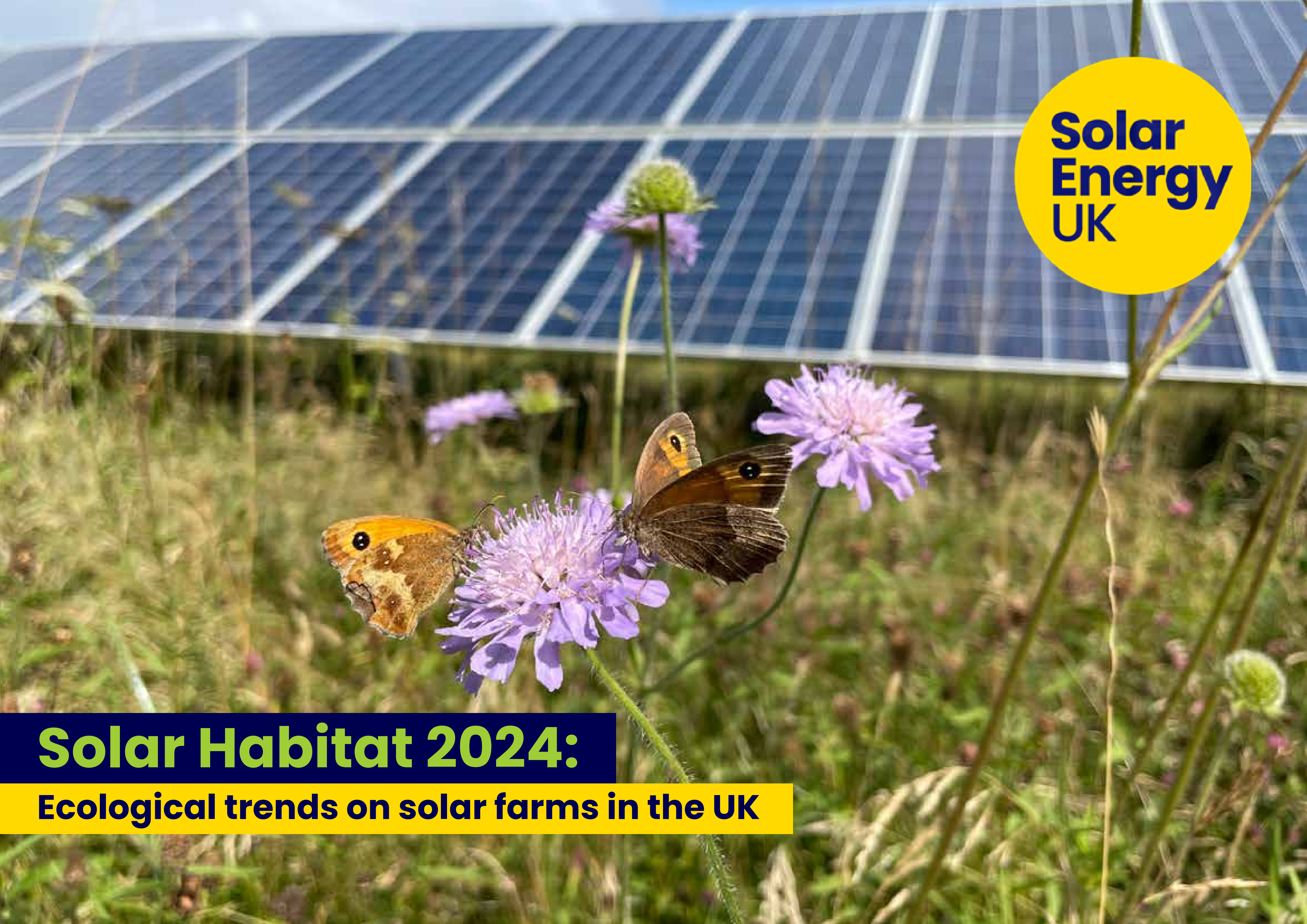


Solar Energy UK

Solar Habitat 2024:

Ecological trends on solar farms in the UK

Solar Energy UK

is an established trade association working for and representing the entire solar and energy storage value chain. Solar Energy UK represents a thriving member-led community of almost 400 businesses and associates, including installers, manufacturers, distributors, large-scale developers, investors and law firms. Our underlying ethos has remained the same since our foundation in 1978 - to be a powerful voice for our members by catalysing their collective strengths to build a clean energy system for everyone's benefit. Our mission is to empower the UK's solar transformation.

Clarkson & Woods

provide a full range of ecological survey and consultancy services in respect to planning and land management. We are a leading consultancy in the survey, assessment and design of proposed and existing photovoltaic solar developments of all scales, from community owned to nationally significant projects.

We provide a range of services including survey and ecological assessment of solar and battery projects, development of bespoke management plans for solar farms and ecological monitoring of operational solar farms. We have a particular interest in furthering our understanding of the interactions between solar farms and ecology and have co-developed guidance in this area as well as embarking on pioneering research and collaboration with academic institutions.

Lancaster University

is a northern powerhouse of research excellence nested within a context of social and environmental sustainability. In the 2021 Research Excellence Framework, 91% of our research was independently rated as 'internationally excellent' or 'world leading'. We are ranked 7th in the UK for social and environmental sustainability.

The Energy Environment Interactions team focus on improving understanding of the implications of the energy transition on the environment, and how land use change for energy can be done in a way that delivers ecological, as well as climate, benefits. They sit within Lancaster Environment Centre, a 400-strong community of high-achieving students, world-class environmental researchers, government scientists and enterprises working together to address today's biggest environmental challenges, cutting across the physical and social sciences.

Wychwood Biodiversity

works with solar asset owners and managers to improve biodiversity on their land. Our team of ecologists is passionate about biodiversity and our core strengths lie in the planning, creation and management of bespoke wildlife habitats.

We've developed a range of services to support organisations at all stages of the project cycle, from pre-planning through to the long-term management of solar farms. We provide technical services to support planning applications, development of site management plans and ecological monitoring. We offer tried and tested means to achieve biodiversity gains for single sites or entire portfolios. We've worked with our project partners to produce guidance on biodiversity management for the entire solar industry.

Pyramidal Orchid, Harry Knight-Smith, British Solar Renewables

Contents

Front cover: Gatekeeper and Meadow Brown butterflies, Hollie Blaydes, Lancaster University

Glossary

Amber Listed – bird species with an unfavourable conservation status in Europe, whose population/range has declined moderately in recent times or has a historically declining population but has made a recent substantial recovery, rare breeders and species for which the UK holds internationally important populations, as categorised by the British Trust for Ornithology[i].

Arisings – vegetation cuttings often left in situ after management.

Birds of Conservation Concern – British Trust for Ornithology Amber or Red Listed species[i].

Biodiversity Net Gain (BNG) – an approach to development that aims to deliver measurable improvements for biodiversity by creating or enhancing habitats.

Botany – relating to plants.

Broadleaf – plant species with relatively broad, flat leaves.

BTO – British Trust for Ornithology.

Climber (plant) - a group of plants that use twining stems, tendrils or sticky pads to cling to surfaces.

Deciduous – plants which lose their leaves during the winter.

eDNA – Environmental DNA.

ESG – Environmental, Social and Governance.

Evergreen – plants that retain their leaves through the winter.

Ferns - a group of vascular plants that reproduce using spores and do not have seeds or flowers.

Graminoid – grasses, sedges and rushes.

Incidental (observations) - biodiversity sightings outside of structured surveys.

Injurious weed – a plant that can damage crops, habitats or ecosystems, as prescribed in the Weeds Act 1959.

Natural England – A non-departmental public body which advises on the natural environment in England, sponsored by the Department for Environment, Food & Rural Affairs.

NERC Act – Natural Environment and Rural Communities Act 2006.

NSIP - Energy projects over a specified generating capacity (50 MWac and above in England and 350MWac and above in Wales) which are of national significance and are determined at a national level.

Open mosaic habitat – habitat which establishes on previously developed land usually comprising sparse, patchy vegetation including stress tolerant plants.

Quadrat – a square plot of land marked out for botanical assessment.

Red Listed – bird species that are globally threatened, whose population/range has declined rapidly in recent times or that have declined historically and not shown recovery, as categorised by the British Trust for Ornithology[i].

Standard error (of the mean) - an indication of how different the population mean is likely to be from a sample mean.

Strings (of panels) – a row of panels that are wired together.

Sward – a grassland area.

Transect – a straight line through a habitat used to make measurements or observations.

Woody plants – plant species whose stems/roots are reinforced with wood (typically trees and shrubs).

Summary & highlighted findings

Until recently, monitoring of solar farms has not been applied consistently across the UK, making comparisons between sites difficult. In response, Solar Energy UK, in collaboration with Lancaster University, Clarkson & Woods and Wychwood Biodiversity introduced the standardised approach to monitoring biodiversity on solar farms. This standard enables the collection of comparable data, providing a clearer understanding of ecological trends on solar farms.

In May 2023, the first Solar Habitat report was released which highlighted ecological trends across 37 sites in the UK monitored in 2022 using the standardised methodology. This report continues that work, collating data from 87 sites monitored throughout 2023. The more than doubling of data in this year's report means trends between management approaches and biodiversity on solar farms can be identified with greater confidence.

This report provides a summary of botany, invertebrates, birds and mammals found on solar farms as part of structured surveys and incidental observations. The analysis indicates a positive relationship between specific management with greater biodiversity focus for biodiversity and plant and animal abundance. It also shows that the presence of diverse plant and invertebrate species has a positive impact on the abundance of bird species.

A direct comparison of the findings from 2022 to those from 2023 is not possible as only 17 sites were monitored in both years. However, over time, as data is accumulated from the same sites year on year, enabling the exploration of temporal trends, impacts of management practices over time and changes in biodiversity as sites mature. The standardised methodology will be reviewed periodically to incorporate feedback and make improvements.

The results of the standardised ecological monitoring set out in this and future annual publications of the Solar Habitat reports will help guide site managers, policymakers, ecologists, and local authorities and inform the effective management of operational sites.

The 87 sites surveyed in 2023 represent only a small proportion (6%) of the more than 1,400 solar farms operating in the UK[i]. It is anticipated that both the number of sites and contributing ecological consultancies will continue to grow year-on-year as the demand for monitoring and number of active sites continue to grow. With a greater data set and understanding of ecological trends, an ever-clearer picture of biodiversity on solar farms will emerge

Wheatear, Conor Mackenzie, Wychwood Biodiversity

Botany

- A total of 298 plant species were recorded across grasslands within 87 solar farms. On average, 27 species were recorded on each site, with a maximum of 52 found on one site.
- Within solar farms, species richness was generally greater in margin areas and those set aside for biodiversity.
- Across all monitored solar farms, on average more plant species were recorded at sites managed with a greater focus on biodiversity.

