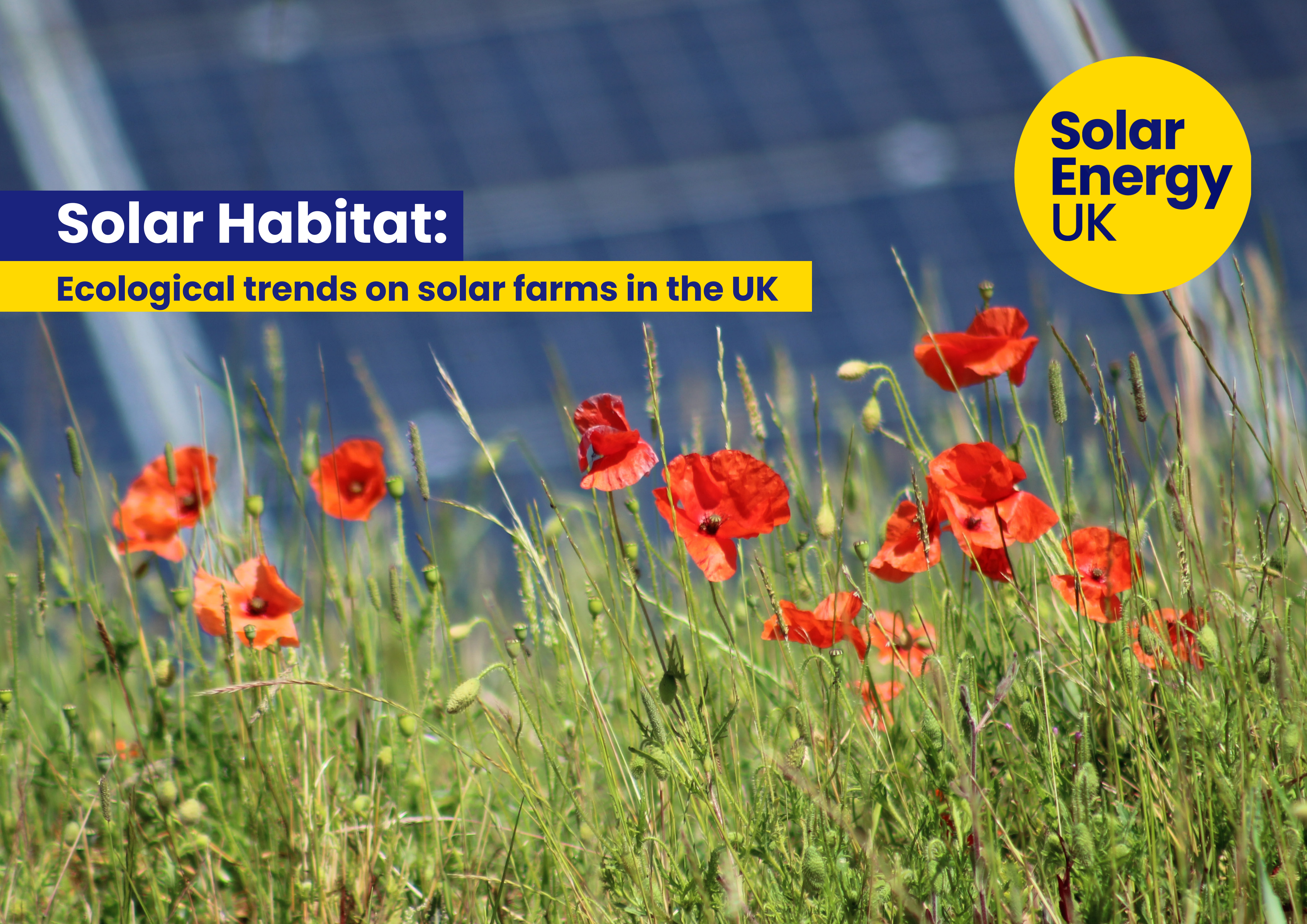
# Solar Habitat:

## Ecological trends on solar farms in the UK



Solar Energy 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 over 320 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 and assessment of 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.

