Carabidae (Ground) beetles as a tool for monitoring habitat restoration on the Great Fen.

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Summary

- Ground beetles are proposed as a tool for monitoring habitat restoration on the Great Fen.
- Surveys of a number of Great Fen compartments were conducted in 2012 & 2013, and data used to derive a range of parameters.
- Parameters included species richness, diversity, rarity scores, species quality indices and habitat type and Fenland basin affinities.
- Unsurprisingly Woodwalton Fen tended to score most highly, and New Decoy the least, reflecting history of management, with Rymes reed bed and Darlow's Farm intermediate. Rymes reed bed yielded the most species and also scored most highly for arable farmland affinity. Woodwalton Fen was always followed by Rymes reedbed in the ranking of affinity for desirable habitat types.
- The results are discussed in relation to the habitat compartments and management from which they are derived, and useful comparison between sites made. The most valuable data that will come from this study will be realised over successive years, as site and management specific trends can analysed as a function of time in conservation management.
- Seven notable species (all of status Nb) have been recorded to-date.
- The survey methodology and variety of approaches to analysis presented represent an excellent basis for the use of the Carabidae as a tool for monitoring wetland restoration on the Great Fen, and suggestions are made for the continuation of this project.

Introduction

The Carabidae or ground beetles are often used in ecological and conservation studies for a variety of reasons. They are species rich enough to allow finely detailed discrimination between good, medium and poor quality sites, species show particular affinities for a variety of habitat types, and occur in most habitats. There are a not un-manageable number of species in the British fauna, around 365, and their live identification is relatively easy, even in the field. In addition to their intrinsic conservation value, there are various approaches to the use of the Carabidae to monitor habitats, and part of their popularity stems from the ease with which many species may be sampled from pitfall traps. This document aims to set out the work conducted on the Great Fen to date, to present various approaches and preliminary analyses based on these, and to guide the direction of the ground beetle monitoring project.

Fens Biodiversity Audit

The Fens region is very important for biodiversity (Mossman, H.L., Panter, C.J. & Dolman, P.M. 2013) with records (pooling pre- and post-1987) comprising:

- 13, 473 species
- 1,931 priority species (Global RDB, RDB, Nationally Notable, Birds of Conservation Concern, BAP, Fen Specialists).
- 27% (305 species) of the UK BAP species.
- 81 Fen Specialist species (19 species entirely and 7 largely restricted to the Fens in the UK and 24 that have a primary stronghold, and 35 that have a secondary stronghold, in the region).

True flies were the most species rich group in the fens, with 2,630 species being recorded; this constitutes approximately 37% of the UK Diptera fauna (totally c. 7,000 species (Barnard 2011)). Large numbers of beetles (2,159 species), moths (1,520) and vascular plants (1,531) were also recorded. Thirty-three percent of the 1,904 priority species were beetles, however only one of these is a Carabid, *Paradromius longiceps* for which fenland is a secondary stronghold. Despite this, the Carabidae still offer a species rich, numerous and habitat specific assemblage from which very meaningful assessment of habitats can be made.

Methods

Following completion of a 10 week training course in the identification of ground beetles delivered by one of the authors, volunteers were engaged in field recording days on various sites on the Great Fen. Ground beetles were sampled by direct searching across the range of microhabitats found in each management compartment surveyed, and identified to species in the field. On a small number of occasions pitfall traps were set several days in advance and checked on the day of survey.

There are a variety of ways in which data collected from studies such as this can be utilised. Here the use of species richness, species diversity, species rarity scores, Species Quality Indices and habitat affinities are described.

Species richness: refers to the number of different species represented in an ecological community, landscape or region. It is simply a count of species, and it does not take into account the abundances of the species or their relative abundance distributions.

Species diversity is calculated by an index which takes into account both species richness and evenness. Communities with a large number of species that are evenly distributed are the most diverse and communities with few species that are dominated by one species the least diverse. Species rarity is not taken into consideration. There are a number of species diversity indices in common usage, perhaps the most popular being Shannon's, given by:

$H = -\sum \ pi \ln pi$

Where pi = the proportion of individuals of species i.

