding season (April-June). Early morning surveys in late Spring and early Summer were undertaken at each site following a timed (two and a half hour) transect route around each site, with stops at key vantage points. Repeat surveys were undertaken eight times at Strafford and six times at Woolley during 2019.

Birds were identified based on visual observation and vocalisations with abundance counted in each habitat unit present at the sites. Species present were compared to established lists of conservation concern (BTO, 2021b; IUCN, 2021) to consider the relative conservation importance of birds observed. Overall bird density (bird abundance per hectare) was compared across the sites using a T-test to test the null hypothesis that there was no significant difference in average bird density between the sites. A Chi-Squared test was undertaken to test if there was a significant association between bird group and Phase 1 habitat type.

Results and Discussion

Bird species and abundance

Over three hundred and fifty birds across thirty species were documented at the two sites during the surveys. These include a number of birds of conservation concern under the British Trust for Ornithology (BTO) Birds of Conservation Concern designation (BoCC4) including four red listed species, eight amber listed and eighteen green listed species (Tab. 1).

There were also 16 species rated on the amber or red list of the International Union for the Conservation of Nature (IUCN, 2021). Of particular note were the reedbed specialist species such as Reed Bunting (*Emberiza schoeniclus*), Sedge and Reed Warblers (*Acrocephalus schoenonaenus* and *Acrocephalus scirpaceus* respectively) and species that are considered indicators of healthy aquatic environments such as the Grey Heron (*Ardea cinerea*) and Kingfisher (*Alcedo atthis*: Furness and Greenwood, 2013). Two red list species more commonly associated with agricultural habitats, Linnet (*Linaria cannabina*) and Yellowhammer (*Emberiza citrinella*), were observed around the margins of the Woolley site (Tab. 1).

There was no significant difference in average bird density at the two sites (T-test: t: 0.66; degrees of freedom: 12; $P>0.05$) despite the slight differences in species encountered at the two sites (Tab. 1; Fig. 1). Woolley had a mean bird density of 7.8 birds/ha (standard deviation: 1.99) with Strafford showing on average 9.1 birds/ha (standard deviation: 1.97). It is worth noting that these densities are of a similar range to published densities for bird populations from natural or modified wetland systems. For example, Báldi and Kisbenedek (1999) observed bird densities of 10.2-11.4 birds/ha across both margins and the interior of mature reedbed in central Hungary, while Paracuellos (2006) reports densities ranging from 0.9 to 25.9 birds/ha in fragmented reedbed in the Netherlands.

Bird species habitat preference

As would be anticipated given the range of species observed, there were strong and significant associations between bird species and Phase 1 habitat (Chi-squared: 386; degrees

Table 1 *Examples of bird species of conservation importance observed at the Woolley and Strafford coal mine water treatment systems and their UK and international conservation status. Only bird species of amber or red status on either scheme included. Sites: S: Strafford; W: Woolley.*

Common name	Scientific name	Site	BTO BoCC4 rating	IUCN rating
Buzzard	*Buteo buteo*	W	Green	Amber (least concern)
Carrion Crow	*Corvus corone*	W	Green	Amber (least concern)
Grey Heron	*Ardea cinerea*	SW	Green	Red (least concern)
Grey Wagtail	*Motacilla cinerea*	W	Red	Unknown
House Martin	*Delichon urbicum*	SW	Amber	Red (least concern)
Kestrel	*Falco tinnunculus*	W	Amber	Red (least concern)
Kingfisher	*Alcedo atthis*	W	Amber	Unknown
Linnet	*Linaria cannabina*	W	Red	Red (least concern)
Long-tailed Tit	*Aegithalos caudatus*	W	Green	Amber (least concern)
Moorhen	*Gallinula chloropus*	SW	Green	Amber (least concern)
Reed Bunting	*Emberiza schoeniclus*	SW	Amber	Red (least concern)
Reed Warbler	*Acrocephalus scirpaceus*	SW	Green	Amber (least concern)
Sedge Warbler	*Acrocephalus schoenobaenus*	W	Green	Amber (least concern)
House Sparrow	*Passer domesticus*	SW	Red	Red (least concern)
Swallow	*Hirundo rustica*	SW	Green	Red (least concern)
Swift	*Apus apus*	SW	Amber	Amber (least concern)
Willow Warbler	*Phylloscopus trochilus*	SW	Amber	Red (least concern)
Yellowhammer	*Emberiza citrinella*	W	Red	Red (least concern)

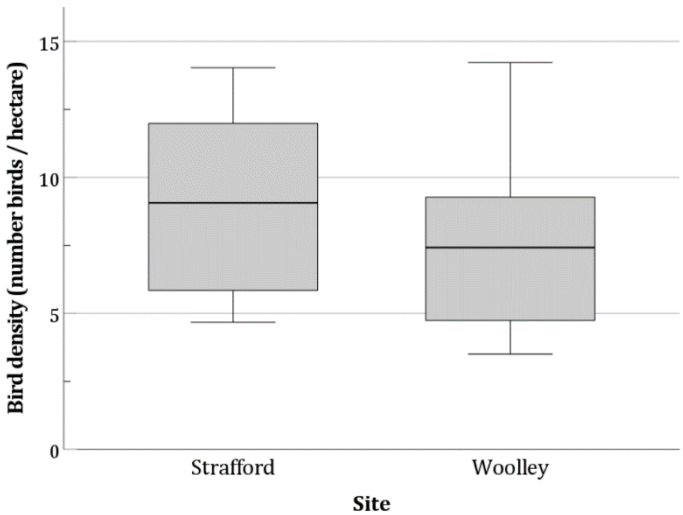

Figure 1 *Bird density (number of birds per hectare) observed at the two study sites. Data show mean, interquartile range and range (n: 8 for Strafford; n: 6 for Woolley)*

of freedom: 21; P<0.001; Tab. 2). Reedbeds were favoured by passerine (perching bird) species including the amber listed Reed Bunting (*Emberiza schoeniclus*) and green listed Sedge and Reed Warblers (*Acrocephalus schoenonaenus* and *Acrocephalus scirpaceus* respectively). Swifts (*Apus apus*) were also commonly found feeding above reedbed areas.