Invertebrates

- At least 47 invertebrate species and more than 3,000 individuals were recorded as part of structured surveys, including bumblebees, butterflies, moths, dragonflies and damselflies. On average, six species were recorded at each site, with a maximum of 15 observed at one site.
- Along transects, butterflies were five times more abundant than bumblebees. The most frequently recorded species was the meadow brown butterfly.
- The abundance and species richness of bumblebees and butterflies was greater along transects walked in solar farm margins and areas managed for biodiversity than between the rows of panels.

Birds

- A total of 99 bird species and almost 8,000 individuals were recorded across solar farms as part of structured surveys. On average, 25 species were recorded at each site, with a maximum of 47 found at one solar farm.
- Species recorded included 21 British Trust for Ornithology (BTO) Red Listed Species of Conservation Concern, as well as 25 BTO Amber Listed species.
- Higher numbers of bird species were associated with higher numbers of plant species across solar farms. Bird abundance was also greater with higher invertebrate abundance.

Mammals

- Incidental observations from 33 sites reported ten species of mammal present on solar farms, including rabbit, brown hare, weasel, field vole, common shrew, fox and badger. Fallow deer, muntjac deer and roe deer were also sighted.
- Brown hare were the most frequently recorded species, making up 40% of all observations.
- Targeted surveys would increase our understanding of mammals and solar farms.

Flower rich grassland, Hollie Blaydes, Lancaster University

Introduction

In May 2023 Solar Energy UK, in collaboration with Clarkson & Woods, Lancaster University and Wychwood Biodiversity, published the pilot Solar Habitat report highlighting ecological trends on solar farms in the UK.

Using the guidance set out in The Standardised Approach to Monitoring Biodiversity on Solar Farms, published in 2022, the pilot report summarised the results of ecological monitoring conducted at 37 operational solar farms in the UK. It looked at trends and observations to highlight how solar farms and their management can interact with local biodiversity.

This report continues that effort and collates the results of monitoring data from 87 solar farms undertaken by Clarkson & Woods and Wychwood Biodiversity throughout 2023. The report focuses on botany, invertebrates, birds and mammals found at solar farms and presents additional case studies looking at: growing shade tolerant grasses and wildflowers beneath panels, growing chamomile between panels and the use of environmental DNA (eDNA) to identify invertebrates. The report also revisits the application of Biodiversity Net Gain (BNG) on solar farms.

Solar Habitat has taken inspiration from Clarkson & Woods annual Solarview reports (2018 - 2020) which presented the results of ecological monitoring on solar farms undertaken by Clarkson & Woods solely. It is the intention of the authors to continue to report on the ecological monitoring on solar farms each year, encompassing data collected by ecological consultancies active across the UK, to build an ever-clearer picture of biodiversity on solar farms.

Monitoring ecology

Solar farms can contribute towards addressing the twin crises of climate change and biodiversity loss by reducing emissions and, with good management, encouraging biodiversity. While the first claim is widely accepted, it is important that claims about biodiversity are substantiated by ongoing observations.

Monitoring ecology is important for assessing the influence of solar farms on biodiversity. These include changes in the climate, growth in the scale and number of solar farms, changes in technology and changes in management practices, not to mention changes in policy and planning requirements.

The Standardised Approach to Monitoring Biodiversity on Solar Farms was published in 2022 by the authors of this report in order to be able to build a comparable data set across solar farms. The data will allow for a greater understanding of the influence solar farms can have on biodiversity and help to identify the impacts of management approaches.

The standardised methodology has been used for two consecutive years to monitor 37 sites in 2022 and 87 sites in 2023, beginning the process of building a credible evidence base, which will paint a representative picture of ecological trends on solar farms. Management styles vary greatly across operational solar farms. Though the trends identified from the analysis of data collected in 2022 and 2023 may be comparable, the data itself cannot be directly compared. This is because many sites go more than one year between monitoring and because the standardised methodology is designed to be achievable within a single day meaning that the time of year or weather on the day can impact results. However, over time, the accumulation of data collected from the same sites over multiple years, will enable the exploration of temporal trends, impacts of management practices over time and changes in biodiversity as solar farms age.

The results of the ecological monitoring set out in this, and future annual publications of the Solar Habitat reports, will help to guide policy, help ecologists and local authorities to appraise solar farm impacts and inform the management of operational sites. It is anticipated that the number of sites as well as the number of contributing ecological consultancies will continue to grow year on year as the demand for monitoring and number of active sites to continue growing.

Brown argus butterfly, Conor Mackenzie, Wychwood Biodiversity

Overview of solar farms

A total of 87 solar farms were monitored in 2023, with sites spread across England and a number located in Wales and Northern Ireland (Figure 1).

Most sites were located in England, with many in the south-west (30%), east (23%) and south-east (18%), which broadly matches the distribution of solar farms across the UK (Figure 1). Although the sample is generally representative of solar farms in England, it did not include any sites in the regions of London or the north-west. Just 3% of sites were located in Wales, compared to 11% at the national level. One site was located in Northern Ireland, and this was broadly similar to the distribution across the UK (1% vs. 2%). No solar farms in Scotland submitted monitoring data to this report in 2023, although 1% of sites across the UK are located there.

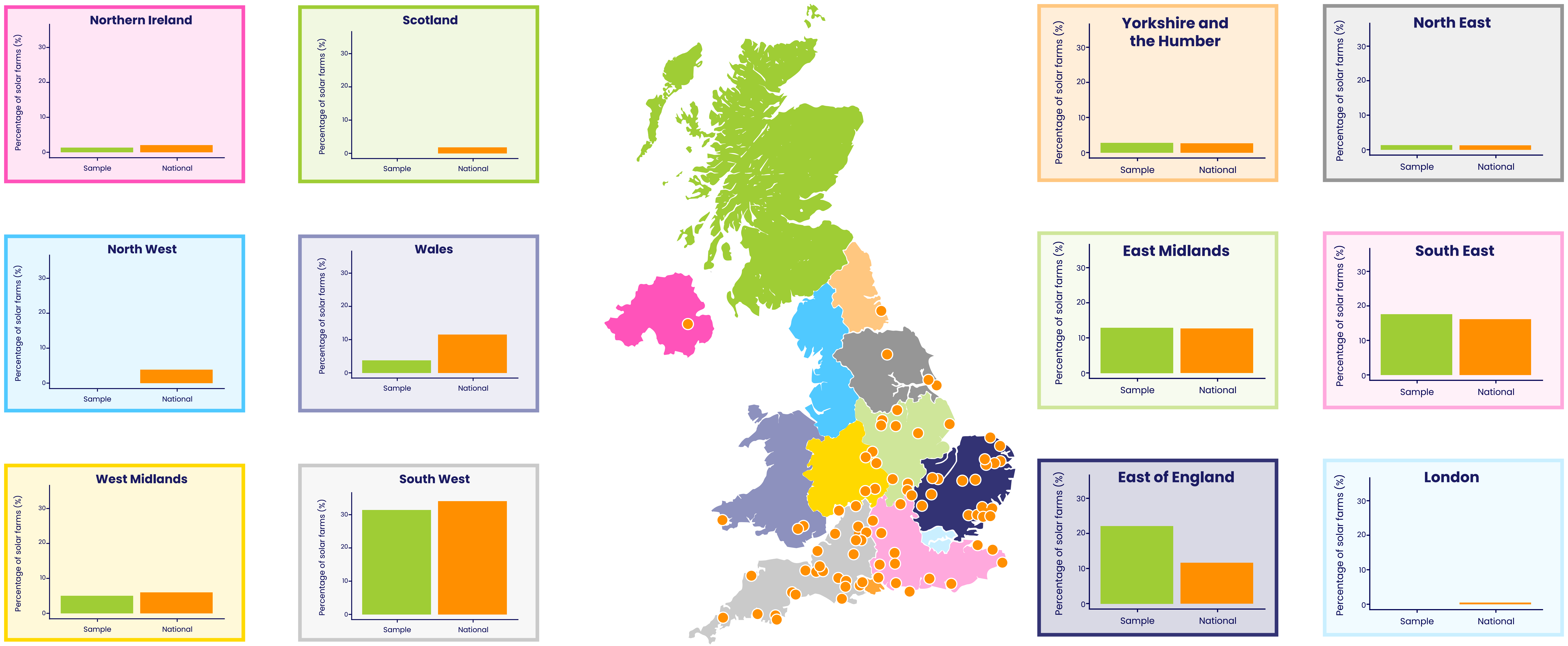
The age and size of solar farms in the Solar Habitat sample were generally representative of sites across the UK. The average age (years since grid connection) of sites in the sample was eight years but ranged from one to ten years old (nationally, the average age of operational solar farms is eight years, ranging from one to twelve years).

The generation capacity of solar farms included within the Solar Habitat sample based on megawatt (MW) output ranged from 1 MW to 70 MW, with an average of 10 MW. Again, this reflects the profile of operational sites nationally, which range from < 1 MW to 75 MW, with an average of 8 MW, based on solar farms that were operational as of October 2023[3].

Figure 1: A map of the UK where England is split into regions and Wales, Scotland and Northern Ireland are represented at the country level. Orange points represent solar farms monitored in 2023. For each region/country, a bar graph shows the percentage of solar farms in (i) the Solar Habitat sample (n = 87) and (ii) at the national level (excluding sample sites; n = 1,004). National data were taken from the Renewable Energy Planning Database quarterly for October 2023.

Region	Sample	National
South West	26	339
South East	16	158
East Midlands	11	126
East of England	20	111
Wales	5	110
West Midlands	4	56
North West	0	37
Yorkshire and the Humber	3	22
Northern Ireland	1	19
Scotland	0	14
North East	1	11
London	0	2

Table 1: Count of solar farms in the Solar Habitat sample and nationally, by region



The solar farms monitored in 2023 were graded from one to five, depending on the sites focus on biodiversity (Table 2). Due to the lack of a national database management, it is not known if sites included in the Solar Habitat sample are representative of how sites are managed across the UK. Most sites in the sample were placed in Categories 2 (41%) or 3 (45%), indicating some consideration of biodiversity. Two sites in the sample were assigned to Category 1 (2%), suggesting management practices are aligned with optimal biodiversity enhancement and eight sites were assigned to Category 4 (9%), indicating less optimal management for biodiversity. Two sites were placed in Category 5 (2%); this encompassed a newly constructed site without any kind of management established as yet and an old coal storage site which comprised open mosaic habitat and so standard grassland management did not apply.