Species rarity scores: The presence of rare species in a community is often used in the determination of conservation value (Margules & Usher, 1981). Two are in common usage for invertebrates, and in each species are assigned a value which is positively correlated with its conservation status. Ball (1986) and Foster (1987) use similar status categories but different scoring systems. The former evaluates sites based only on rare species, while the later also takes common species into account. See Table 1 below for details.

Table 1. **Point scores for species conservation status categories after Ball (1986) and Foster (1987).**

Status	Ball (1986)	Foster (1987)
Red Data Book (RDB)	100	32
Notable A (Na)	50	16
Notable B (Nb)	40	8
Regionally Notable (Nr)	20	4
Local (L)	0	2
Common (C)	0	1

By summing the scores for each species recorded a site score is derived. The interpretation of these indices is somewhat ambiguous however, as they vary regionally, and are strongly influenced by recording effort; a cumulative species score will increase as the number of species recorded from a site increases, not necessarily reflecting natural variation.

Species Quality Indices (SQI's) are a partial solution to this issue. Averaging the rarity score will in theory eliminate the effect of recorder effort:

SQI = Rarity Score / Number of Species

Habitat affinities are derived from a system of scoring each species based on its occurrence or otherwise, in different habitat types, giving increased weighting to species with increasingly habitat specific occurrence.

Affinity definitions: 1 = occurs; 2 = occurs more than in other habitats; 3 = main or sole habitat

Fenland Basin affinity was derived from distribution maps of each species (Luff, 1998) recorded on the Great Fen, as a % of the total 10 km UK distribution that occur in the Fenland basin. Due to the patchy trend of historical records, it is recommended that only post- 1970 records are included in this analysis. 'Fenland' may be defined as a geographically discrete area and by determining the group of 10 km squares which make up the region, species may be ranked according to the proportion of their British range which fall within the Fenland region, and compartments by the sum total of the Fenland affinity of each species recorded therein.

Results

Over the two years of this study, 302 individuals of 84 species of ground beetle have been found in surveys on the Great Fen. Rymes reedbed is both the most populous and specious site, and Holme Fen the least. Woodwalton Fen ranks most highly for most determined parameters, while New Decoy and Holme Fen are generally the lowest ranked.

Table 2 **Summary of numbers of species, individuals, diversity and indices for Carabid beetles recorded from Great Fen compartments in 2012 & 2013.**

Location	Species	Individuals	Shannon's Diversity Index	Invertebrate Index	Rarity Score	SQI (a)	SQI (b)
Woodwalton Fen	29	55	3.05	160	57	5.52	1.97
Darlow's Farm	24	75	2.77	80	42	3.33	1.75
Rymes reedbed	41	122	3.31	40	54	0.98	1.32
Holme Fen	8	22	1.73	0	10	0.00	1.25
New Decoy	23	29	3.06	0	27	0.00	1.17

Notes: Invertebrate Score after Ball (1986), Rarity Score after Foster (1987), SQI (a): Species Quality Index after Ball, SQI (b) Species Quality Index after Foster.

Table 3 **Sum totals of habitat affinity scores of Carabid species recorded from Great Fen Compartments in 2012 & 2013**

Habitat Affinity	Woodwalton Fen	Darlow's Farm	Rymes Reedbed	Holme Fen	New Decoy
Wet Grassland	25	12	23	5	16
Bogs and wet heath	27	18	24	8	18
Fens and marshes	57	39	40	6	22
Arable farmland	25	23	50	5	24
Fenland Basin	135.14	97.73	166.89	28.33	95.81

Notes: Habitat affinity scores B. Eversham (pers. comm.) Fenland Basin affinity compiled from Luff, 1998)

