Ecological survey of ponds at Frost's Common, Great Hockham, Norfolk

A report for Freshwater Habitats Trust

Martin Hammond Ecology

martinhammondecology@gmail.com

1. Introduction

Frost's Common / Fox Covert is an area of mixed plantation owned by the Forestry Commission near Great Hockham, Norfolk. It forms part of the Breckland Forest Site of Special Scientific Interest (SSSI). The Common is notable for its cluster of natural ponds formed by freezing and thawing of upwelling groundwater during the late glacial. Variously referred to as pingos, palsa-scars or lithopalsas, such ponds are a characteristic feature of Breckland. Where water and habitat quality are favourable, pingos can support exceptionally important assemblages of wetland invertebrates, often including rare and highly sedentary 'relict fen' species.

Frost's Common contains over 30 pingos large enough to appear on Ordnance Survey maps plus other smaller, seasonal pools. For this reason, it has been identified as a Flagship Pond site by the Freshwater Habitats Trust. This survey was commissioned by the Trust to provide information on the ecological interest of selected ponds and to guide future management.

Early Ordnance Survey maps show that the central area of Fox Covert was wooded by the late 19th century but fringed by open habitats, presumably including grazed fen and heath (Figure 1). The area of Poors Allotment to the north-west was cut for peat while Furze Allotment to the north-east was a source of gorse for fuel.

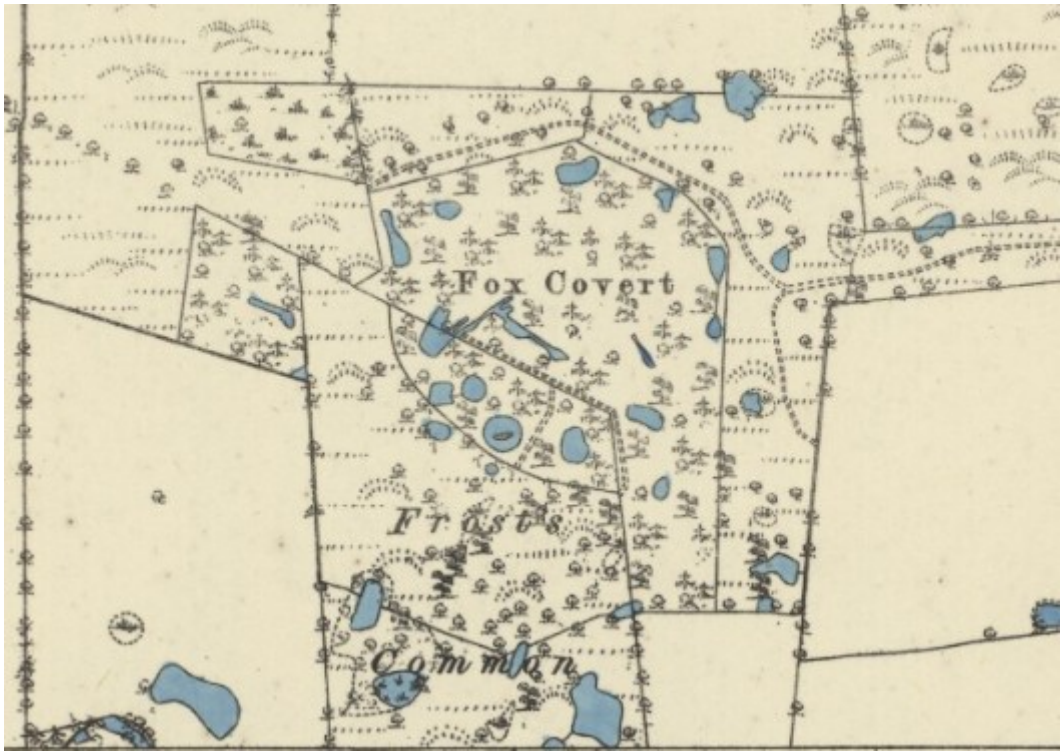

Figure 1: Ordnance Survey 6" map, 1885

2. Survey methods

Frost's Common was visited on 23rd to 26th April 2018, when aquatic invertebrates were recorded from 11 ponds (Ponds A-K). In each instance, the pond was trawled using a long-handled net and the catch sorted in a white plastic tray until no further taxa could be recognised. On 14th to 17th May 2018, four ponds (A, C, F and L) were re-visited and surveyed using PSYM, the standard methodology for monitoring the ecological quality of ponds and small lakes (Environment Agency, 2002).

PSYM (**P**redictive **Sy**stem for **M**ultimetrics) uses six 'metrics' (measurements) representing important indicators of ecological quality. The botanical survey involves a careful examination of each pond to record wetland plants listed on the PSYM pro-forma. The three botanical metrics are:

- diversity of emergent and submerged plant species
- the number of uncommon wetland plant species
- Trophic Ranking Score (TRS, an indication of nutrient status based on selected plant species)

The three invertebrate metrics are based on a timed sample obtained by netting each of the 'meso-habitats' (e.g. grass mats, floating vegetation, open water) present in the pond. Although PSYM requires identification of aquatic macro-invertebrates to family level only, during this survey most material was identified to species level to add value to the data. Because pingos are known to support important populations of rare species, samples were sorted in a white polythene tray on the bankside, to avoid removing large numbers of individuals (normally PSYM samples are preserved in bulk and sorted in the laboratory). Material was either identified in the field or preserved for identification at a later date. The three invertebrate metrics are:

- Average Score Per Taxon (ASPT, an estimation of biological water quality based on the sensitivity of different invertebrate families to organic enrichment)
- diversity of dragonfly, damselfly and alderfly families[1]
- diversity of water beetle families

Environmental data obtained for each pond include surface area, altitude, grid reference, water pH, presence/absence of inflows, substrate composition, degree of shade, accessibility to livestock and cover of emergent vegetation.

The results are analysed using software which compares them with values predicted from a large reference dataset of undegraded ponds. PSYM predicts how a high quality pond with similar attributes *should* score for each metric, and compares the predictions with the survey results. The scores for each metric are combined to produce an Index of Biotic

[1] No alderflies (Sialidae) were collected during the survey, so this metric is referred to simply as diversity of damselfly and dragonfly families or diversity of Odonata families.