The lack of sites in Category 1 is likely linked to the current difficulties in cutting and collecting grass arisings related to both the requirement for specialist machinery and the issue of disposing arisings once collected. In contrast, very few sites fell into Category 4, as in most cases there will be a requirement for screening through woody planting as part of the planning application. In addition, field margins are often difficult to access for management and may become tussocky through lack of access rather than as an intentional biodiversity enhancement. Difficulties were encountered with some sites as they did not readily fit into a specific category. This is something being addressed in the revised standardised methodology.

Table 2: Site management categories as defined in the Standardised approach to monitoring biodiversity on solar farms

1	Optimal management for biodiversity with conservation cutting/grazing and no herbicide use. Arisings are removed from the site. A range of habitats (e.g. meadows, tussocky grassland, woodland planting, hedgerow planting) are present.
2	Conservation cutting/grazing. Arisings are left on the site with signs of a thatch of vegetation in places. A range of habitats are present. Herbicides may be used, but spot treatment only.
3	Site cut or grazed throughout the season leading to short sward in the summer months. However, some other habitats present such as tussocky margins or planted hedgerows/woodland. Use of herbicides apparent (i.e. blanket spraying beneath panels).
4	Site cut or grazed throughout the season leading to short sward in the summer months. No other habitats (tussocky margins, new hedgerows/woodland). Use of herbicides apparent (i.e. blanket spraying of fields or beneath panels).
5	Site unmanaged or "other".

Bee orchid, Hannah Montag, Clarkson & Woods

Botany

Botanical quadrats

A total of 1,504 botanical quadrats were assessed across the 87 solar farms. A mixture of 1 m x 1 m (75%) and 2 m x 2 m (25%) quadrats were used across sites, but as a statistical analysis showed no impact on survey results, it is thus possible to compare data collected from both quadrat sizes.

At most sites, five quadrats were assessed directly beneath the solar panels ("Under"; a total of 503 quadrats), five were assessed between the rows of solar panels ("Between"; 506 quadrats) and five were assessed outside the main footprint of the solar panels, in field margins or other areas within the security fencing ("Outside"; 387 quadrats). At some sites, additional quadrats were assessed in areas managed especially for biodiversity ("Biodiversity"; 94 quadrats). These locations were within an adjacent field to the solar farms. They were also managed in the same way as the solar farm sites, prior to construction ("Control", 15 quadrats). However, quadrats in control areas were excluded from analyses as they were outside of the solar farm itself and thus managed differently.

On average, 17 quadrats were assessed at each site (encompassing "Under", "Between", "Outside" and "Biodiversity" areas), ranging from 14 to 33. More quadrats tended to be surveyed at larger sites and those with more variation in habitat types.

Botanical species richness

Across all solar farms monitored in 2023, a total of 298 plant species were recorded, including 59 species of graminoid (grass, sedge or rush), 211 broadleaf plants and 28 other species including woody plants, climbers, ferns and agricultural species.

Yorkshire fog (*Holcus lanatus*) was the most frequently recorded graminoid species, present in more than half of all quadrats assessed (52%), followed by common bent (*Agrostis capillaris*) which was present in 35% of quadrats and red fescue (*Festuca rubra*), found in almost a third of quadrats (32%). Interestingly, these grasses are less associated with agricultural grassland which tends to comprise a monoculture dominated by ryegrasses, indicating that these solar farms are moving towards a more diverse grassland more typical of low intensity management[3].

The most frequently recorded broadleaf species were cut-leaved crane's-bill (*Geranium dissectum*), common dandelion (*Taraxacum officinale*) and creeping buttercup (*Ranunculus repens*), each present in 15% of quadrats. White clover (*Trifolium repens*) and cleavers (*Galium aparine*) were also common within solar farms, recorded in more than 10% of all quadrats. These species (apart from the cranes bill) are indicative of high nutrient levels and may be prevalent due to residual fertilizers which remain present in the soil. Soil nutrient levels are expected to reduce over time, which may result in a greater diversity of species.

The number of species recorded inside quadrats varied, ranging from one to 24, but with an average of five species (including all plant types). When considering the two main plant types (graminoid and broadleaf), species richness was greatest in "Biodiversity" areas (Figure 2). Interestingly, on average, more broadleaf plant species were recorded

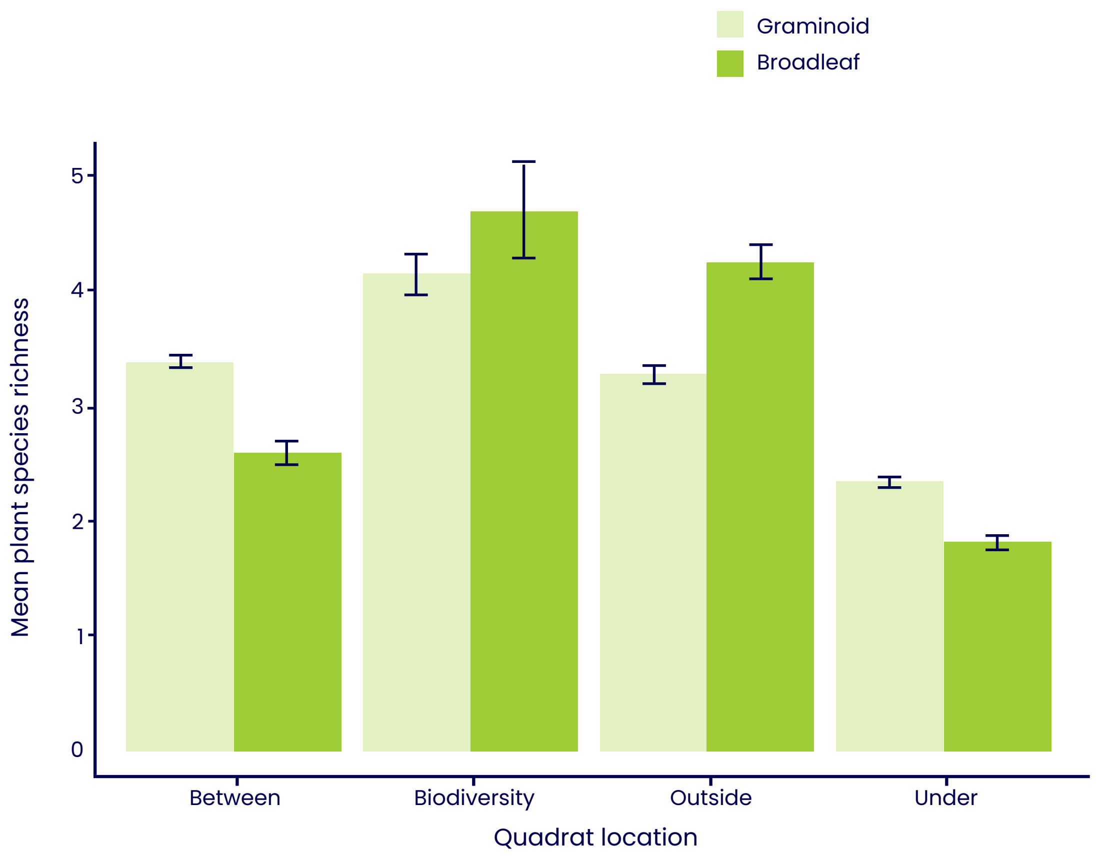


Figure 2: Mean species richness of graminoid and broadleaf plant species inside quadrats surveyed in different areas of the solar farm (n = 1,489, all quadrats excluding those in "Control" areas). Error bars represent standard error.

in "Biodiversity" and "Outside" quadrats, compared to graminoid species, whereas in "Between" and "Under" quadrats, there were more species of graminoids..

There was also variation in plant species richness at the site level. On average, a total of 27 plant species were recorded across each site, ranging from nine to 52. Variation in plant species richness is likely due to a combination of factors but solar farm management will be influential. Figure 3 shows how the number of plant species recorded on a site, on average, increases with solar park biodiversity management score. The two sites in Category 5 showed a high diversity of plant species due to the open mosaic habitat on one of the sites; this is a habitat that can be particularly ecologically important often with a wide variety of plant species present.

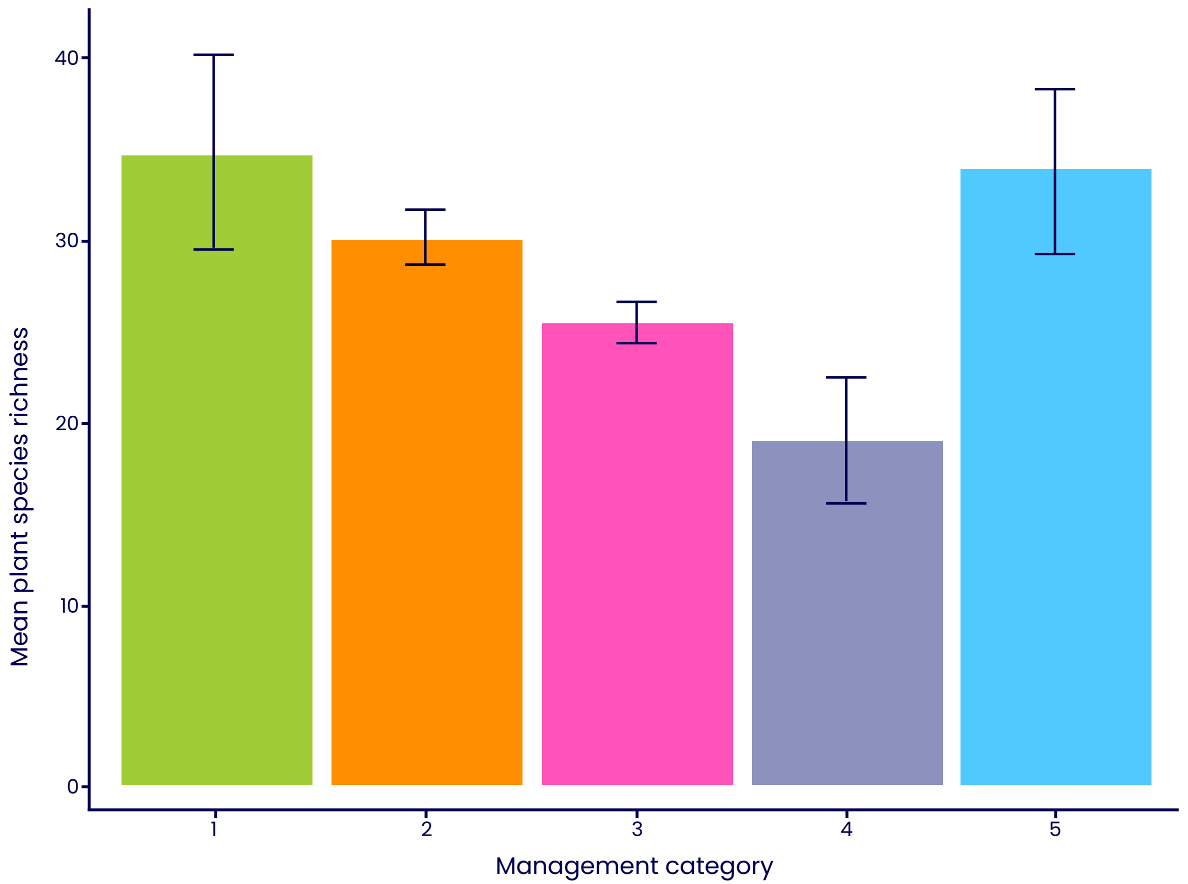


Figure 3: Mean plant species richness by management category (n = 87, all solar farms). Most sites were in management Category 3 (n = 39) or 2 (n = 36), with fewer in Categories 4 (n = 8), 1 (n = 2) and 5 (n = 2). Error bars represent standard error.