Table 4 **Site rankings based on scores, indices and affinities**

Score or index	
Species Richness	Rymes Reedbed > Woodwalton Fen > Darlow's Farm > New Decoy > Holme Fen
Invertebrate Index	Woodwalton Fen > Darlow's Farm > Rymes Reedbed > Holme Fen > New Decoy
SQI (a)	Woodwalton Fen > Darlow's Farm > Rymes Reedbed > Holme Fen = New Decoy
Rarity Score	Woodwalton Fen > Rymes Reedbed > Darlow's Farm > Holme Fen = New Decoy
SQI (b)	Woodwalton Fen > Darlow's Farm > Rymes Reedbed > Holme Fen > New Decoy
Habitat affinities	
Wet Grassland	Woodwalton Fen > Rymes Reedbed > New Decoy > Darlow's Farm > Holme Fen
Bogs and wet heath	Woodwalton Fen > Rymes Reedbed > Darlow's Farm = New Decoy > Holme Fen
Fens and marshes	Woodwalton Fen > Rymes Reedbed > Darlow's Farm > New Decoy > Holme Fen
Arable farmland	Rymes Reedbed > Woodwalton Fen > New Decoy > Darlow's Farm > Holme Fen
Fenland Basin	Rymes Reedbed > Woodwalton Fen > Darlow's Farm > New Decoy > Holme Fen

Notable species

Seven notable species have been recorded to-date. The species names and locations of each record are given in table 5, and descriptions and notes on their ecology given below.

Table 5 **Notable species by compartment**

Species	Status	Woodwalton Fen	Darlow's Farm	Rymes Reedbed	Holme Fen	New Decoy
Amara lucida	Nb			✓		
Blethisa multipunctata	Nb	✓	✓			
Chlaenius nigricornis	Nb	✓				
Demetrias monostigma	Nb	✓				
Oodes helopioides	Nb	✓				
Stenolophus teutonus	Nb		✓			
Syntomus obscuroguttatus	Nb					✓

Amara lucida A nationally scarce ground beetle which occurs in dry sandy grassland, about 5 mm long, black with a green or brassy metallic sheen. Known mainly from the coast around England, and inland in Norfolk and Suffolk. Elsewhere its distribution is very local. Found on the Great Fen at Rymes Reedbed, and area which entered restoration management in 2011, and where significant engineering works have been undertaken to construct new water bodies and channels, which will eventually form a reedbed/fen/wet grassland matrix.

Blethisa multipunctata A nationally scarce black ground beetle with a distinctive coppery reflection, relatively large at over 10 mm in length. It is widely but very locally distributed in Britain, with a very strong affinity for fens and marshes. It was found unsurprisingly at both Woodwalton Fen and Darlow's Farm, both areas of the Great Fen that are established wet habitats, although in far greater abundance on Darlow's.

Chlaenius nigricorni A colourful and metallic green and copper beetle, nationally scarce, widespread in all but the extreme north of England. It has an affinity for both wet grassland and fens, as well as being found in the coastal littoral zone. In this study found only on Woodwalton Fen, as a single individual.

Demetrias monostigma A relatively small (5 mm) nationally scarce species with a black head, red-brown pronotum and pale elytra with a diamond and spot pattern. Distributed locally in the south and east of England, and with a strong affinity for fens and marshes, but found in two contrasting habitat types (*Phragmities* reedbeds and tussocks of Marram grass on dry sand dunes) but both characterised by stiff vertical grass stems. Again only a single individual was found on Woodwalton Fen.

Oodes helopioides Uniformly black and not particularly shiny, this nationally scarce species gets to 10 mm in length, lives in litter and vegetation near still or slow flowing water, and with a strong affinity for fens and marshes. Single individuals were found on Woodwalton Fen in both 2012 and 2013.

Stenolophus teutonus A nationally scarce wetland ground-beetle in Britain, about 6 mm long, this species is known from a scatter of sites in southern England and East Anglia. Previously recorded from just two sites in Cambridgeshire, this seems to be the first record for Huntingdonshire. The species is distinguished from the much commoner *S. mixtus* by the bright orange pronotum, and from the third, rare, species, *S. skrimshiranus* by the oval dark spot in the rear half of the elytra and the blackish antennae with pale bases. It runs actively over wet mud in rich wetland habitats, and is also an agile climber among grass and reeds. This one was found among rushes and grasses on the edge of a permanently flooded part of Darlow's Farm, an area which has been restored as wetland in the past decade.