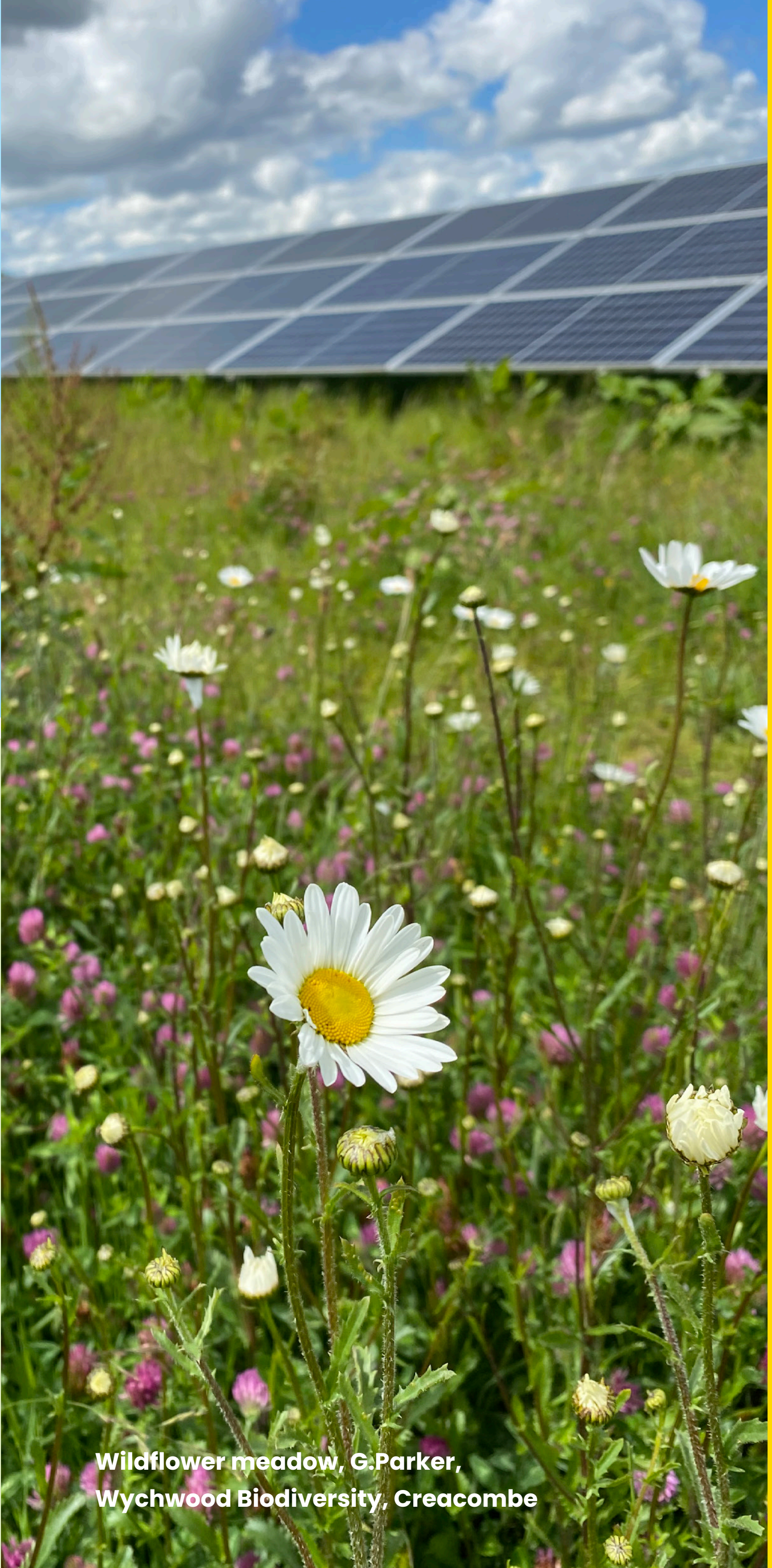
The Energy Environment Interactions team focus on improving understanding the implications of the energy transition on the environment, and how land use change for energy can be done in a way that delivers ecological, as well as climate, benefits. They sit within Lancaster Environment Centre, a 400-strong 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 habitat creation and management.