Under panel wildflower planting, Guy Parker, Wychwood Biodiversity

Case Study

Sowing shade tolerant grasses and wildflowers beneath panels – results of a trial on NextEnergy solar farms

Shading by solar panels, both from rain and sunlight, can create an environment that does not suit many grassland species, often resulting in bare ground that allows problem species, such as curled dock (*Rumex crispus*) and common nettle (*Urtica dioica*), to establish. As such, NextEnergy Solar Fund commissioned Wychwood Biodiversity to undertake trials into suitable vegetation to grow beneath solar panels with the intention of suppressing problematic weed species such as common nettle and creeping thistle, while encouraging biodiversity.

Trials were established to create a low growing sward comprised of species native to UK woodland and hedgerows, tolerant of both shade and drought. The sward aimed to provide ground cover sufficiently dense to prevent the establishment of problem species, while increasing biodiversity value. The trials were undertaken at two solar farms, Emberton Solar Park and Temple Normanton Solar Limited, and used different approaches.

Seeding beneath panels

The first trial was undertaken at Emberton solar farm beneath three solar panel rows. Two shade tolerant fine grass mixes were sown (*Emorsgate EG9 and EG29*), with common vetch (*Vicia sativa*), selfheal (*Prunella vulgaris*), bird's foot trefoil (*Lotus corniculatus*), bluebell (*Hyacinthoides non-scripta*), primrose (*Primula vulgaris*) and hedge bedstraw (*Galium mollugo*) added. Seed was sown into a clean seed bed as per the supplier's instructions.

The site was monitored annually during the growing season for three years. Several sown grass and herb species, mainly red fescue (*Festuca rubra*) and hedge bedstraw (*Galium mollugo*), established and covered nearly half of the trial area in Year 1, but in Year 2 they were overgrown by agricultural grasses, mainly cock's foot (*Dactylis glomerata*) and Yorkshire fog (*Holcus lanatus*), encroaching from the wider solar farm. By Year 3 the seeded grasses and herbs had all but disappeared and the agricultural grasses dominated.

The trial suggested that the fine grass and wildflowers were not fast growing and robust enough to establish ground cover and were consequently swamped by agricultural grasses. This is a common problem where soil nutrient levels are relatively high (the site was formerly an arable field) and agricultural grasses are present.

Planting plugs and bulbs beneath panels

The second trial took place at Temple Normanton solar farm and was designed using more vigorous wildflowers that were planted as plugs and pot-grown plants, rather than seeds. In total, 1,000 bulbs of four species of wildflower and 1,050 wildflower plugs of seven species were planted beneath four panel rows. In addition, 150 native ferns were planted, most of which were evergreen.

The trial has been monitored for 2 years during the growing season to date. Establishment of pot-grown plants after Year 1 was positive, with approximately 80% of all plants surviving. Of the four bulb species that were planted, wild garlic (*Allium ursinum*) and bluebell (*Hyacinthoides non-scripta*) established well, whilst lesser celandine (*Ficaria verna*) and wood anemone (*Anemone nemorosa*) appeared to have been less successful.

Most of the plugs of all seven species survived, except in two areas where the topsoil was very shallow (only two or three centimetres deep). Two cranesbill species, herb robert (*Geranium robertianum*) and hedge cranesbill (*Geranium pyrenaicum*), as well as red campion (*Silene dioica*) established most successfully and formed a dense ground cover. Five species of fern were planted (a mixture of evergreen and deciduous species) and wherever there was sufficient soil depth, established well.

The outcomes of both trials indicated that the planting of potted plants and plugs was more successful than seeding, with most species establishing well, and several species forming a dense ground cover. The results indicate that a number of wildflower species can establish in under-panel conditions, but the ability to cover ground effectively may be influenced by a site's soil conditions. The next steps include selecting the most successful species for wider trials and trialling seeding and planting at larger scales.

Ferns growing beneath solar panels, Guy Parker, Wychwood Biodiversity

Case Study

Growing chamomile between rows of solar panels – results of a trial on a NextEnergy solar farm

Emberton Solar Park Limited, which is an asset owned by NextEnergy Solar Fund, commissioned Wychwood Biodiversity to undertake a trial to investigate the feasibility of growing chamomile as a cash crop within a solar farm. This was supported by WiseEnergy, TWIG and the NEC Biodiversity team. The scale of this trial was intentionally small to enable management of the crop by hand rather than by mechanical means wherever possible. NEC recognised that this trial was unlikely to be financially viable at this scale, but it would nonetheless help to define logistical processes and constraints.

Annual or German chamomile (*Matricaria recutita*) was selected as the most suitable variety for this study. The crop was sown into a clean seed bed (as per seed supplier's instructions) approximately 50 m long by 2 m wide between the rows of solar panels in the northern field of the solar farm. The seed was sown in September 2020, weeded in April the following year and harvested in two sessions in June and July. Once harvesting was complete, the crop was recultivated and resown for harvesting the following year.

The trial suggested that it is possible to grow annual chamomile between the rows of solar panels in the southern United Kingdom and to attain commercial yields when grown in small plots. No irrigation was required, and the initial harvest equalled 3.7 kg of wet flower heads, equivalent to 370 kg per hectare which is within the commercial yield range for chamomile in Northern Europe[4]. Wet heads were air dried and placed into glass jars for use as chamomile tea called 'Meadow Sweet.'

Whilst the trial was successful at this scale, manual weeding and harvesting were labour intensive, where 0.25 person days were needed for weeding (equivalent to 25 days per hectare) and 0.75 person days were required for harvesting (equivalent to 75 days per hectare). If chamomile were to be planted at a larger scale, this would be uneconomical and mechanical options would need to be identified. There are also costs associated with ground preparation (mechanical clearance of grasses, cultivation, sowing) which are higher compared to an open field, as compact equipment must fit between the panel rows. Next steps should therefore focus on identifying the best options for scaling up production using mechanised means.

Chamomile between the rows of solar panels, Guy Parker, Wychwood Biodiversity

Injurious weeds

Particular attention is paid to plant species categorised as "injurious weeds" under the Weeds Act 1959. Common ragwort (*Jacobaea vulgaris*), broad-leaved dock (*Rumex obtusifolius*), curled dock (*Rumex crispus*), creeping thistle (*Cirsium arvense*) and spear thistle (*Cirsium vulgare*) are all injurious weeds. These species are generally more aggressive colonisers that can lead to a reduction in species richness within a grassland sward. In agricultural land, these species can also damage crops or may be harmful to grazing animals, if allowed to proliferate. However, injurious weed species provide important food sources for invertebrates and are highly attractive to many bees, butterflies and moths.

Injurious weeds were recorded on the majority of solar farms (82%) and within 22% of all quadrats. The most frequently recorded injurious weed species were creeping thistle, recorded in 13% of quadrats, followed by broad-leaved dock (6% of quadrats), common ragwort (4% of quadrats), curled dock and spear thistle (each in 2% of quadrats).

Under the Weeds Act 1959, if injurious weeds are spreading to adjacent agricultural land, they need to be managed. However, injurious weeds do not require active control if they are not spreading or causing maintenance issues. As such, injurious weeds that are at lower density and considered to be under control may be left within a solar farm to benefit invertebrates and birds. By undertaking regular monitoring of sites, it is possible to detect emerging problems and identify specific areas within a solar farm which may require management.

Six spot burnet moth on common ragwort, Hollie Blaydes, Lancaster University.

Invertebrates

Common blue butterfly, Hannah Montag, Clarkson & Woods

Transect walks

Transects focusing on bumblebees and butterflies were walked on 73 solar farms (84% of sites). A total of 794 transects were walked across all sites, either between the rows of solar panels ("Between"; 382 transects) or in margins, open areas or areas managed for biodiversity ("Outside"; 371 transects). The locations of the remaining 41 transects were not specified ("Unknown"). Transects were 100 m in length and on average, eleven were walked on each solar farm, ranging from five to 19.

Along all transects, a total of 3,088 individual invertebrates were counted and there were around five times more butterflies recorded than bumblebees overall (2,589 individual butterflies compared to 499 individual bumblebees). A total of 25 butterfly species were observed; the meadow brown (*Maniola jurtina*) was by far the most abundant (a total of 1,386 observations), followed by the gatekeeper (*Pyronia tithonus*, 248 observations) and marbled white (*Melanargia galathea*, 243 observations). In comparison, at least six bumblebee species were recorded, where the red-tailed bumblebee (*Bombus lapidarius*; 186 observations) and white-tailed bumblebee (*Bombus lucorom*; 94 observations) were observed most frequently. The majority of bumblebee and butterfly species recorded along transects were relatively common, although the small heath butterfly (*Coenonympha pamphilus*), a Species of Principal Importance under the NERC Act, was observed along transects on ten sites.

On average, one bumblebee or butterfly species and four individuals were recorded along a transect (per 100 m). However, this differed depending on where the transect was located. For example, species richness in "Outside" areas was approximately double that of "Between" areas, on average (Figure 4). Moreover, three times as many bumblebees and butterflies were counted in "Outside" areas, compared to between the panel strings ("Between"; Figure 4). This is likely because "Outside" areas tend to be managed less intensively and may offer more feeding resources to invertebrates. The "Outside" areas are also often on the outskirts of solar farms and may also be closer to other habitats such as hedgerows, which provide resources and shelter to many species.