Syntomus obscuroguttatus This tiny (3.5mm) ground-beetle is widespread but uncommon in southern England, and seems to be new to Huntingdonshire. It is distinguished from the other two British *Syntomus* species by the brownish colour and the faint pale spot at each shoulder. It is most often found in damp places or on heavy clay soils. This one was at New Decoy in grassland which had been flooded in the previous winter, in restored habitat in the middle of the Great Fen.

Table 4 **List of all Carabid beetle species recorded on Great Fen compartments, status, invertebrate indices, rarity scores and affinities.**

Species	Status	Invertebrate Index	Rarity Score	Wet Grassland affinity	Bogs and wet heath affinity	Fens and marshes affinity	Arable affinity	Fenland affinity (%)
Abax parrallelepipedus	Common	0	1	1	0	0	0	2.08
Agonum afrum (Agonum emarginatum = moestum)	Common	0	1	0	0	0	0	8.20
Agonum assimile	Common	0	1	0	0	0	0	3.46
Agonum dorsale	Common	0	1	0	0	0	0	3.88
Agonum fuliginosum	Common	0	1	0	2	3	0	3.10
Agonum marginatum	Common	0	1	0	1	3	0	7.54
Agonum obscurum	Common	0	1	0	0	3	0	8.04
Agonum piceum	Local	0	2	0	0	3	0	1.25
Agonum thoreyi	Common	0	1	0	1	3	0	4.14
Agomun viduum	Local	0	2	0	0	0	0	2.56
Amara aenea	Common	0	1	0	1	1	3	5.70
Amara apricaria	Common	0	1	0	0	0	2	5.86
Amara bifrons	Local	0	2	0	0	0	2	5.21
Amara communis	Common	0	1	0	0	0	2	3.74
Amara convexior	Common	0	1	0	0	0	2	1.14
Amara familiaris	Common	0	1	1	2	2	3	4.69
Amara lucida	Nb	40	8	0	1	0	0	4.35
Amara lunicollis	Common	0	1	1	2	1	2	1.94
Amara ovata	Common	0	1	0	0	0	0	2.48
Amara plebeja	Common	0	1	3	1	2	2	3.67
Amara similata	Common	0	1	0	0	0	0	3.60
Amara tibialis	Local	0	2	0	0	0	0	5.61
Anchomenus (=Agonum) dorsalis (Agonum dorsale)	Common	0	1	1	1	1	3	4.86
Anisodactylus binotatus	Local	0	2	2	2	2	2	0.00
Badister bullatus	Common	0	1	0	1	2	0	4.29
Bembidion aeneum	Common	0	1	0	0	0	0	3.78
Bembidion assimile	Common	0	1	0	0	3	0	9.09
Bembidion guttula	Common	0	1	0	0	3	0	3.51
Bembidion illigeri (=genei)	Common	0	1	0	1	3	0	7.91
Bembidion lampros	Common	0	1	1	1	2	3	3.81
Bembidion mannerheimi (Bembidion unicolor)	Common	0	1	1	2	3	0	4.25
Bembidion obtusum	Common	0	1	1	3	2	0	7.27
Bembidion properans	Common	0	1	0	0	0	0	4.12
Bembidion tetracolum	Common	0	1	0	0	3	0	2.94
Bembidion varium	Common	0	1	0	0	0	0	10.32
Blethisa multipunctata	Nb	40	8	0	0	3	0	5.88
Bradycellus harpalinus	Common	0	1	1	1	1	3	1.72
Bradycellus ruficollis	Local	0	2	0	3	0	0	0.47
Bradycellus verbasci	Common	0	1	1	0	0	3	2.89
Calathus melanocephalus	Common	0	1	1	1	2	3	1.72
Carabus granulatus	Common	0	1	0	2	0	0	2.68