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 offer convenient and effective means to improve biodiversity, from a single site to an entire portfolio.

We provide technical services including input to planning applications, development of site management plans and ecological monitoring. We create and manage bespoke wildlife habitats. Our corporate services help businesses to develop biodiversity policies and strategies. Our supporting services include staff training, education, scientific research and marketing.



Wildflower meadow, G.Parker, Wychwood Biodiversity, Creacombe

# Contents



Front cover: Common Poppies, G.Parker, Wychwood Biodiversity, Oxfordshire

# Glossary

**Ad hoc (wildlife observation)** impromptu recordings of species outside a survey methodology

**Birds of Conservation Concern** British Trust for Ornithology amber or red-listed species

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

**Biomass** The quantity of living matter by weight or volume

**Botany** Relating to plants

**BTO** Birds Trust for Ornithology

**DNO station** Distribution Network Operator substation structure which houses technology which links the solar farm to the National Grid

**DNS** Development of National Significance under the Planning (Wales) Act 2015

**Ecosystem Services** the goods and services provided by ecosystems to humans

**Entomologist** A person that studies insects

**Graminoid** Grasses, sedges and rushes

**Hibernacula** Shelter for dormant animals such as reptiles over winter

**Injurious Weeds** Plants that can damage crops, habitats or ecosystems, as prescribed in the Weeds Act 1959

**Lepidoptera** An order of insects containing butterflies and moths

**MWh** Megawatt hours, a unit of energy

**NERC Act** Natural Environment and Rural Communities Act 2006

**NSIP** Nationally Significant Infrastructure Project under the Planning Act 2008

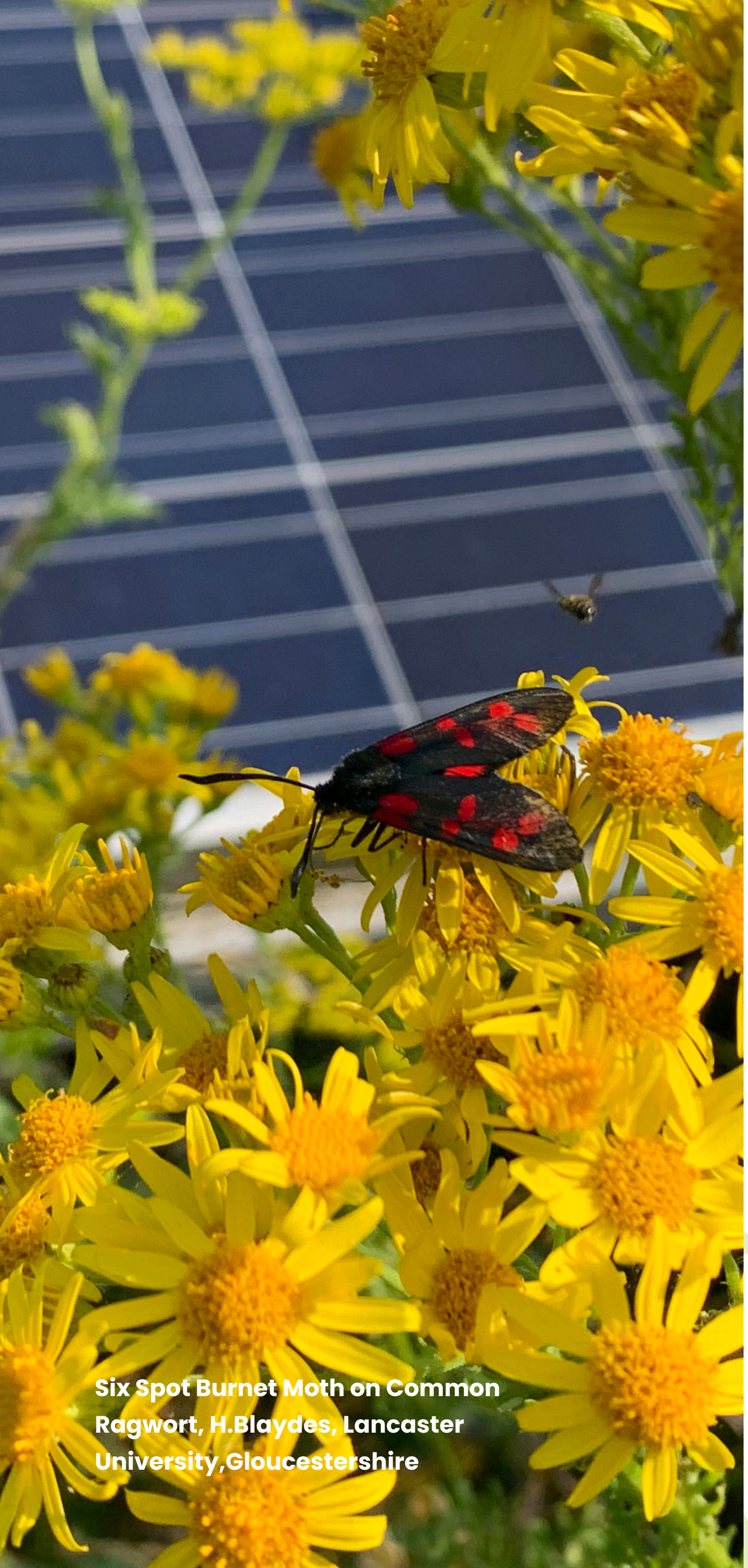