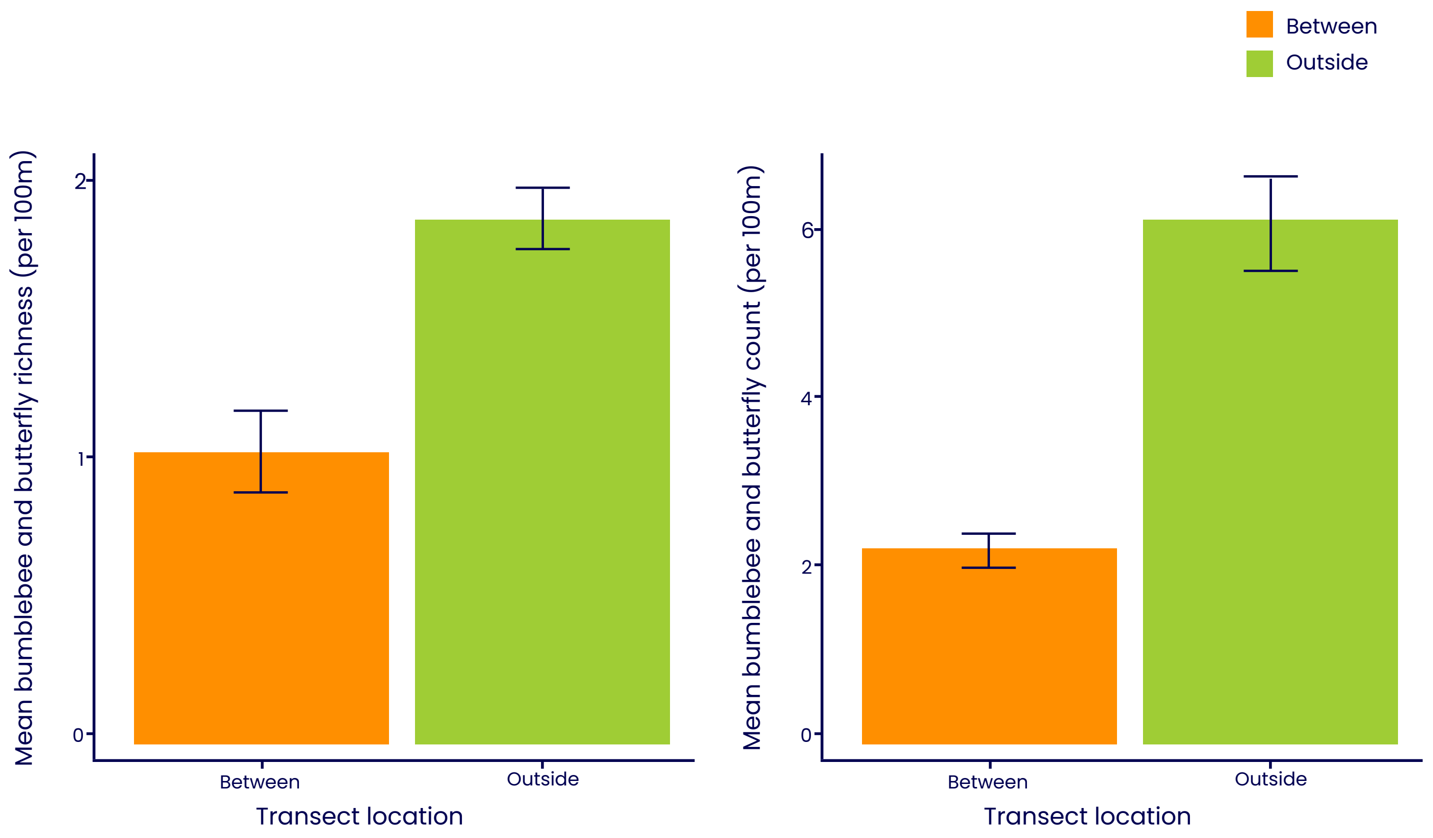


Figure 4: Mean bumblebee and butterfly species richness per 100 m (left) and mean count per 100 m (right) along transects walked between the panel strings ("Between"; n = 382) and in areas away from solar panels ("Outside"; n = 371). Error bars represent standard error.

Invertebrates

Scarce chaser dragonfly, Conor MacKenzie, Wychwood Biodiversity

Other invertebrate groups were also recorded along transects, including moths (six species), odonates (damselflies and dragonflies; five species), other bee species (three species), hoverflies (one species) and hornets (one species). Considering all groups, species richness varied across solar farms, ranging from zero to 15 species, with an average of six. Variation is likely due to a combination of factors, including site management, and it was found that species richness was greatest on solar farms that had a high biodiversity management score (those placed in Category 1; Figure 5). There was also a positive relationship between plant and invertebrate species richness, indicating that solar farms with more plant species can support a greater diversity of invertebrates (Figure 6).

It is also important to note that the conditions in which transects were walked are likely to have a large impact on the invertebrates recorded. Surveys should be undertaken in warm, dry and still weather when invertebrates are most active and transects walked in suboptimal conditions may underestimate invertebrate abundance or species richness. However, due to inflexibility in survey schedules it is not always possible to walk transects in optimal conditions and therefore biodiversity could be underestimated in some cases.

Incidental observations

Alongside transect walks, 2,809 invertebrates were counted as part of incidental observations on solar farms, where ecologists recorded invertebrates they saw whilst undertaking other surveys. At least 83 species were identified, including six bumblebee species, 24 butterfly species, nine moth species, 17 odonates (dragonflies or damselflies) and various grasshoppers, crickets, beetles, flies, hornets, ladybirds and spiders. Notable species included the Norfolk hawker dragonfly (*Aeshna isoceles*), which is a protected species listed as Endangered, and scarce chaser dragonfly (*Libellula fulva*) which is listed as Near Threatened.

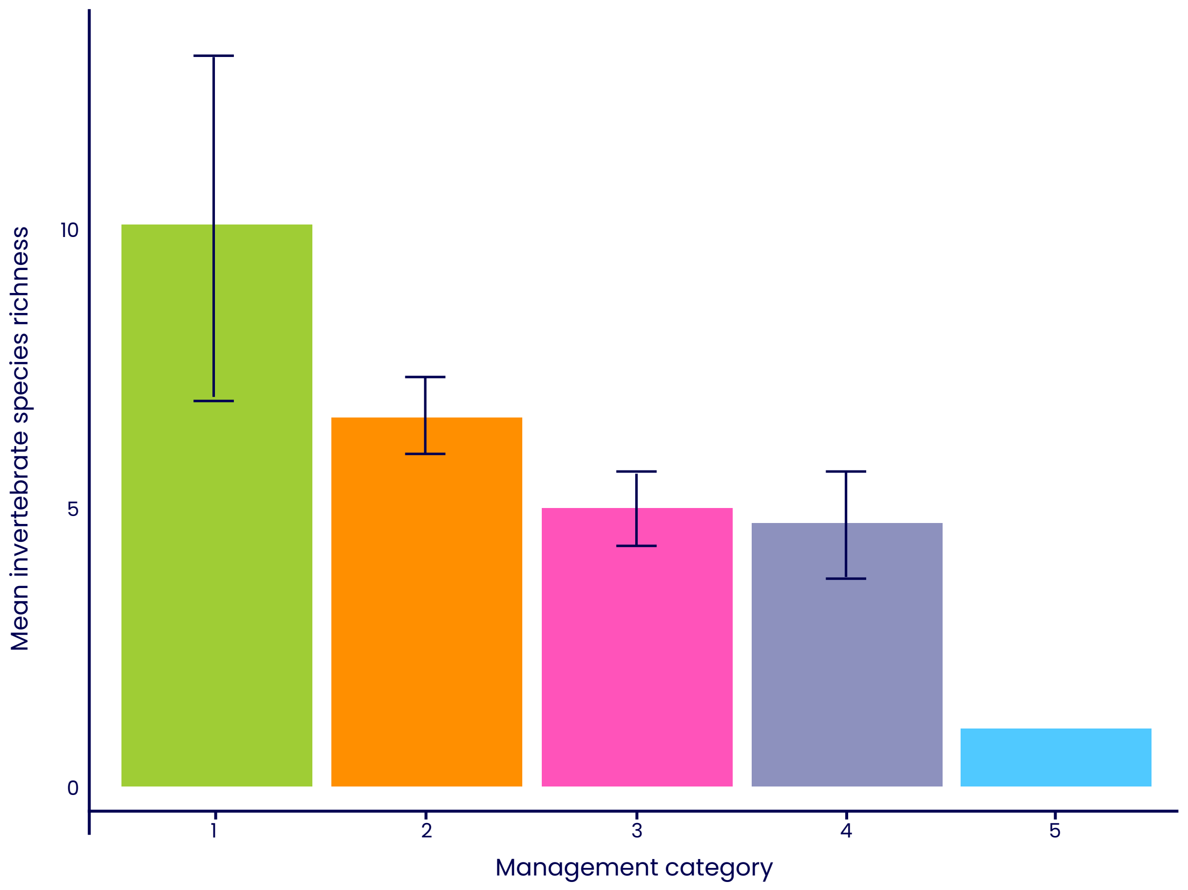


Figure 5: Mean invertebrate species richness by management category (n = 73, including only solar farms where invertebrates were recorded along transects). Most sites were in management category 3 (n = 34) or 2 (n = 27), with less in categories 4 (n = 8), 1 (n = 2) and 5 (n = 2). Error bars represent standard error.

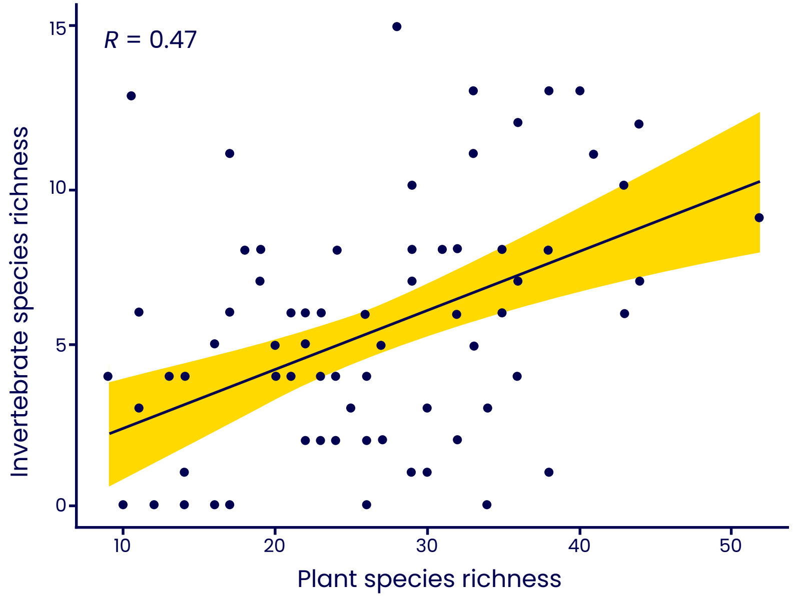


Figure 6: The relationship between plant and invertebrate species richness on solar farms (n = 73, including only solar farms where invertebrates were recorded along transects). The black line represents the trend line and shaded areas represent 95% confidence intervals. The R value is the Pearson correlation coefficient.