Calathus cinctus	Local	0	2	0	0	0	0	3.57
Calathus fuscipes	Common	0	1	1	0	0	0	2.71
Chlaenius vestitus	Local	0	2	0	0	3	0	6.73
Chlaenius nigricornis	Nb	40	8	2	0	2	2	1.33
Curtonotus (=Amara) aulicus (Amara aulica)	Common	0	1	1	1	1	3	3.64
Curtonotus (=Amara) convexiusculus (Amara convexiuscula)	Local	0	1	0	0	0	0	0.00
Demetrias atricapillus	Common	0	1	0	2	0	0	5.37
Demetrias monostigma	Nb	40	8	0	0	3	0	6.67
Dyschirius globosus	Common	0	1	0	0	0	0	4.33
Elaphrus cupreus	Common	0	1	0	2	3	0	2.10
Elaphrus riparius	Common	0	1	0	2	3	0	3.72
Harpalus affinis (=aeneus)	Common	0	1	1	1	1	3	4.29
Harpalus rufipes	Common	0	1	0	0	0	0	3.92
Harpalus tardus	Common	0	1	0	1	1	3	5.00
Leistus fulvibarbis	Common	0	1	2	1	2	1	3.41
Loricera pilicornis	Common	0	1	2	2	2	2	3.79
Metabletus truncatellus	Local	0	2	0	0	0	0	11.32
Microlestes ? minutulus	Local	0	2	0	0	0	0	0.00
Microlestes maurus	Common	0	1	0	0	0	0	9.82
Nebria brevicollis	Common	0	1	0	0	0	0	2.48
Notiophilus biguttatus	Common	0	1	2	1	2	3	3.60
Notiophilus germinyi	Local	0	2	0	0	0	0	2.08
Notiophilus palustris	Common	0	1	2	2	3	0	3.85
Notiophilus substriatus	Common	0	1	0	0	0	0	1.58
Oodes helopioides	Nb	40	8	0	0	3	0	5.88
Ophonus rufibarbis (Harpalus rufibarbis)	Common	0	1	1	0	2	1	8.37
Oxypselaphus (=Agonum) obscurus (Agonum obscurum)	Common	0	1	2	2	2	0	7.59
Paradromius (=Dromius) linearis	Common	0	1	2	1	2	2	4.01
Philorhizus (=Dromius) melanocephalus	Common	0	1	2	0	0	1	4.95
Poecilus (=Pterostichus) cupreus	Common	0	1	1	0	0	3	1.37
Pseudophonus rufipes (Harpalus rufipes)	Common	0	1	1	0	0	3	3.94
Pterostichus melanarius	Common	0	1	1	0	1	3	3.45
Pterostichus niger	Common	0	1	2	1	2	3	2.37
Pterostichus nigrita	Common	0	1	1	0	3	1	2.13
Pterostichus strenuus	Common	0	1	0	3	0	0	4.28
Stenolophus mixtus	Common	0	1	0	1	3	0	7.65
Stenolophus teutonus	Nb	40	8	0	0	3	0	0.00
Stomis pumicatus	Common	0	1	2	1	3	0	6.58
Syntomus (=Metabletus) foveatus	Common	0	1	0	0	0	0	5.02
Syntomus obscuroguttatus	Local	0	2	0	0	0	0	0.00
Synuchus nivalis	Local	0	2	0	0	0	0	3.59
Trechus obtusus	Common	0	2	1	0	1	3	1.40
Trechus quadristriatus	Common	0	2	1	0	1	3	6.45

Notes: Invertebrate Score after Ball (1986), Rarity Score after Foster (1987).

Great Fen

Discussion

It is difficult to interpret data such as these without comparison to other sites. Nevertheless by ranking management compartments and comparing them, in combination with knowledge about each habitat and history of management, useful interpretation of the results to-date can be achieved. As intuitively expected, Woodwalton Fen which is an established and managed NNR and SSSI, scores most highly in terms of rarity and species quality indices. It is followed in the main by Darlow's Farm, which of all the land acquired by the Great Fen partnership has been conservation management the longest. One of the newest areas in restoration is Rymes reedbed, which exceeds even Woodwalton Fen in terms of species richness. This is probably due in part to the engineering works carried out to construct the reed bed resulting in larges expanses of bare open substrate, acting to attract prospecting beetles. It is very encouraging also to find rare and notable species on other compartments.