Integrity (IBI) which provides an overall indication of the ecological quality of the pond. This can be categorised as Very Poor, Poor, Medium and Good. Good quality ponds are those which have an Index of over 75%.

PSYM data and outputs are provided in Appendix 1. Plant and invertebrate records have been provided separately in spreadsheet format.

3. The ponds surveyed

Pond A

TL 94750 93372

This pond is close to the car park on Ride 83, off the A1075 (cover photo). It is fringed by broadleaved woodland but trees have been removed around its southern margin since 2008[2]. There are Tufted Sedge *Carex elata* tussocks, grass mats and a modest amount of floating duckweed vegetation. Small pockets of silt, litter and low marginal vegetation around the southern edge of the pond accounted for some of the more notable invertebrate records. A few Smooth Newts were netted on both visits and Great Crested Newt eggs were found. A water sample collected on 23rd April 2018 produced a pH reading of 7.10 with electrical conductivity of 410 µS/cm-¹. A second sample, collected on 14th May, gave a pH reading of 7.53 with conductivity of 880 µS/cm-¹.

Sixty-four aquatic macro-invertebrate taxa were recorded from Pond A over the two visits, with 45 in the PSYM sample. Species of conservation concern included Variable Damselfly; the great diving beetle *Dytiscus dimidiatus*; the small diving beetle *Clemnius decoratus*; the scavenger water beetles *Hydrochus brevis*, *H. crenatus* and *Helochares punctatus*; the moss beetle *Limnebius aluta*; the marsh beetle *Contacyphon pubescens*; and the caddisfly *Trichostegia minor*. Caddis larvae of the genus *Limnephilus* were exceptionally abundant in shallow water in late April.

Thirteen wetland plants were recorded, including Tufted Sedge, Water Violet *Hottonia palustris* and Orange Foxtail *Alopecurus aequalis*.

PSYM analysis produced an Index of Biotic Integrity of 89%, placing Pond A in the top (**Good**) category for ecological quality. It scored highly for diversity of emergent and submerged plants, representation of uncommon wetland plants, biological water quality (ASPT) and diversity of water beetle families. Scores for trophic status (TRS) and diversity of Odonata families were moderate.

The faunal quality of this pond has improved considerably since it was surveyed by Geoff Nobes in 2008. He described it as heavily shaded and in need of opening-up, recording only

[2] C.f. 2008 photograph in Nobes (2008); this water body was Pond 11 in Geoff Nobes' survey.

18 water beetle species “in very small numbers” (Nobes, 2008). Thirty-seven water beetle species were recorded in 2018, just over the double the number recorded previously.

Pond B

TL 94700 93411

This shallow, seasonal pingo is located on the south side of the main track at Fox Covert. It is fringed by multi-stemmed birch and alder with a grass mat (mainly Rough Meadow-grass *Poa trivialis*) covering around 30% of the surface. A water sample collected on 23rd April 2018 produced a pH reading of 7.00 with electrical conductivity of 300 µS/cm.

Sixteen aquatic macro-invertebrate taxa were recorded on 23rd April, including the Nationally Scarce diving beetle *Hydaticus seminiger*.

Pond C

TL 947 935

This large permanent pond is situated to the north-west of the car park. It was much more extensive than shown on the OS base map, perhaps as a result of the merging of more than one basin due to high water levels in spring 2018. It has a broadly sinuous shape with a range of meso-habitats including open water, submerged macrophytes, grass mats, floating duckweed vegetation, tussocks and shaded areas with leaf litter. There are a number of connecting channels, though these are only seasonally wet. Nine-spined Sticklebacks are present in modest numbers.

A water sample collected on 25th April 2018 produced a pH reading of 8.06 with electrical conductivity of 1,660 µS/cm-^{1}. A second sample obtained on 16th May gave a pH reading of 7.95 with conductivity of 1,160 µS/cm. These results are high for both parameters, although there was no obvious evidence of pollution. Interestingly, Nobes (2008) also recorded high readings (pH 7.8, conductivity 850 µS/cm-^{1}) from this pond, suggesting that alkaline and solute-rich conditions are a constant characteristic.

A remarkable total of 74 aquatic macro-invertebrate taxa were recorded from this pond, with 43 in the PSYM sample. Species of conservation concern included Variable Damselfly; the burrowing water beetle *Noterus crassicornis*; the diving beetles *Clemnius decoratus* and *Laccornis oblongus*; the scavenger water beetle *Hydrochus crenatus*; and the small water beetle *Limnebius aluta*. Also of note were four soldierfly taxa and a single specimen of Caspian Whirligig *Gyrinus caspius*, a beetle normally associated with mildly brackish coastal ponds and drains.

Nobes (2008) recorded two additional species of conservation concern from this pond[3]: the Vulnerable diving beetle *Hydroporus glabriusculus* and the Near Threatened pygmy water-cricket *Microvelia buenoi*.

Thirty-two species of wetland plants included Tufted Sedge, Orange Foxtail, Water Violet and Fan-leaved Water-crowfoot *Ranunculus circinatus*.

PSYM analysis produced an Index of Biotic Integrity of 89%, placing Pond C in the top (**Good**) category for ecological quality. As with Pond A, this water body scored highly for diversity of emergent and submerged plants, representation of uncommon wetland plants, biological water quality (ASPT) and diversity of water beetle families. Scores for trophic status (TRS) and diversity of Odonata families were moderate.

[3] Pond C is Pond 13 in Nobes' report.

Pond D

TL 94722 93559

This was a shallow, seasonal depression on the line of a ditch extending north from Pond C. It is shaded by sallows and fringing trees and contains much leaf litter but also extensive grass mats. A water sample collected on 25th April 2018 produced a pH reading of 8.12 with electrical conductivity of 1,260 µS/cm.

Twenty-five aquatic macro-invertebrate taxa were collected on 25th April, with species of conservation concern including the diving beetles *Agabus uliginosus* and *Hydaticus seminiger* and the scavenger water beetle *Helophorus strigifrons*.