Birds

Common buzzard, Harry Knight-Smith, British Solar Renewables

Bird surveys

A total of 67 structured bird surveys were undertaken across solar farms. Bird surveys were conducted on 59 solar farms, where most sites had one survey undertaken (86%), but others had two (undertaken during different months; 14%). The survey methodology included a walked transect across the site so that all habitats were accessed within 50 m; all birds heard and seen were recorded with notes on their behaviour (including singing, foraging and flying over).

A total of 99 bird species were recorded during structured surveys, of which the majority were BTO Green Listed (47%), but a notable proportion were Amber (25%) or Red (21%) Listed Species of Conservation Concern. Six species had no status, representing those not categorised by the BTO as they are non-native (such as game birds: 6%). In terms of abundance, 7,886 individual birds were counted as part of structured bird surveys. On average, 134 individual birds were counted on a solar farm, but there was much variation, with counts ranging from 1 to 389 individuals.

The most abundant species was the wood pigeon (*Columba palumbus*, 974 individuals), an Amber Listed Species, recorded on almost all solar farms where bird surveys were undertaken (56 sites; Figure 7). The most abundant Red Listed Species was the starling (*Sturnus vulgaris*, 658 individuals), recorded at 18 sites (Figure 7). Skylarks (*Alauda arvensis*) were the Red Listed Species recorded across the highest number of sites (71%), with 279 individuals observed across all bird surveys (Figure 7). Whilst not assessed in terms of conservation status, a notable species recorded at one solar farm was the common rosefinch (*Carpodacus erythrinus*). This species is a scarce visitor to the UK, with very few breeding records, and is a Schedule 1 Protected Bird under the Wildlife and Countryside Act 1981.

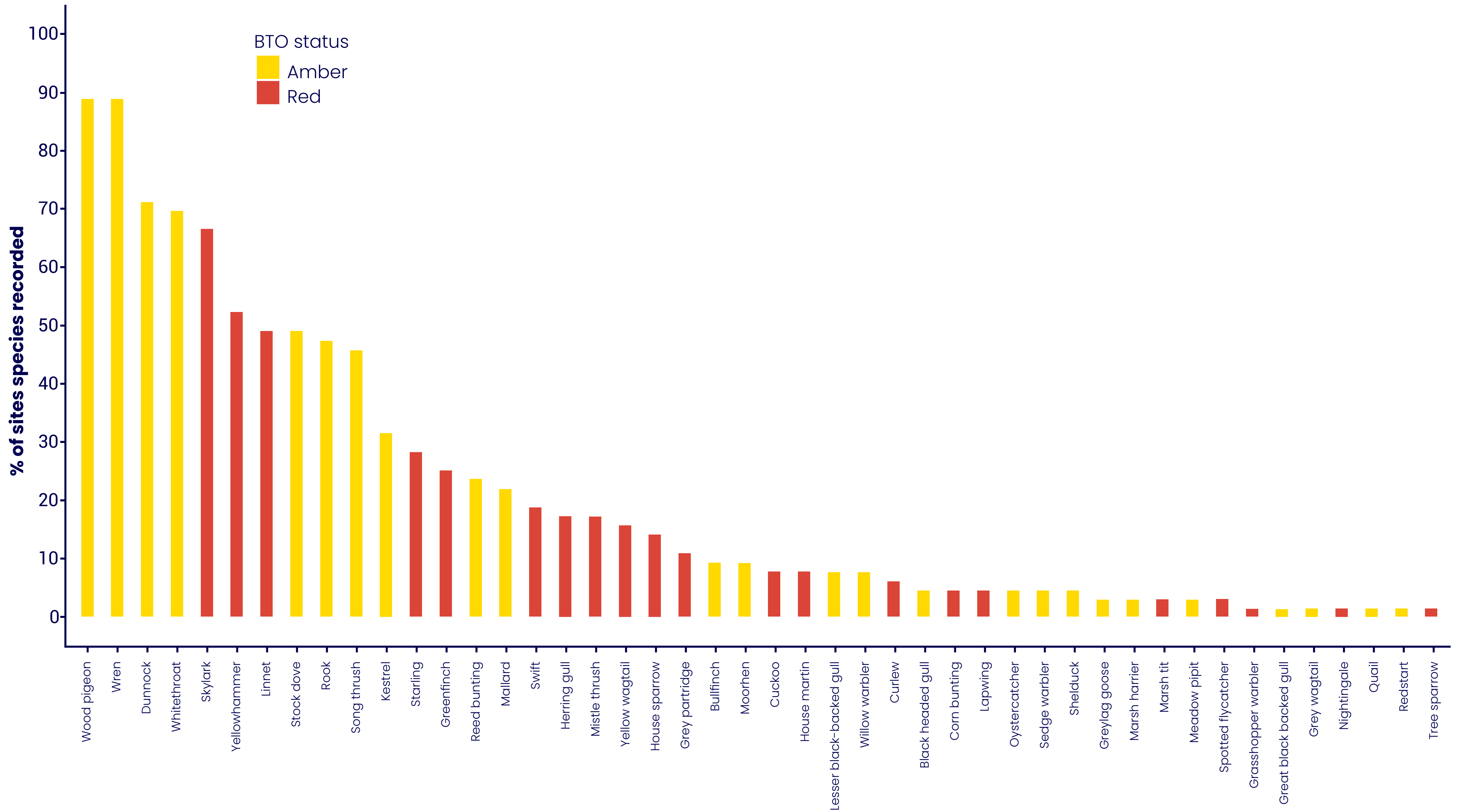


Figure 7: The percentage of sites each BTO Amber or Red Listed bird species was recorded (n = 59, including only solar farms where structured bird surveys were undertaken), arranged by most to least frequently recorded.

On average, 25 bird species were recorded during surveys at each solar farm, but this varied from one to 47. As with invertebrate biodiversity, variation in bird species richness is likely due to several factors including characteristics of the solar farm itself, the location of the site and weather conditions. Whilst no clear patterns between bird biodiversity and site management was directly found, there were positive relationships between bird species richness and plant species richness, as well as a positive relationship between bird abundance and invertebrate abundance across solar farms (Figure 8).

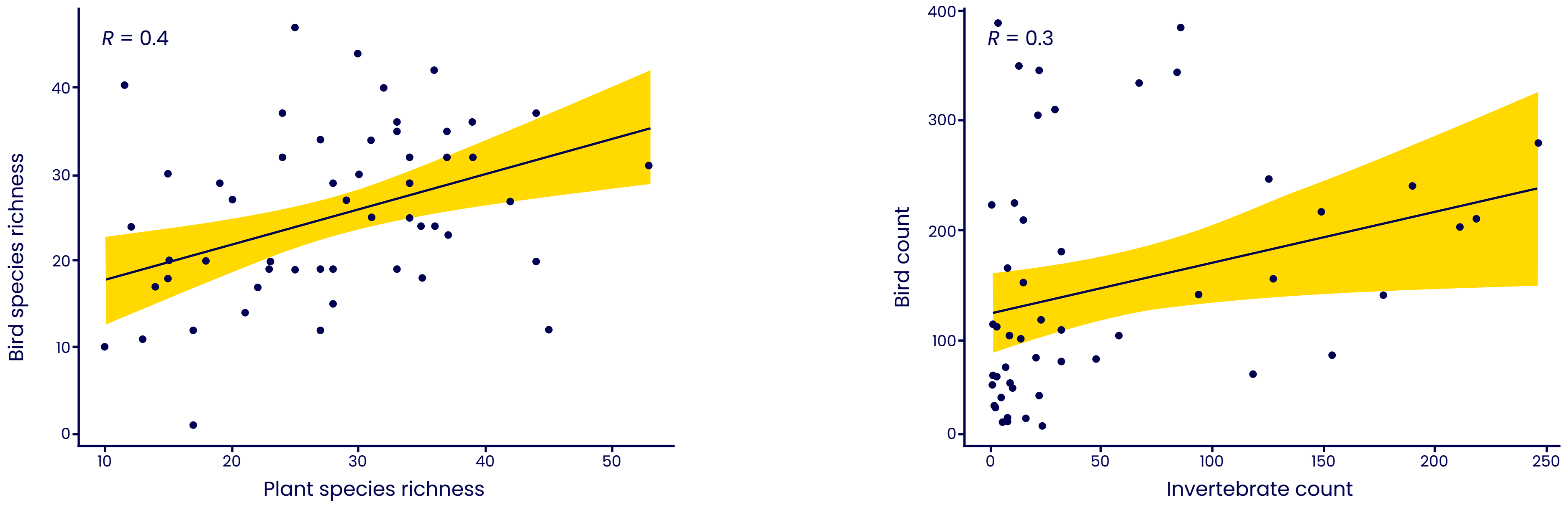


Figure 8: On the left, the relationship between plant and bird species richness. On the right, the relationship between invertebrate and bird count (abundance; n = 59, including only solar farms where structured bird surveys were undertaken). The black line represents the trend line and shaded areas represent 95% confidence intervals. The R value is the Pearson correlation coefficient.

Ground nesting birds

Skylarks continue to be recorded regularly on solar farms, however, no records of nesting on solar farms have been observed yet[5]. One bird survey conducted in 2023 focussed on nest searching on a site where skylarks were observed. No nests were found, however, a bird was observed regularly collecting food from within the solar farm then flying to an adjacent arable field, indicating that the solar farm offered a preferred resource for foraging by skylarks.

Other ground nesting bird species recorded included oystercatcher (*Haematopus ostralegus*) on three sites, where individuals were observed foraging or flying over the solar farm. Meadow pipit (*Anthus pratensis*) were also observed on two sites and breeding behaviour was observed at one solar farm.

Incidental observations

Incidental observations of birds also took place at 41 solar farms (sometimes alongside structured bird surveys, but also at sites without bird surveys). As part of incidental observations, 1,621 individual birds made up of 65 species were recorded across all solar farms. In total, twelve Red Listed Species of Conservation Concern and 17 Amber Listed species were observed. Birds of Conservation Concern recorded as part of incidental observations, but not structured surveys, included Dartford warbler (*Curruca undata*; Amber Listed) and tree pipit (*Anthus trivialis*; Red Listed).