Considering the carabid fauna in the context of landscape history can help explain some aspects of the results. For several thousand years before drainage in the 17th – 19th centuries, the fen basin would have been crossed by a large number of river channels, which would flood their banks frequently. These would create areas of bare mud or exposed peat, which would take a few years to revegetate. Within this dynamic floodplain, the raised mires and fens would provide areas of more stable dense vegetation. Most of the scarce and local species recorded on the new habitats are fully-winged and able to colonise transient habitats. Areas like Darlow's and Rymes Reedbed currently provide areas of exposed mud, adjacent to standing water, and these are likely to be visual signals which beetles flying overhead search for. There are some carabid species which are largely confined to ancient stable fens or wet woodlands, such as *Agonum livens*, which were not recorded in the survey, but which would not be expected to occur in newly created habitats.

Habitat affinity scores provide some useful insight. The desirable habitat types in creation and management on the Great Fen include Wet grassland, Bogs and wet heath, and Fens and marshes. Arable farmland affinity is a useful parameter with which to asses change in the Carabid assemblage from its former land use, consequently we would hope to see increases in the habitat affinity scores for desirable habitats, and a decrease in the affinity of assemblages for arable farmland. Again Woodwalton Fen consistently ranks most highly for each desirable habitat type. Given its management history, Darlow's Farm is the most obvious assumption to follow in the ranking, however Rymes Reedbed is constantly the next most highly ranked. An encouraging finding, but probably due in part to the recent ground disturbance caused by the construction of new water bodies, acting to attract prospecting Carabids. Contrary to expectation, Darlow's follows in the ranking for bogs & wet heath, and fens & marshes, but not for wet grassland. For New Decoy to rank above Darlow's is a very positive sign, but probably not a reflection of unsuitable conditions on Darlow's. It is no surprise that the Holme Fen birch woodland ranks lowest for all habitat type affinities. It is important to remember that the cumulative score for habitat affinity not only gives weighting to habitat specialists, but also generalists that occur in each habitat. Generalists may act to overinflate the total score for a habitat, if for instance there are a large number of low-scoring generalist species and a low number of high-scoring specialist species recorded in a given compartment. A similar pattern was observed in the ranking based on Fenland basin affinity, although scores appear comparatively low compared to a similar Breckland study (Eversham, 2012). Percentage scores were as high as 100 % for the Breckland example, while in this study the highest score was 11.32 %. i.e. 11 % of this species' UK range is found within the Fenland basin. With the progression of time and the development of habitats we would expect new colonists of more fen-specific species to increase these scores. Despite some limitations, habitat affinities provide a useful tool with which to compare and interpret change in carabid assemblages, and the changing habitat characteristics these imply.

Monitoring & management recommendations

The limitations of these approaches have been discussed above. The true value they can offer will be realised with the accumulation of data from a standardised sampling protocol conducted on repeated occasions over time. This will allow assessment of change in individual management compartments and some measure of the quality of these changes relative to conservation objectives. With repeat survey data over time statistical analysis becomes possible, the predictive power of which will increase with sample size. Long-term analysis of trends coupled with the determination of their statistical significance is the most powerful scientific approach to monitoring the progress of habitat management and restoration.

The standardisation of the sampling approach is perhaps less rigorous than other types of ecological survey, in that recorders hand search habitats, without using a sampling unit. It is assumed that any bias in the data will be negligible due to the approach of using a three-year rolling accumulation of species records. Not all species present may be recorded each year, but over three years a far more comprehensive species inventory will be recorded. This approach also accounts for the un-likelihood of rare species being recorded each year. If a rare species was recorded last year, can we be confident it is not still present a year or two later simply because we didn't record it? By assuming species are present for two years after initial record, their likely continued presence is assumed, and after three consecutive years of absence in records, their absence from the site is taken to be accurate.