Pond E

TL 94748 93546

This is a small (ca 80 sq m), shallow, seasonal pond with grassy margins near the boundary with Furze Allotment. Its centre is dominated by water-starwort *Callitriche* sp. It is not connected to ditches. Single Smooth Newt and Common Frog adults were netted during invertebrate sampling. Sixteeen aquatic macro-invertebrate taxa were recorded including the Near Threatened diving beetle *Agabus uliginosus*.

Pond F

TL 94442 93408

This pear-shaped permanent pond is relatively unshaded, with a large proportion of open water. It adjoins plantation to the east and a ride to the west with a bank of Gorse and *Rhododendron* at its southern end. There is a connecting channel in the south-west corner. Marginal vegetation includes scattered tussocks of Tufted Sedge, more frequent Soft Rush *Juncus effusus* and grass mats. A water sample collected on 25th April 2018 produced a pH reading of 7.2 with electrical conductivity of 320 µS/cm.

Fifty aquatic macro-invertebrates were recorded from Pond F (34 in the PSYM sample). Species of conservation concern included Variable Damselfly; the scavenger water beetles *Hydrochus brevis*, *H. crenatus*, *H. elongatus* and *Enochrus nigritus*; and the small water beetle *Limnebius aluta*.

When this pond was surveyed by Nobes (2008), he also recorded the Near Threatened diving beetle *Laccornis oblongus* and mentioned the occurrence here of the Scarce Emerald damselfly *Lestes dryas*.

Twelve wetland plant species were recorded, including Tufted Sedge, Orange Foxtail and Water Violet.

PSYM analysis produced an Index of Biotic Integrity of 83%, placing Pond F in the top (**Good**) category for ecological quality. It scored highly for representation of uncommon wetland plants, biological water quality (ASPT) and diversity of water beetle families. Scores for diversity of emergent and submerged plants, trophic status (TRS) and diversity of Odonata families were moderate.

Pond G

TL 94515 93318

This is a large, permanent pingo with a very convoluted outline in the centre of Frost's Common. The banks are steep in places and access is limited by fallen timber and brambles. There are sparse tussocks of Tufted Sedge around the margins, rather more Soft Rush, grass mats and floating duckweed vegetation. A water sample collected on 25th April 2018 produced a pH reading of 6.74 with electrical conductivity of 310 µS/cm.

Thirty-eight aquatic macro-invertebrate taxa were recorded. Species of conservation concern included the scavenger water beetles *Hydrochus brevis*, *H. crenatus* and *Enochrus*

nigritus; and the small water beetle *Limnebius aluta*. Nobes (2008) reported the Near Threatened diving beetle *Laccornis oblongus* from this pond.

Pond H

TL 94729 93260

This roughly rectangular pond is located on the eastern edge of Frost's Common and is accessed from the path running south from the main ride. A stand of sallow and several birch trees grow within the basin, suggesting that it is only seasonally wet although small amounts of Water Violet indicate that it may contain pockets of semi-permanent water. There are extensive grass mats, scattered tufts of Soft Rush and patches of low emergents such as Common Marsh Bedstraw *Galium palustre*, Greater Yellow-cress *Rorippa amphibia* and Water Forget-me-not *Myosotis scorpioides*. Cover of floating duckweed vegetation was less extensive than on many of the Fox Covert/Frost's Common ponds in April 2018. Several Smooth Newts were netted.

A water sample collected on 26th April 2018 produced a pH reading of 5.84 with electrical conductivity of 400 µS/cm. Thirty-four aquatic macro-invertebrate taxa were recorded on this date with species of conservation concern including the small diving beetle *Hydroporus neglectus*; the scavenger water beetles *Hydrochus crenatus* and *Enochrus nigritus*; and the caddisfly *Trichostegia minor*.

Pond I

TL 94741 93118

This pond is close to the A1075 and at the eastern end of the ditch running W-E across the south of Frost's Common. It is largely unshaded, with permanent open water in the centre and marginal grass mats. Notably, small amounts of Fan-leaved Water-crowfoot occur in the shallow water. A few Smooth Newts were caught during sampling. A water sample collected on 26th April 2018 produced a pH reading of 7.46 with electrical conductivity of 1,020 µS/cm.

Thirty seven aquatic macro-invertebrate taxa were recorded, with species of conservation concern being the scavenger water beetles *Hydrochus crenatus*, *Enochrus nigritus* and *Helochares punctatus*.

This pond has improved significantly since it was surveyed by Geoff Nobes in 2008, who described it as "heavily shaded by tall trees and ...smothered with dead leaves and duckweed". He recorded only 13 species of water beetles and water bugs (28 in 2018) with the only species of conservation concern being *Hydroporus neglectus*.

Pond J

TL 94615 92970

This was a small, shallow, seasonal depression within a conifer plantation near the western edge of Frost's Common. There was a thick layer of organic material, mainly conifer needles. There were patches of Soft Rush, Flote-grass *Glyceria fluitans*, water-starwort and Common Marsh Bedstraw with very small amounts of Cyperus Sedge *Carex pseudocyperus* and Greater Yellow-cress. The very impoverished invertebrate fauna was dominated by mosquito larvae with a few common and highly mobile water beetles making up the majority of the eight taxa recorded. No species of conservation concern were encountered.

Pond K

TL 94630 92991

This was a larger seasonal pingo close to Pond I, possibly containing pockets of semi-permanent water. There has been more extensive tree clearance around this pond, which provides shallow, swampy habitat.

Twenty five aquatic macro-invertebrate taxa were recorded. Species of conservation concern included the small diving beetles *Hydroporus neglectus* and *Clemnius decoratus* and the scavenger water beetle *Hydrochus crenatus*.

Pond L

TL 94648 93432

A mid-sized, probably semi-permanent pond, surveyed on 17th May 2018. Tufted Sedge forms a tussocky margin with Water Violet in open water. Seventeen wetland plant species were recorded.

Forty-two aquatic macro-invertebrate taxa were recorded (38 in the PSYM sample). Species of conservation concern included the diving beetles *Hydaticus seminiger* and *Laccornis oblongus*; the scavenger water beetles *Hydrochus crenatus*, *Enochrus nigritus* and *Helochares punctatus*; and the small water beetle *Limnebius aluta*.