Skylark, Conor MacKenzie, Wychwood Biodiversity

Mammals

Brown hare, Harry Knight-Smith , British Solar Renewables

Mammal observations

While conducting other surveys, ecologists also noted down any mammals they observed on solar farms, or saw signs of (such as scat, footprints and feeding remains). Mammal observations were made on 33 sites (38%), with ten species observed or signs of their presence recorded. These included badger (*Meles meles*), fox (*Vulpes vulpes*), brown hare (*Lepus europaeus*), rabbit (*Oryctolagus cuniculus*) and weasel (*Mustela nivalis*), along with small mammals including common shrew (*Sorex araneus*) and field vole (*Microtus agrestis*). Fallow deer (*Dama dama*), muntjac deer (*Muntiacus reevesi*) and roe deer (*Capreolus capreolus*) were also sighted.

The most frequently observed species was the brown hare, making up 40% of observations. This is a Species of Conservation Concern which thrives on solar farms; on one site visited large groups of brown hares were recorded, with the site effectively being grazed by this species.

On sites where mammals were observed, their presence has likely been underestimated given that some species are less active during the daytime, many small mammal species are less visible and targeted surveys were not conducted. Future surveys may include more targeted approaches such as small mammal trapping, camera traps and eDNA.

Bats and solar farms

Recently published research has shown solar farms may influence bat activity, although the reasons are not understood. More information and research is needed on how bats interact with solar farms and this will, hopefully, become a focus of future monitoring and management of operational sites.

Case Study

Using eDNA to identify vertebrates on solar farms – results of a trial on a Gridserve solar farm

eDNA has been used in the past to detect the presence of individual species such as the great crested newt (*Triturus cristatus*) in ponds. However, it has recently become possible to extract eDNA for multiple species and other biodiversity groups from water and even soil and air samples including mammals, birds and reptiles.

Gridserve commissioned Wychwood Biodiversity to undertake biodiversity assessments of four solar farms and at one site, requested the sampling of a pond to assess the technique.

eDNA was collected in the field and the samples were analysed in the laboratory for the presence of all vertebrates. The results provided the following details:

- Number of species: 12 (three amphibians and seven birds)
- Identity of species: 100% of species were identified to taxonomic Order; 58% of species were identified to Genus.
- Taxonomic relatedness was displayed as a dendrogram (Figure 9)
- Number of threatened species: none
- Presence of invasive species: none

Information provided by eDNA is valuable as it allows the detection of cryptic species (species which are hard to detect conventionally), such as polecat (*Mustela putorius*), harvest mouse (*Micromys minutus*) and otter (*Lutra lutra*). This technology will also be useful in identifying invasive species and Red Listed species, both of which are relevant to Environmental, Social and Corporate Governance (ESG) reporting and the ongoing management of solar farms.

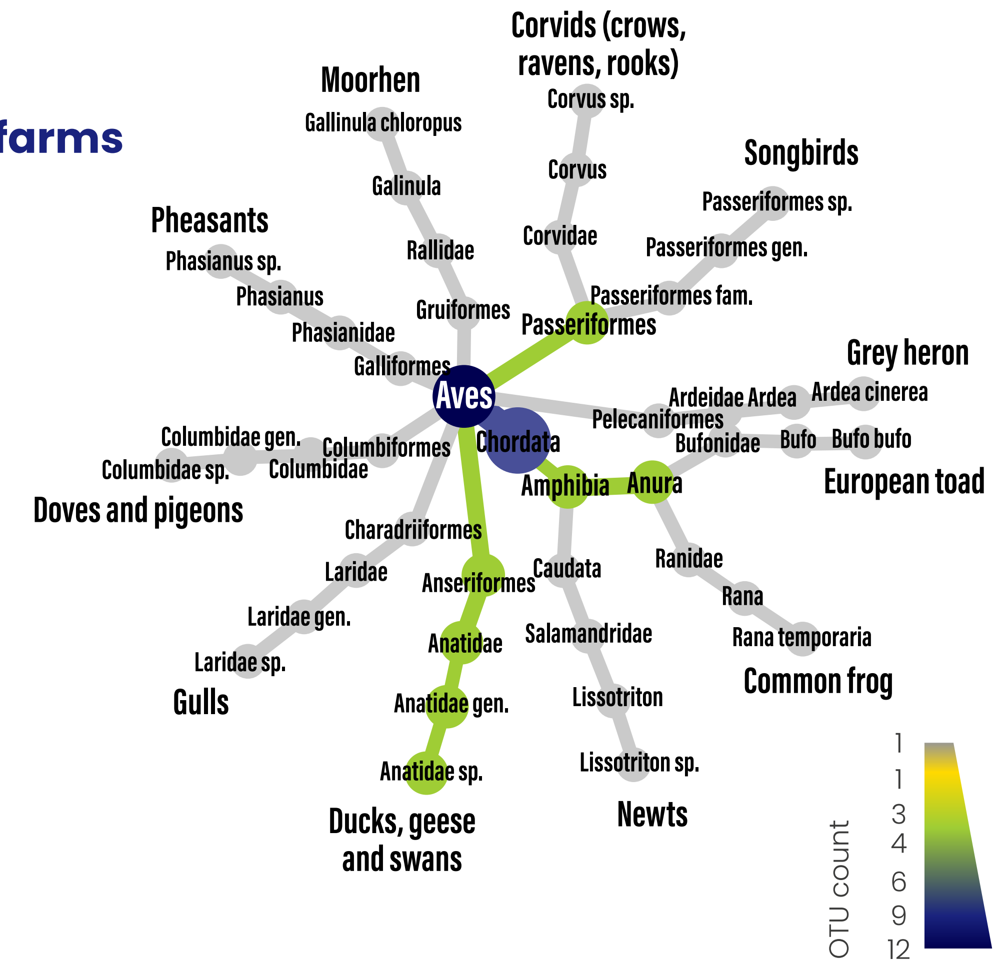


Figure 9: A dendrogram providing a tree-of-life view of the vertebrate species detected using eDNA and their taxonomic relationship. Names on the same branch are more similar than those on different branches and the dendrogram is structured with the highest taxonomic rank in the centre. Branch colour indicates the number of species along a scale, from grey which represents very few species to blue, representing many species.

Biodiversity Net Gain on solar farms

Diverse easement, Hannah Montag, Clarkson & Woods

Biodiversity Net Gain (BNG) is a policy mechanism to stimulate the creation and improvement of natural habitats and biodiversity. BNG enforces a measurably positive impact ('net gain') of all new developments on biodiversity, with a focus on on-site benefits, although credit trading will enable off-site improvements. From 12 February 2024, BNG is mandatory for new planning applications, including solar farms, which will need to deliver at least a 10% increase in relation to the pre-development biodiversity value of the development granted permission. Implementation for Nationally Significant Infrastructure Projects is planned for November 2025.

Solar farms offer the potential to manage land for BNG well above the 10% requirement, particularly as most developments are sited on previously intensively managed agricultural land. During the construction and operational phases of the solar farm, there can be minor habitat loss due to the creation of access tracks, substations and mounting frames. However, the overall infrastructure footprint of a solar farm can be as little as 2% of the total land area, with the panels oversailing around 40% of land within the fenced boundary, on average.

BNG can be calculated by an ecological consultant by comparing the baseline Biodiversity Units (derived from the UK Habitat Classification and taking into account habitat size, condition, distinctiveness, and location) measured in the pre-development state, with results that would be expected once the project is operational, along with any ecological enhancements included. Previous use of the metric for BNG on solar farms has proven challenging due to poorly understood impacts of panel structures on the habitats below.

Research relating botanical datasets to the BNG metric and UK Habitat definitions in different areas of solar farms is ongoing, led by Clarkson and Woods, Natural Power and Wychwood Biodiversity. The outcomes from this research will provide an evidence base and insight relevant to solar farm planning applications, including highlighting some of the wider factors that influence vegetation establishment. Natural England is using the outcomes of this research to produce a case study for applying BNG to solar farm developments, which will be published in 2024.

Several asset owners are now using the BNG metric to assess their "biodiversity stock" in a standard, measurable way; a calculation can be made based on an existing solar farm to assess its current ecological value and explore ways in which this can be increased.

Wildflowers, Hannah Montag, Clarkson & Woods

Tree planting on solar farm, Henry Sturgess, Clarkson & Woods

Case Study

Foresight JLEN Environmental Assets Group portfolio - biodiversity study

Foresight JLEN Environmental Assets Group, a sustainability-led investment fund, commissioned Clarkson and Woods to undertake a biodiversity assessment of ten of their ground-mounted solar farm assets in 2023. The aim was to use the Biodiversity Net Gain (BNG) metric to measure the baseline units on these sites, consider potential options for ecological enhancements and calculate their potential BNG uplift.

It was found that measures could be introduced to significantly increase the habitat value on all ten sites. The anticipated biodiversity increase ranged from 8 to 110%, with significant delivery of both Habitat and Hedgerow Units – the "currency" of the BNG system, which can be utilised in trading or habitat banking.

Figure 10 shows one of the sites within the study, Pylle solar farm, where the habitat survey revealed 60.54 Habitat Units and 26.22 Hedgerow Units within the site. Recommendations that could potentially increase the number of units included enhancement of existing Modified Grassland to a higher condition, new pond and wetland area creation within a low-lying part of the field, tree planting with locally appropriate species, enhancement of existing hedgerows and new hedgerow planting. The calculations resulting from these enhancements showed a potential uplift of 13.97 Habitat Units and 10.65 Hedgerow Units; a total net gain of 23% for habitats and 41% for hedgerows.

If such recommendations are accepted, a legal agreement would need to be secured and a finalised Habitat Management and Monitoring Plan prepared and submitted to the relevant authority to secure the BNG units and to trade them. The site would also need to be registered with Natural England.

Figure 10: Habitat enhancements proposed at Pylle solar farm.

Walnut orb weaver, Hannah Montag, Clarkson & Woods

Looking ahead

The Solar Habitat report will be issued annually, presenting findings from ecological monitoring conducted in the preceding year.

It's not possible to directly compare findings from 2022 to those from 2023, as only 17 sites were monitored in both years. One of the reasons for this is that monitoring doesn't always happen annually. Another is that the key components of the current methodology are designed to be achievable within a single day, so the time of year or even the weather on the day can have a marked impact on the results. However, the accumulation of data collected from the same sites over multiple years will enable the exploration of the trends and impacts of management practices over time.

While the number of solar farms monitored using the standardised approach increased by 50 sites from 2022 to 2023, the sites surveyed remain only a small number of those operational across the UK. It is anticipated that the methodology will be used by more ecological consultancies and applied across more solar farms in future years as demand for monitoring grows and the solar sector expands.

The standardised methodology has been revised in line with feedback and evolving approaches, as well as the experience of its use in the field over two years. Alongside the partners on the project, environmental NGOs and ecological consultancies have been involved in updating the standardised methodology and in line with feedback an update will be will be released in 2024

In an effort to improve the methodology, authors of the report have been looking at how the industry can better collaborate with voluntary citizen science projects monitoring biodiversity on operational solar farms. This may include multi-day bird and butterfly surveys carried out by the volunteers of environmental NGOs.