Repeat surveys of each site should be conducted annually. Invertebrates, particularly Carabids, are short lived, mobile, and selective and specific in their habitat requirements. Resource requirements for these surveys are minimal, each survey having been conducted in half a day by a small group of pre-trained volunteers. Consequently Carabids can be expected to respond rapidly to habitat change, and produce meaningful results with relatively little resource expenditure. They can be used effectively in the approaches described here to monitor the progress of management with a quick results.
The choice of management compartments in this survey was designed to allow both assessment of trends over time (an intrinsic component of standardised long-term monitoring) and comparison of paired compartments of similar habitats at different stages of management. Thus Woodwalton Fen is paired with Rymes Reedbed, (reedbed & fen) and Darlow's with New Decoy (wet grassland), the latter in each case being more recently established, and intended to develop into a similar habitat mosaic as the former. Holme Fen was included in the initial study predominately as part of the training of volunteers, and it is not deemed necessary to maintain its inclusion. The study was initially limited to two pairs due to limitations of time and resources. It may be desirable in the future to add sites, but the initial design of two pairs should not be reduced.

A Microsoft Excel database has been pre-populated with the formulae required to calculate each parameter described here, and subsequent survey data need only be added to the existing format.

On-going monitoring of SQI and affinities.
It is difficult to interpret rarity scores, or indeed SQI scores, although comparisons with the scores of other sites can be made. No data on sites similar to the monitoring locations on the Great Fen have so far been available for comparison. It is proposed to use SQI scores as an ongoing tool for monitoring changes in the carabid assemblage in response to changing habitat parameters as restoration progresses. A three-year rolling average SQI is proposed as the unit for comparison, which will help to ensure a complete picture of the assemblage, accounting for variation in sampling effort and absence of species in records for a particular year which may in fact still be present, particularly rare species which have a lower probability of detection. Common species are more likely to be recorded each year if they continue to be present, thus a species not recorded in three successive years will drop out of the analysis. Statistical analysis of SQI's (and indeed diversity and species richness) are possible after only two years data collection, however will not take account of the provisions of the rolling three-year average, and statistical power will be minimal due to sample size. Intuitive and meaningful interpretation of SQI scores is however possible with two years data. The full benefit of the proposal will be realised after four years of survey, by modelling the three-year average SQI for a paired sample of years 1,2 & 3, with years 2,3 & 4 as a function of time.

Pitfall trapping
Although many published studies of ground beetles have used pitfall traps as the main or sole sampling technique, and some authors have argued that these are less subjective than direct searching, it is well documented that pitfall trap efficiency is highly sensitive to vegetation structure. Traps set in bare ground catch a much larger number of species and individuals than those in more dense vegetation. As the newly restored habitats in the Great Fen are likely to see massive changes in vegetation structure year to year, the pitfall catch would be affected by these changes even more than direct searching would be. Consequently pitfall trapping has not been a preferred method to-date, although it would no doubt yield some interesting results.

Conclusion
A survey methodology, preliminary data, and a variety of approaches to analysis are presented, and represent an excellent basis for the use of the Carabidae as a tool for monitoring wetland restoration on the Great Fen. It may not be necessary to take all of these approaches forward, however they represent no additional resource usage over and above the field survey; determination of each parameter is effectively an automated process once field data is computerised. Each approach has merits in terms of its descriptive capabilities, and careful interpretation of these is essential. It is fully expected that the overall approach described here will be refined over the life of the project.

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The approaches presented here and portions of the text are taken from Eversham (2012), augmented by discussion with the author.

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(Margules & Usher, 1981).

Appendix

The database of ground beetle records and analysis is stored as a Microsoft Excel spreadsheet file in the 'V drive' on the Bedfordshire, Cambridgeshire and Northamptonshire Wildlife Trust servers at the headquarters, The Manor House, Broad Street, Cambourne.