PSYM analysis produced an Index of Biotic Integrity of 83%, placing Pond L in the top (**Good**) category for ecological quality. It scored highly for diversity of emergent and submerged plants, representation of uncommon wetland plants, biological water quality (ASPT) and diversity of water beetle families. Diversity of Odonata families was moderate and the score for trophic status (TRS) was poor, i.e. it indicated significantly more eutrophic conditions than predicted for an undegraded pond with similar attributes.

4. Results

Water chemistry

Water pH readings ranged from 5.84 to 8.12, with a mean value of 7.21 and a median of 7.26 (n = 8)[4]. Electrical conductivity readings (a measure of solute content) ranged from 300 to 1,660 µS/cm-[1], with a mean of 708 and a median of 523 µS/cm-[1].

For seven ponds, it is possible to compare pH and conductivity readings obtained during this survey with those recorded by Geoff Nobes in May 2008 (Table 1). Taking into account natural fluctuation in these parameters and variation in meter readings, this suggests that there has no marked change in physico-chemical status in any of these ponds over the past ten years. The ponds which had high pH and conductivity in 2018 (C & I) also produced high readings in 2008.

Pond	pH 2018	pH 2008	conductivity 2018	conductivity 2008
A	7.32	6.9	645	314
B	7	7	300	292
C	8.01	7.8	1360	880
F	7.2	7	320	262
G	6.74	7.3	310	335
H	5.84	5.8	400	133
I	7.46	7.3	1020	937

Table 1: comparison of water pH and electrical conductivity readings recorded in 2008 and 2018

Nonetheless, it is noticeable that pH and conductivity are notably elevated in Ponds C & D[5], which are plumbed into a system of channels to the north of the main ride. Conductivity was also high in Pond H, which is at the eastern end of a ditch extending across the south of Frost's Common and also adjoins the A1075. More work is needed to better understand water chemistry in these ponds.

Aquatic invertebrates

One hundred and twenty seven aquatic macro-invertebrate taxa were recorded during this survey (Appendix 2).

Molluscs (Gastropoda and Bivalvia)

Eleven widespread aquatic mollusc taxa were recorded. Neither of the rarities sometimes associated with pingo systems (Pond Mud Snail *Omphiscola glabra* or Shining Ram's-horn *Segmentina nitida*) were located.

[4] A mean figure has been used where more than one reading was obtained per pond. It is acknowledged that this is a crude method since the pH scale is logarithmic.
[5] Pond D was not surveyed by Nobes (2008).

Damselflies and dragonflies (Odonata)

Ten species of Odonata were identified as larvae, including the Near Threatened Variable Damselfly *Coenagrion pulchellum* and the local Hairy Dragonfly *Brachytron pratense*. Nobes (2008) referred to the occurrence of Scarce Emerald damselfly *Lestes dryas* in Pond F but no *Lestes* larvae were found during this survey.

Water bugs (Hemiptera)

A modest fauna of 11 mostly common water bug species was recorded. Nobes (2008) recorded the Near Threatened pygmy water-cricket *Microvelia buenoi* from two ponds (including Pond C). Large numbers of wingless *M. reticulata* were found in Pond C in 2018 so it is quite possible that *M. buenoi* was overlooked.

Water beetles

The list of water beetles is impressive, with 70 species recorded in 2018. These include seven categorised as Near Threatened and six classified as Nationally Scarce. Fox Covert/Frost's Common supports several water beetles which are largely or entirely restricted to wetlands of natural, prehistoric origin in Britain. In 2018, these were *Laccornis oblongus*, *Hydrochus brevis* and *Limnebius aluta* but Nobes (2008) also found *Hydroporus glabriusculus* and *Hydraena palustris*. In 2018, *Hydraena palustris* was recorded just outside the Frost's Common boundary at Furze Allotment and it is very likely that both species are still present on the site, emphasising its importance for relict-fen invertebrates.

Species found mostly in ancient wetlands but with the ability to colonise secondary habitats within their restricted ranges include *Noterus crassicornis*, *Agabus uliginosus* and *Enochrus nigritus*.

Several water beetles found in 2018 were not recorded in 2008, which is unsurprising since populations of individual species fluctuate from year to year. The great diving beetle *Dytiscus dimidiatus* is likely to be a recent colonist since this large and distinctive species was first detected in Breckland only in 2001 (Foster & Friday, 2011).

The available data suggests that Fox Covert/Frost's Common lacks some of the rarities associated with extensive moss carpets in the very best pingo systems (e.g. the small diving beetles *Hydroporus elongatulus* and *H. scalesianus*) and also the rare *Dryops* species associated with grassy draw-down zones.

5. Species of conservation concern

Odonata (dragonflies and damselflies)

Variable Damselfly *Coenagrion pulchella* (Coenagrionidae)

GB status: Near Threatened

Coenagrion larvae with blunt caudal lamellae (compared to *C. puella*) were provisionally identified as Variable Damselfly from Ponds A, C & F. This is a well-known species of the Breckland pingos with other recent larval records from nearby Thompson Common and Stow Bedon Common. Variable Damselfly is a very local insect of high quality ponds and ditches in lowland fenland areas.

Coleoptera (beetles)

Noterus crassicornis, a burrowing water beetle (Noteridae)

GB status: Nationally Scarce

This small, flightless water beetle has a patchy and very local distribution in high quality, permanent drains and ponds in lowland fenland districts of England and Wales. A single specimen was collected from Pond C.

Agabus uliginosus, a diving beetle (Dytiscidae)

GB status: Near Threatened

A very local beetle of seasonal pools in unimproved grassland, fens and old woodland. *Agabus uliginosus* has one of its main population centres in the Brecks. It is classified as Near Threatened due to the vulnerability of its habitats and evidence of localised contractions in range (Foster, 2010). During this survey it was found in good numbers in Ponds D & E. Females were of the matt *dispar* form.

Hydaticus seminiger, a diving beetle (Dytiscidae)

GB status: Nationally Scarce

A fairly large diving beetle, often associated with shaded ponds containing leaf litter but also in rich fen vegetation. In the Breckland lithopalsas, *H. seminiger* is one of the few rarities typical of more wooded seasonal ponds, where it presumably preys on the abundant mosquito larvae. Recorded from Ponds B, D & L.