A survey form for collecting monitoring data using the standardised approach has also been produced. This was still in development at the time of publication.

To access the latest information, including The Standardised Approach to Ecological Monitoring on Solar Farms and monitoring form please scan the QR code or go to solarenergyuk.org.

Please visit solarenergyuk.org/resource/solar-energy-uk-guidance-a-standardised-approach-to-monitoring-biodiversity/

Or scan the QR code to access this guidance.

Case Study

Using Wild Power's Solar Biodiversity Scorecard to assess and improve solar farm biodiversity

Wild Power is an independent third-party certification standard for biodiversity and natural capital enhancements on solar farms. It is built around a 23-point scorecard and accompanying technical notes on biodiversity management.

Wild Power's scorecard combines on-site and desktop activities to provide a holistic assessment of biodiversity on solar farms. It incorporates assessment of site and surrounding areas, species, habitat and guild management, connectivity and management systems in place for biodiversity, the degree of site monitoring, photo documentation, fulfilment of obligatory and voluntary biodiversity commitments, ecosystem services and research contributions (Figure 11).

The scorecard can be used to align site design, construction, and management with best practise in natural capital, and scores allow comparison and benchmarking across projects, offering a way to set and communicate standards via a score-based gold/silver/bronze certification scheme (Figure 12).

Wild Power's scorecard has been used to identify, scope and prioritise both on- site and desktop-based opportunities for biodiversity enhancement on solar farms. Actionable options for improving biodiversity and Wild Power scores include creation and management of valuable native habitats, and strengthening ecological connectivity. Such measures typically require material investment of time and capital and are most easily addressed at site design/planning/construction stages. Further actionable areas for improving site Wild Power scores include site documentation, microhabitat provision such as log piles, bat and bird boxes (often the simplest post-construction on-site action for biodiversity enhancement), fulfilment of obligatory planning commitments and voluntary actions to improve habitat,

online assessment of ecosystem service potential, data submission for research and comprehensive photo documentation.

Wild Power certification provides a basis for benchmarking and communicating investment in solar farm biodiversity. Wild Power certification is a way to demonstrate commitment to biodiversity, creating value in stakeholder management, fund raising, and compliance, and providing monetisation opportunities for projects which comply with Wild Power standards via the development of biodiversity-rich consumer electricity products.

Wild Power completed its beta testing phase in 2023, during which time the scorecard was used to assess 39 sites in the UK from community-to commercial-scale solar farms (Figure 11). Wild Power's certification scheme is due to launch in 2024, with sites currently working towards achieving the UK's first Wild Power certification.

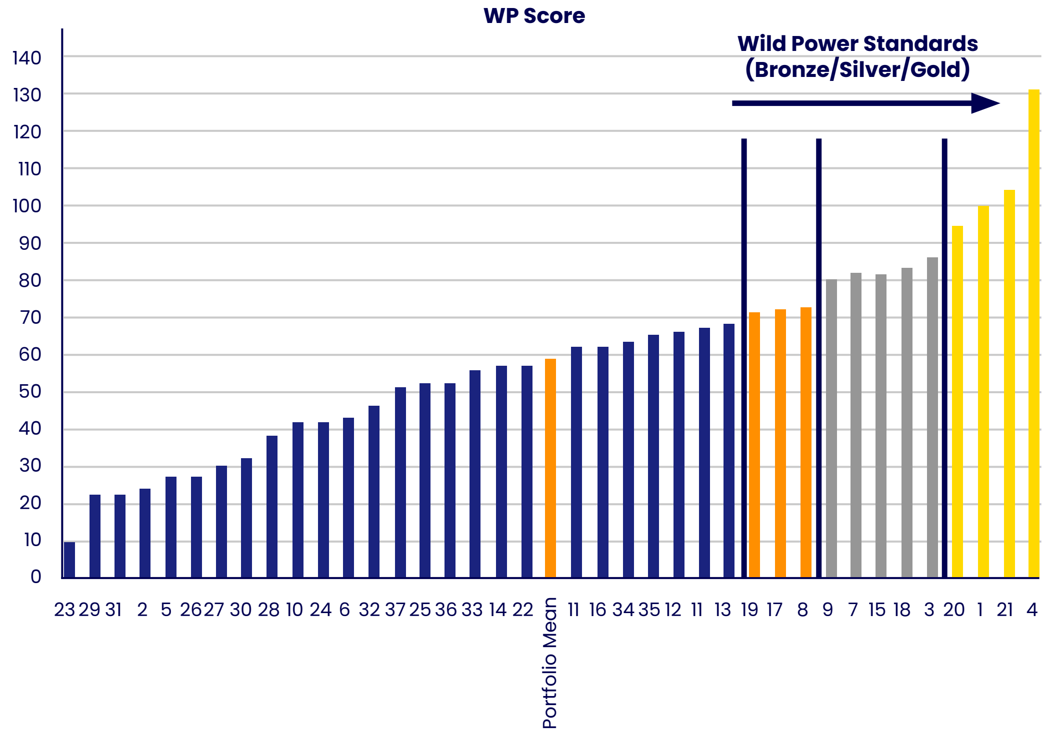
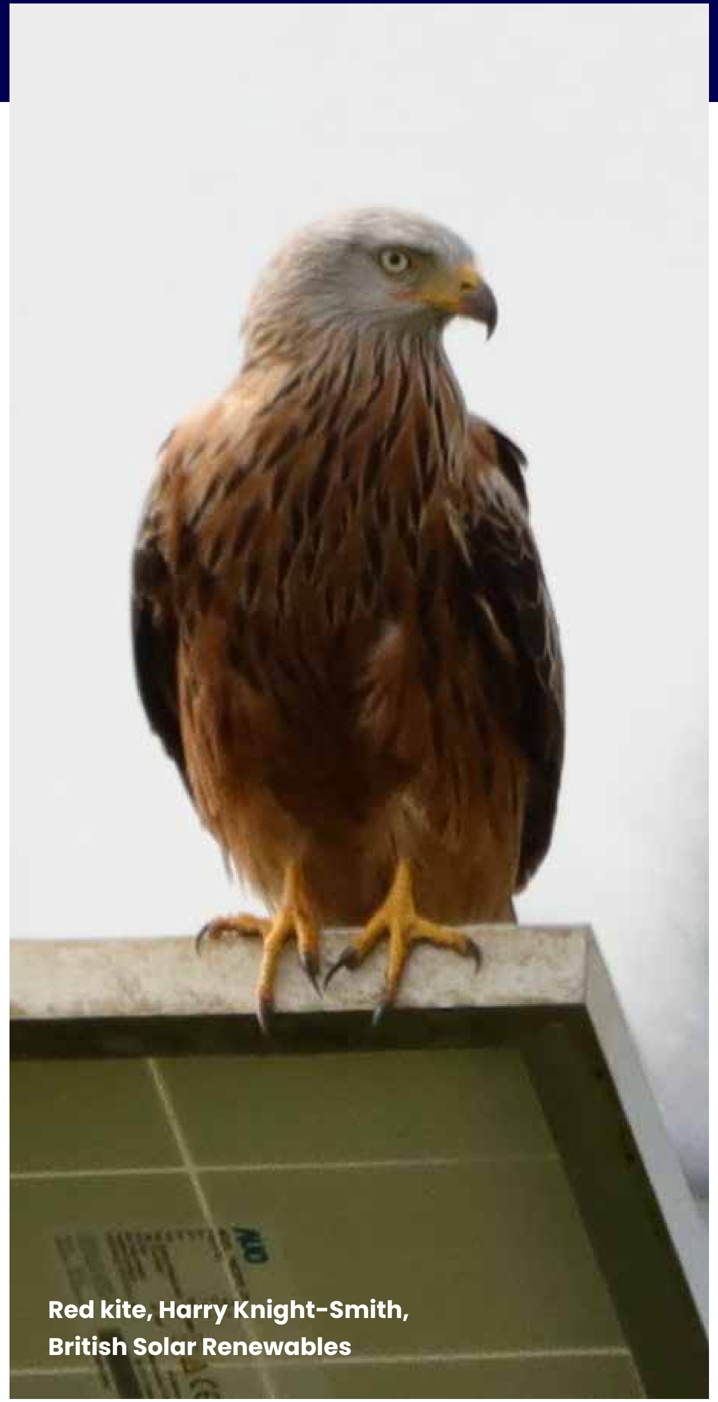


Figure 11: The score distribution for 39 solar farms assessed using the Wild Power scorecard during the beta testing phase.

Category	WP Scorecard Item(s)	Notes	Possible uplift		
			Site X	Site Y	Site Z
Score at survey			X	Y	Z
Delta to WP status			+ ●	+ ●	+ ●
Site documentation	1-7	Max 19 pts	+ ●	+ ●	+ ●
Microhabitat provision	11	1/2 pt per microhabitat, max 10 pts	+ ●	+ ●	+ ●
Current penalty for missed planning commitments	15	-2pts per missed commitment	+ ●	+ ●	+ ●
Online assessment of ecosystem service potential	18	+5 pts	+ ●	+ ●	+ ●
Photo documentation	19-20	Max 14 pts, subject to site details	+ ●	+ ●	+ ●
Data submission for research	23	+3pts	+ ●	+ ●	+ ●
TOTAL ACHEIVABLE UPLIFT			+ ●	+ ●	+ ●
ACHEIVABLE SCORE AND WILD POWER STANDARD			+ ●	+ ●	+ ●

Figure 12: Example scorecard results provided by Wild Power that includes an action plan that identifies opportunities to improve biodiversity. Opportunities range in scope, investment and time requirement and can be used to produce workable and costed biodiversity action plans.



Red kite, Harry Knight-Smith, British Solar Renewables

Contributors

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RES – power for good

GRIDSERVE Sustainable Energy

Foresight

Eden Renewables

JLEN

Octopus Energy Generation – investing for impact

References

1. bto.org/sites/default/files/publications/bocc-5-a5-4pp-single-pages.pdf

2. Based on data provide by Solar Media Market Research.

3. National level data came from the Renewable Energy Planning Database which lists renewable energy projects in the UK, including ground mounted solar farms, allowing comparison between our sample and those across England, Wales, Scotland and Northern Ireland.

4. Yield of commercial chamomile ranges from 300-500lb per acre / 337-561 kg per Ha in Northern Europe (Foster, S. 1993. Herbal Renaissance. Gibbs-Smith Publishers, Salt Lake City, UT).

5. clarksonwoods.co.uk/wp-content/uploads/PDF/HF%20from%20InPractice117_Sep2022-9.pdf

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