**Quadrats** A square plot of land marked out for for botanical assessment

**Strings (of panels)** A row of panels that are wired together

**Sward** Grassland area

**Transect** A straight line through a natural habitat used to make measurements or observations

**Vascular plants** Plants with vascular tissues (in this context includes all plants found within solar farms, excluding mosses)



Six Spot Burnet Moth on Common Ragwort, H.Blaydes, Lancaster University,Gloucestershire

# Summary & highlighted findings

Ecological monitoring over the last decade has shown that well-designed and well-managed solar farms have the potential to influence ecology and make significant contributions to addressing biodiversity loss in the UK.

However, much remains to be learnt about the relationship between the management of solar farms and the species and habitats they harbour. Of particular interest is how these relationships change over time. Until recently, monitoring of solar farms has not been applied consistently across the UK and this has made comparisons between sites difficult.

To address this, in 2022 Solar Energy UK (SEUK), Clarkson & Woods, Wychwood Biodiversity and Lancaster University published a standardised approach to ecological monitoring on solar farms; providing a uniform approach to how the solar industry collects ecological monitoring data on solar sites. This allows for the amalgamation of data; forming a robust, credible evidence base which gives sight to the ecological trends found on solar farms.

This pilot report outlines results from 37 operational solar sites surveyed in 2022 across the UK. These sites range in age, geography, and output. The report highlights the positive relationships solar farms can have with ecology, with a focus on botany, invertebrates, mammals and birds. Key highlights have been outlined on the next page.

## Botany

- Across 37 solar sites, a total of 178 plant species were recorded. An average of 32 species of plant were found on each site, with one site recording as many as 52 species.
- The most abundant group was grasses, with Yorkshire fog being the most abundant, found in 66% of quadrats. This was twice as many as cocksfoot, which was the second-highest species recorded in 28% of quadrats.