Laccornis oblongus, a diving beetle (Dytiscidae)

GB status: Near Threatened

The only one of the rare Hydroporinae detected during this survey, with single specimens collected from Pond C on 25th April and 16th May and two found at Pond L on 17th May. *Laccornis* is characteristic of mossy pools in relict fen, but occurs occasionally in dense marginal vegetation without moss. It is relatively frequent in the Breckland lithopalsas, with nearby records from Stow Bedon and Thompson Commons. Nobes (2008) found it in several other ponds in the vicinity of Frost's Common.

Hydroporus neglectus, a diving beetle (Dytiscidae)

GB status: Nationally Scarce

A tiny diving beetle typically found in leaf litter or moss in very shallow, seasonal pools and pond margins. It has a widespread but local and predominantly eastern distribution in England, and is not restricted to relict sites. During this survey, *H. neglectus* was recorded from Ponds H & K.

Clemnius decoratus, a diving beetle (Dytiscidae)

GB status: Nationally Scarce

Formerly known as *Hygrotus decoratus*, this small but attractively-marked dytiscid is very local in richly-vegetated pond margins. It can be frequent in less shaded pingos with records during this survey from Ponds A, C & K.

Helophorus strigifrons, a scavenger water beetle (Helophoridae)

GB status: Nationally Scarce

A widespread but very local beetle of seasonal pools in fens and floodplain swamps, *H. strigifrons* was collected from Pond D. It has not been recorded previously from Frost's Common.

Hydrochus brevis, a scavenger water beetle (Hydrochidae)

GB status: Near Threatened

Nearly always associated with ancient wetlands, *H. brevis* has a widely scattered but extremely local distribution in Britain. Specimens were collected from Ponds A, F & G. It occurs nearby at Oldhouse Yard Plantation, Stow Bedon Common and Thompson Common. Nobes (2008) found it in several other ponds in the vicinity of Frost's Common.

Hydrochus crenatus, a scavenger water beetle (Hydrochidae)

GB status: Near Threatened

This small *Hydrochus* is relatively frequent in Breckland but has a very restricted British distribution, confined to fenland areas in eastern England (Foster *et al*, in press). Although highly characteristic of pingo systems, *H. crenatus* flies and is not restricted to ancient wetlands. During this survey, specimens were collected from Ponds A, C, F, G, H, I, K & L. Its frequency (60% of ponds sampled) was very similar to Geoff Nobes's 2008 survey (57%).

Hydrochus elongatus, a scavenger water beetle (Hydrochidae)

GB status: Near Threatened

Although more widespread than *H*. *brevis* and *H. crenatus* nationally, *H. elongatus* is nonetheless a very local beetle of lowland fens. It is not confined to relict sites. Single specimens were collected from Pond F on each of the two visits. This species has not been found previously at Frost's Common.

Enochrus nigritus, a scavenger water beetle (Hydrophilidae)

GB status: Near Threatened

Like *Hydrochus crenatus* and *Limnebius aluta*, this is a relatively common beetle in the Breckland pingos, where it is often found in good numbers. However, it is very local elsewhere and generally restricted to relict habitats. *Enochrus nigritus* flies readily but presumably has weak powers of dispersal beyond a local level. It was collected from Ponds A, F, G, H, I & L. Its frequency was higher in 2018 than in 2008 (50% of ponds sampled compared to 17%), which might reflect its ability to colonise ponds where marginal vegetation structure has improved as a result of 'haloing'.

Helochares punctatus, a scavenger water beetle (Hydrophilidae)

GB status: Nationally Scarce

Found in Ponds A, I & L at Frost's Common, *H. punctatus* is frequent in pingos. It is a widespread but local beetle nationally which is widespread in Breckland pingo systems.

Limnebius aluta, a moss beetle (Hydraenidae)

GB status: Near Threatened

This tiny beetle, around a millimetre in length, is often numerous in the extreme margins of pingos but is another species which is very rare elsewhere. It can be found in pockets of silt and shallow litter in the fluctuating margins but not in heavy shade and not usually in the smaller pools. During this survey, *L. aluta* was found at Ponds A, C, F, G & L, often in good

numbers. Its frequency was rather lower in 2018 than in 2008 (44% of ponds sampled compared to 66%).

Contacyphon pubescens, a marsh beetle (Scirtidae)

Conservation status: Nationally Scarce

This beetle has aquatic larvae with the adults found amongst emergent vegetation. It is a lowland fen species with a thinly scattered distribution. An adult was collected from Pond A and confirmed by Professor G.N. Foster.

Trichoptera (caddisflies)

Trichostegia minor, a caddisfly (Phryganeidae)

Conservation status: Nationally Scarce

As a larva, this caddis makes its case from pieces of dead tree leaves and is associated with shaded, shallow water. It is localised and uncommon nationally but not infrequent in the Breckland pingo systems. Larvae were collected from Ponds A & L.

6. Implications for conservation management

6.1 Reducing tree shade

Geoff Nobes's 2008 survey provides a valuable baseline against which to compare the present study. In the case of Ponds A and I, we can say with confidence that 'haloing' of woodland pingos by removing overhanging trees around at least part of the pond margin has been positively beneficial for wetland invertebrates. In both of these ponds, the number of water beetle species recorded in spring using similar methods has more than doubled and no species of conservation have been lost. More analysis of the data is needed but there is no indication that haloing promotes invasion by highly mobile generalists at the expense of habitat specialists. It is likely that by promoting more abundant and varied emergent vegetation, haloing allows sedentary species already present to increase their populations and encourages colonisation of fen specialists capable of localised dispersal. With the possible exception of the caddisfly *Trichostegia minor*, Frost's Common does not support any invertebrates of conservation concern which are obligately dependent on shaded leaf-litter pools, and in any case there is never likely to be a shortage of such habitat. Water beetles which opportunistically exploit heavily shaded mosquito pools, such as the diving beetles *Hydaticus seminiger* and *Hydroporus neglectus*, will also inhabit rich fen habitat in unshaded or partially shaded conditions. Therefore further haloing, and periodic clearance of regenerating bankside tree/shrub growth should be encouraged.