Open water areas of lagoons and margins of wetlands were beneficial for waterfowl, herons and kingfisher, while marginal grassland and scrub habitat was used by a range of passerines including the red-listed Yellowhammer (*Emberiza citrinella*) and Linnet (*Linaria cannabina*). Field observations showed kingfishers actively preying on small fish in open water areas of wetland cells at the Woolley site, which offers a useful indication of a healthy aquatic ecosystem at distal parts of the treatment system.

Management implications

The data highlight the potential importance of coal mine water treatment sites for bird life, including some species of conservation concern. The presence of species associated with open water and reedbed habitat (e.g., Sedge and Reed Warbler: *Acrocephalus schoenonaenus* and *Acrocephalus scirpaceus*) during the breeding season is encouraging given many mine treatment systems in the UK are located in valleys that would have historically contained floodplain wetlands prior to agricultural and industrial modification (Davidson, 2014).

Habitat variability within and around the margins of treatment systems appears key in driving a greater diversity of species (Tab. 2). Such patterns are widely documented in other settings around heavily modified wetland systems, where greater habitat heterogeneity and complexity can positively influence the diversity of prey species for birds (e.g., Day *et al.*, 2017). This is an area that is being actively considered in coal mine water treatment system design for future schemes where land availability allows.

The design and engineering of coal mine water remediation schemes will continue to be driven by water quality targets (e.g., Sapsford and Watson, 2011) and maintenance requirements, but there is scope for complementary management interventions that enhance bird diversity. For example, reedbed designs now include areas of open water at both cell inlets and outlets to help control the spread of the reeds and to improve access to the wetland cells when reed cutting is required.

Furthermore, trials by the Coal Authority are underway at sites where reedbeds are now being refurbished, to help improve the recovery of the reedbeds through transplantation of plants (and associated sediments and potential invertebrate populations) from acclimatised populations and established seedlings. This should allow the reeds to establish more quickly, which will likely assist iron removal, but also help re-establish the wetland habitat more rapidly. From a habitat

Table 2 *Aggregate number of observations across both sites of species presence (grouped by bird class) in different habitats across the coal mine water treatment systems.*

Bird class	Open water	Reedbed	Grassland / scrub	Woodland
Anatidae (water birds)	87	3	1	0
Galliformes (landfowl)	0	0	1	0
Ciconiformes (herons)	1	3	0	0
Accipitriformes (diurnal birds of prey)	0	1	0	1
Columbiformes (pigeons and doves)	0	2	4	4
Apodiformes (swifts)	0	20	0	0
Passeriformes (perching birds)	0	140	7	32
Coraciiformes (kingfishers)	2	1	0	0

management perspective, this is particularly important for older treatment systems where the reedbeds may be supporting isolated bird communities reliant on the treatment system. It is worth noting that at treatment sites where multiple reedbeds are present, maintenance activities are often staggered to minimise any impact on treatment capacity; this has the added benefit of ensuring that local reedbed habitat is retained.

Routine reed cutting is an essential maintenance activity at coal mine water treatment systems. In natural wetlands, this assists in maintaining the reedbed by slowing the build up of organic debris in the treatment cells (Valkama *et al*., 2008). In mine water reedbeds a build up of organic detritus can reduce treatment performance by causing the water to short circuit, thereby reducing residence times and consequently iron removal rates. Another advantage of reed cutting, however, is that it can also help maximise the extent of reedbed edges, which in other studies have been shown to be preferred by numerous species (e.g., Reed Warbler: *Acrocephalus scirpaceus*) above reedbed interior habitats (Baldi and Kisbenedek, 1999).

Many of the species observed at the sites are not typically associated with aquatic or wetland habitats. Site margins (open grassland, grass banks, hedgerows and woodland) were particularly important for a range of predominantly passerine species which included some of conservation concern (Tab. 1). Maximising site margins for potential bird food resources and breeding sites through a reduced mowing regime (i.e., once per year) and the planting of a diverse mix of native herbaceous and flowering plants to encourage insect prey could be of benefit in these areas of treatment systems. Interestingly, Yellowhammers and Linnets, both Red listed by BTO, (2021b) are farmland birds, suggesting that the careful management of industrial sites across a broader area may have potential for the conservation of these species.

Conclusions

The baseline survey of birds undertaken at two coal mine water treatment systems in the UK shows the presence of a range of bird species of conservation interest during the breeding season. Both sites showed similar bird species density with strong associations apparent between bird type and their habitat usage. Efforts to ensure greater habitat variability within coal mine water treatment systems are likely to benefit bird diversity.

Assessment of bird communities at other mine water treatment systems would help add to this preliminary study as would usage over the entire year to determine if such sites are also used by winter visitors as well as summer breeding species. Comparisons with natural systems would also be useful in assessing the relative contribution of mine water treatment systems to changes in bird biodiversity. Such information could not only assist in helping formulate habitat management plans at established treatment systems, but potentially assist in integrating mine water treatment with landscape scale conservation measures during planning phases.

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