6.2 Consider restoration of more natural hydrology

Relatively few species of conservation concern recorded during this survey (or previously) depend on permanent open water, the exceptions being Variable Damselfly and the burrowing water beetle *Noterus crassicornis*. Frost's Common does not appear to support the rich mollusc fauna found in larger and more permanent pingos on Thompson Common, so maintenance of high water levels throughout the year is not a priority on this site. Many more species of conservation concern are associated with very shallow water in the fluctuating margins of ponds and will tolerate periodic natural drying-out of pond basins.

In the past, considerable efforts have been made to inter-connect many of the ponds on Frost's Common via ditches or runnels, and some are plumbed into the surface water drainage system. This was possibly done to utilise the pingos as drainage sumps during the afforestation of the Common but there may also have been an intention to maintain or stabilise water levels, perhaps to improve their utility as fire-fighting reservoirs or with the perceived aim of improving their amenity, wildlife or sporting value.

Consideration should be given as to whether restoration of a more natural hydrological regime would be beneficial to the specialised flora and fauna of the pingo system. This would require a better understanding of local hydrology. On the one hand, interconnection of ponds may assist the dispersal of less mobile species and may buffer individual ponds

against the effects of droughts or reduction in groundwater levels (e.g. due to abstraction from the local aquifer). On the other hand, interconnection could assist in the spread of invasive species (e.g. *Crassula helmsii*, should it appear) or pathogens. It may facilitate spread of pollutants (including nutrients) entering the surface water drainage system, which might be significant if any of the ditches receive road run-off or leachate from surrounding agriculture. Vertebrate predators such as sticklebacks will also benefit from stabilisation of water levels.

Importantly, if water levels are artificially maintained or stabilised, this could affect hydroseral processes. The persistence of pingos/lithopalas throughout the post-glacial era is poorly understood but may relate to several processes including:

- Primary dependence on ground rather than surface water sources, reducing the inflow of sediment.
- Low groundwater nutrient levels, limiting plant productivity.
- Grazing by wild and domesticated herbivores, also limiting plant biomass and organic matter accumulation.
- Regular oxidative breakdown of organic matter during seasonal draw-down and drying-out (hence pingos do not accumulate peat).

Over-stabilisation of water levels via connection to surface water ditches could potentially alter such processes.

6.3 Assess potential sources of eutrophication

Atmospheric nitrogen deposition from agricultural sources, energy generation and vehicles has a significant impact on natural and semi-natural habitats by increasing plant productivity. Lithopalsa pond systems have evolved in conditions with only natural levels of atmospheric N and are likely to be damaged by anthropogenic inputs. Intensive livestock units are a potent source of NOx, and a strong smell of ammonia was evident during the April survey, arising from nearby pig units and/or slurrying of arable fields. It is important that environmental permitting for emissions takes full account of potential impacts on SSSI features.

PSYM provides a valuable method for monitoring the ecological status of permanent and semi-permanent ponds (it is not calibrated for seasonal/temporary water bodies). Trophic Ranking Score is acknowledged to be a problematic metric as it relies on a relatively small suite of plant species, but any marked change in the Index of Biotic Integrity – such as a shift from Good to Moderate status – is likely to reflect genuine degradation. Regular (e.g. five yearly) monitoring of Ponds A, C, F and L using PSYM is recommended.

6.4 Wood Small-reed

Wood Small-reed *Calamagrostis epigejos* is an invasive native plant which is a management concern in parts of the Breckland Forest SSSI. At the edges of the Frost's Common ponds, *Calamagrostis* litter is a useful habitat for small invertebrates and appears to have similar properties to Tufted Sedge *Carex elata* litter in this respect, often yielding *Hydrochus*, *Enochrus* and *Cercyon* species as well as Hydraenids and terrestrial invertebrates such as rove beetles and money spiders. Chemical or mechanical control of Wood Small-reed should therefore be avoided in the vicinity of pingos.

7. References

Foster, G.N. (2010). *A review of the scarce and threatened Coleoptera of Great Britain, 3: water beetles of Great Britain*. Joint Nature Conservation Committee: Peterborough.

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Nobes, G. (2008). *A survey of the aquatic Coleoptera and aquatic Hemiptera-Heteroptera of Frost's Common, 2008*. Unpublished report to the Forestry Commission.

Appendix 1: PSYM data and analysis

Site details				
Site name	**Frosts Common Pond A**	**Frosts Common Pond C**	**Frosts Common Pond F**	**Frosts Common Pond L**
Survey date	14-May-18	16-May-18	15-May-18	17-May-18
Grid reference (*e.g.* SP123456 or higher precision)	TL947943	TL947935	TL944933	TL946934
Plant metrics				
No. of submerged + marginal plant species (not including floating leaved)	13	28	12	14
Number of uncommon plant species	5	9	7	6
Trophic Ranking Score (TRS)	9.26	9.3	9.5	9.75
Invertebrates metrics				
ASPT	5.2222222	4.6470588	4.8235294	4.5882353
Odonata + Megaloptera (OM) families	2	2	2	2
Coleoptera families	3	4	3	3
Environmental variables				
Altitude (m)	38	38	37	37
Easting	5947	5947	5944	5946
Northing	2943	2935	2933	2934
Shade (%)	50	15	10	2
Inflow (0/1)	0	0	0	0
Grazing (%)	0	50	50	50
pH	7.53	7.95	7.2	6.9
Emergent plant cover (%)	15	30	10	12
Base clay (1-3)	3	3	3	3
Base sand, gravel, cobbles (1-3)	1	1	1	1
Base peat (1-3)	1	1	1	1
Base rock (1-3)	1	1	1	1
Area (m^2)	210	2000	310	295
Results				
Submerged + marginal plant species				
Predicted (SM)	16.0	24.1	17.0	16.9
Actual (SM)	13	28	12	14
EQI (SM)	0.81	1.16	0.70	0.83
IBI (SM)	3	3	2	3
Uncommon plant species				
Predicted (U)	2.8	4.1	2.9	2.9
Actual (U)	5	9	7	6
EQI (U)	1.76	2.21	2.42	2.10

IBI (U)	3	3	3	3
Trophic Ranking Score (TRS)				
Predicted (TRS)	8.75	8.75	8.72	8.66
Actual (TRS)	9.26	9.30	9.50	9.75
EQI (TRS)	1.06	1.06	1.09	1.13
IBI (TRS)	2	2	2	1
ASPT				
Predicted (ASPT)	5.11	5.10	5.09	5.07
Actual (ASPT)	5.22	4.65	4.82	4.59
EQI (ASPT)	1.02	0.91	0.95	0.90
IBI (ASPT)	3	3	3	3
Odonata + Megaloptera (OM) families				
Predicted (OM)	3.46	3.19	3.25	3.20
Actual (OM)	2	2	2	2
EQI (OM)	0.58	0.63	0.61	0.63
IBI (OM)	2	2	2	2
Coleoptera families				
Predicted (CO)	3.75	3.76	3.73	3.73
Actual (CO)	3	4	3	3
EQI (CO)	0.80	1.06	0.80	0.80
IBI (CO)	3	3	3	3
Sum of Individual Metrics	16	16	15	15
Index of Biotic Integrity (%)	89%	89%	83%	83%
PSYM quality category (IBI >75%=Good, 51-75%= Moderate, 25-50%=Poor, <25%=V Poor)	Good	Good	Good	Good
Is this a Priority Pond? (Good quality category)	Yes	Yes	Yes	Yes

Appendix 2: aquatic macro-invertebrates recorded during the survey

Taxon	English name	Family	Order	GB status[6]
Tricladida spp.	flatworms	Tricladida	Tricladida	
Oligochaeta	worms	Oligochaeta	Oligochaeta	
Erpobdella testacea	a leech	Erpobdellidae	Hirudinea	
Theromyzon tessulatum	Duck Leech	Glossiphoniidae	Hirudinea	
Valvata cristata	Common Vale-snail	Valvatidae	Gastropoda	
Galba truncatula	Dwarf Pond Snail	Lymnaeidae	Gastropoda	
Radix balthica	Wandering Snail	Lymnaeidae	Gastropoda	
Stagnicola palustris agg.	Marsh Pond Snail	Lymnaeidae	Gastropoda	
Anisus leucostoma	White-lipped Ram's-horn snail	Planorbidae	Gastropoda	
Bathyomphalus contortus	Twisted Ram's-horn snail	Planorbidae	Gastropoda	
Gyraulus crista	Nautilus Ram's-horn	Planorbidae	Gastropoda	
Hippeutis complanata	a ram's-horn snail	Planorbidae	Gastropoda	
Planorbis carinatus	Keeled Ram's-horn snail	Planorbidae	Gastropoda	
Planorbis planorbis	Margined Ram's-horn	Planorbidae	Gastropoda	
Pisidium sp.	a pea-mussel	Sphaeriidae	Bivalvia	
Asellus aquaticus	Water Hoglouse	Asellidae	Isopoda	
Proasellus meridinianus	a water hoglouse	Asellidae	Isopoda	
Crangonyx pseudogracilis	an amphipod shrimp	Crangonyctidae	Amphipoda	
Cloeon dipterum	Pond Olive mayfly	Baetidae	Ephemeroptera	
Caenis sp.	a mayfly	Caenidae	Ephemeroptera	
Coenagrion puella	Azure Damselfly	Coenagrionidae	Odonata	
Coenagrion pulchellum	Variable Damselfly	Coenagrionidae	Odonata	NT
Pyrrhosoma nymphula	Large Red Damselfly	Coenagrionidae	Odonata	
Libellula depressa	Broad-bodied Chaser	Libellulidae	Odonata	

[6] NT = Near Threatened; NS = Nationally Scarce

Libellula quadrimaculata	Four-spotted Chaser	Libellulidae	Odonata	
Orthetrum cancellatum	Broad-bodied Chaser	Libellulidae	Odonata	
Sympetrum striolatum	Common Darter	Libellulidae	Odonata	
Aeshna cyanea	Southern Hawker	Aeshnidae	Odonata	
Aeshna juncea	Common Hawker	Aeshnidae	Odonata	
Brachytron pratense	Hairy Dragonfly	Aeshnidae	Odonata	
Nepa cinerea	Water Scorpion	Nepidae	Hemiptera	
Corixa punctata	a lesser water-boatman	Corixidae	Hemiptera	
Hesperocorixa linnaei	a lesser water-boatman	Corixidae	Hemiptera	
Hesperocorixa sahlbergi	a lesser water-boatman	Corixidae	Hemiptera	
Notonecta glauca	Common Backswimmer	Notonectidae	Hemiptera	
Plea minutissima	Pygmy Backswimmer	Pleidae	Hemiptera	
Ilyocoris cimicoides	Saucer Bug	Naucoridae	Hemiptera	
Gerris lacustris	Common Pond-skater	Gerridae	Hemiptera	
Gerris lateralis	a pond-skater	Gerridae	Hemiptera	
Hydrometra stagnorum	Water-measurer	Hydrometridae	Hemiptera	
Microvelia reticulata	a pygmy water-cricket	Velidae	Hemiptera	
Gyrinus caspius	a whirligig beetle	Gyrinidae	Coleoptera	
Gyrinus marinus	a whirligig beetle	Gyrinidae	Coleoptera	
Gyrinus substriatus	Common Whirligig	Gyrinidae	Coleoptera	
Haliplus ruficollis	an algivorous water beetle	Haliplidae	Coleoptera	
Noterus clavicornis	a burrowing water beetle	Noteridae	Coleoptera	
Noterus crassicornis	a burrowing water beetle	Noteridae	Coleoptera	NS
Agabus bipustulatus	a diving beetle	Dytiscidae	Coleoptera	
Agabus sturmii	a diving beetle	Dytiscidae	Coleoptera	
Agabus uliginosus	a diving beetle	Dytiscidae	Coleoptera	NT
Ilybius ater	a diving beetle	Dytiscidae	Coleoptera	
Ilybius chalconatus	a diving beetle	Dytiscidae	Coleoptera	
Ilybius montanus	a diving beetle	Dytiscidae	Coleoptera	

Ilybius quadriguttatus	a diving beetle	Dytiscidae	Coleoptera	
Colymbetes fuscus	a diving beetle	Dytiscidae	Coleoptera	
Nartus grapii	a diving beetle	Dytiscidae	Coleoptera	
Rhantus exsoletus	a diving beetle	Dytiscidae	Coleoptera	
Rhantus suturalis	a diving beetle	Dytiscidae	Coleoptera	
Liopterus haemorrhoidalis	a diving beetle	Dytiscidae	Coleoptera	
Acilius sulcatus	a diving beetle	Dytiscidae	Coleoptera	
Dytiscus dimidiatus	a great diving beetle	Dytiscidae	Coleoptera	NT
Dytiscus marginalis	Great Diving Beetle	Dytiscidae	Coleoptera	
Dytiscus semisulcatus	a great diving beetle	Dytiscidae	Coleoptera	
Hydaticus seminiger	a diving beetle	Dytiscidae	Coleoptera	NS
Hydroglyphus geminus	a diving beetle	Dytiscidae	Coleoptera	
Hydroporus angustatus	a diving beetle	Dytiscidae	Coleoptera	
Hydroporus erythrocephalus	a diving beetle	Dytiscidae	Coleoptera	
Hydroporus figuratus	a diving beetle	Dytiscidae	Coleoptera	
Hydroporus gyllenhalii	a diving beetle	Dytiscidae	Coleoptera	
Hydroporus neglectus	a diving beetle	Dytiscidae	Coleoptera	NS
Hydroporus nigrita	a diving beetle	Dytiscidae	Coleoptera	
Hydroporus palustris	a diving beetle	Dytiscidae	Coleoptera	
Hydroporus striola	a diving beetle	Dytiscidae	Coleoptera	
Porhydrus lineatus	a diving beetle	Dytiscidae	Coleoptera	
Clemnius decoratus	a diving beetle	Dytiscidae	Coleoptera	NS
Hygrotus inaequalis	a diving beetle	Dytiscidae	Coleoptera	
Hyphydrus ovatus	a diving beetle	Dytiscidae	Coleoptera	
Laccornis oblongus	a diving beetle	Dytiscidae	Coleoptera	NT
Helophorus ?minutus	a scavenger water beetle	Helophoridae	Coleoptera	
Helophorus flavipes/obscurus	a scavenger water beetle	Helophoridae	Coleoptera	
Helophorus strigifrons	a scavenger water beetle	Helophoridae	Coleoptera	NS
Hydrochus brevis	a scavenger water beetle	Hydrochidae	Coleoptera	NT

Hydrochus crenatus	a scavenger water beetle	Hydrochidae	Coleoptera	NT
Hydrochus elongatus	a scavenger water beetle	Hydrochidae	Coleoptera	NT
Laccobius bipunctatus	a scavenger water beetle	Hydrophilidae	Coleoptera	
Hydrobius fuscipes	a scavenger water beetle	Hydrophilidae	Coleoptera	
Hydrobius subrotundus	a scavenger water beetle	Hydrophilidae	Coleoptera	
Anacaena bipustulata	a scavenger water beetle	Hydrophilidae	Coleoptera	
Anacaena globulus	a scavenger water beetle	Hydrophilidae	Coleoptera	
Anacaena limbata	a scavenger water beetle	Hydrophilidae	Coleoptera	
Anacaena lutescens	a scavenger water beetle	Hydrophilidae	Coleoptera	
Cymbiodyta marginellus	a scavenger water beetle	Hydrophilidae	Coleoptera	
Enochrus coarctatus	a scavenger water beetle	Hydrophilidae	Coleoptera	
Enochrus nigritus	a scavenger water beetle	Hydrophilidae	Coleoptera	NT
Enochrus ochropterus	a scavenger water beetle	Hydrophilidae	Coleoptera	
Enochrus testaceus	a scavenger water beetle	Hydrophilidae	Coleoptera	
Helochares lividus	a scavenger water beetle	Hydrophilidae	Coleoptera	
Helochares punctatus	a scavenger water beetle	Hydrophilidae	Coleoptera	NS
Coelostoma orbiculare	a scavenger water beetle	Hydrophilidae	Coleoptera	
Cercyon convexiusculus	a scavenger water beetle	Hydrophilidae	Coleoptera	
Cercyon sternalis	a scavenger water beetle	Hydrophilidae	Coleoptera	
Hydraena riparia	a small water beetle	Hydraenidae	Coleoptera	
Hydraena testacea	a small water beetle	Hydraenidae	Coleoptera	
Limnebius aluta	a small water beetle	Hydraenidae	Coleoptera	NT
Ochthebius minimus	a small water beetle	Hydraenidae	Coleoptera	
Contacyphon pubescens	a marsh beetle	Scirtidae	Coleoptera	NS
Contacyphon variabilis	a marsh beetle	Scirtidae	Coleoptera	
Notaris acridulus	a weevil	Erirhinidae	Coleoptera	
Tanysphyrus lemnae	Duckweed Weevil	Erirhinidae	Coleoptera	
Datonychus melanostictus	a weevil	Curculionidae	Coleoptera	
Poophagus sisymbrii	Water-cress Weevil	Curculionidae	Coleoptera	

Chaoboridae	phantom midge larvae	Chaobordidae	Diptera	
Chironomidae	non-biting midge larvae	Chironomidae	Diptera	
Culicidae	mosquito larvae	Culicidae	Diptera	
Dixidae	meniscus midge larvae	Dixidae	Diptera	
Tipuloidea	cranefly larva	Tipuloidea	Diptera	
Odontomyia tigrina	a soldierfly	Stratiomyidae	Diptera	
Oplodontha viridula	a soldierfly	Stratiomyidae	Diptera	
Oxycera sp.	soldier-fly larvae	Stratiomyidae	Diptera	
Stratiomyidae indet (other)	a soldierfly	Stratiomyidae	Diptera	
Stratiomys potamida	a soldierfly	Stratiomyidae	Diptera	
Glyphotaelius pellucidus	a caddis larva	Limnephilidae	Trichoptera	
Limnephilus ?rhombicus	a caddis fly	Limnephilidae	Trichoptera	
Limnephilus flavicornis	a caddis fly	Limnephilidae	Trichoptera	
Limnephilus lunatus	a caddis fly	Limnephilidae	Trichoptera	
Limnephilus vittatus	a caddis fly	Limnephilidae	Trichoptera	
Trichostegia minor	a caddis fly	Phryganeidae	Trichoptera	NS