## Invertebrates

- 3764 individual invertebrates were recorded across all of the sites.
- The most commonly recorded was the Meadow Brown butterfly, although more notable species, such as the small health butterfly (which is a species of principle importance under NERC act) were recorded on nine sites.
- Solar farms with higher nectar productivity (from flower-rich grassland, created through appropriate management) can accommodate significantly higher bumblebee richness and abundance.

## Birds

- Across the solar farms surveyed, 91 different bird species were recorded from ad hoc sightings and structured bird surveys.
- Of the species recorded, 20 were BTO Red Listed Species of Conservation Concern, and 26 were BTO Amber listed.
- An average of 25 different bird species were recorded on each site, with 42 different bird species being recorded on one site.

## Mammals

- Ad-hoc sightings showed that mammals were recorded on 38% of solar farms, with six species observed or signs of their presence recorded (including badgers, rabbits, foxes and deer).
- Brown hares were the most frequently observed mammal species, making up 43% of the total count and recorded on 24% of sites.

Meadow Brown Butterfly on Common Ragwort, H.Blaydes,Lancaster University, Dorset

# Introduction

Solar Energy UK, in collaboration with Clarkson & Woods, Lancaster University and Wychwood Biodiversity have published this report highlighting ecological trends on solar farms in the UK.

Using the standardised approach to ecological monitoring, which was published in 2022, the report sets out a summary of ecological monitoring on operational solar farms. It looks at trends and observations to raise awareness of how solar farms and their management can interact with local biodiversity.

The report provides analysis on botany, invertebrates, birds and mammals found on solar farms. The report also looks into Biodiversity Net Gain (BNG), current research on solar farms and ecology from academic institutions, as well as looking into future research and innovative technologies for monitoring.

This document takes inspiration from Clarkson & Woods annual 'Solarview' report (2018-2020) which presented the results of ecological monitoring on solar farms undertaken by Clarkson & Woods solely. 'Solar Habitat' seeks to build on this by amalgamating ecological monitoring data from environmental consultancies across the UK and pooling expertise and resources within the industry to produce annual reports.

# Monitoring ecology

Ecological monitoring on solar farms plays an important role in assessing change, identifying management issues, and ensuring that planning obligations are met. It also provides valuable data to explore the impacts that solar farm developments may have on our environment; this will become increasingly important as larger solar farms are constructed to meet our energy and climate change commitments.

The standardised methodology sets out surveying methods and techniques for assessing biodiversity on solar farms, allowing data from across the UK to be compiled and analysed. This will provide a credible evidence base, which will paint a representative picture of ecological trends on solar farms in order to guide policy, help ecologists and local authorities to appraise solar farm impacts and inform the management of operational sites.

In 2022, 37 solar farms across the UK adopted the methodology, with data collected by two ecological consultancy firms. Although this is positive for the methodology's first year of publication, with greater buy-in from the industry and wider ecological consultancies, we hope to see the number of sites using this methodology increase, building a robust evidence base. This will allow further in-depth analysis to be conducted and will provide a resource for peer-reviewed publication.


**Please visit [https://solarenergyuk.org/resource/solar-energy-uk-guidance-a-standarised-approach-to-monitoring-biodiversity/](https://solarenergyuk.org/resource/solar-energy-uk-guidance-a-standarised-approach-to-monitoring-biodiversity/)**

**Scan the QR code to access this guidance.**

# Overview of solar farm sites

In 2022, a total of 37 solar farms were monitored, with site locations spread across most UK regions (as can be seen in Figure 1). The exceptions were the North East, West Midlands, London and Northern Ireland. The majority of sites were located in the South West (over 35%).

Interestingly, this geographical spread closely matches the distribution of solar farms in the UK as a whole, as can be seen in Figure 2.

The age of the solar farms in the study varied, with the most recently constructed site being 5 years (since grid connection) and the oldest being 10 years, with a mean age of 6.8 years. This again closely reflects the mean age of solar farms across the UK, which is calculated as 6.9 years (but with a range of 0 to 11 years).

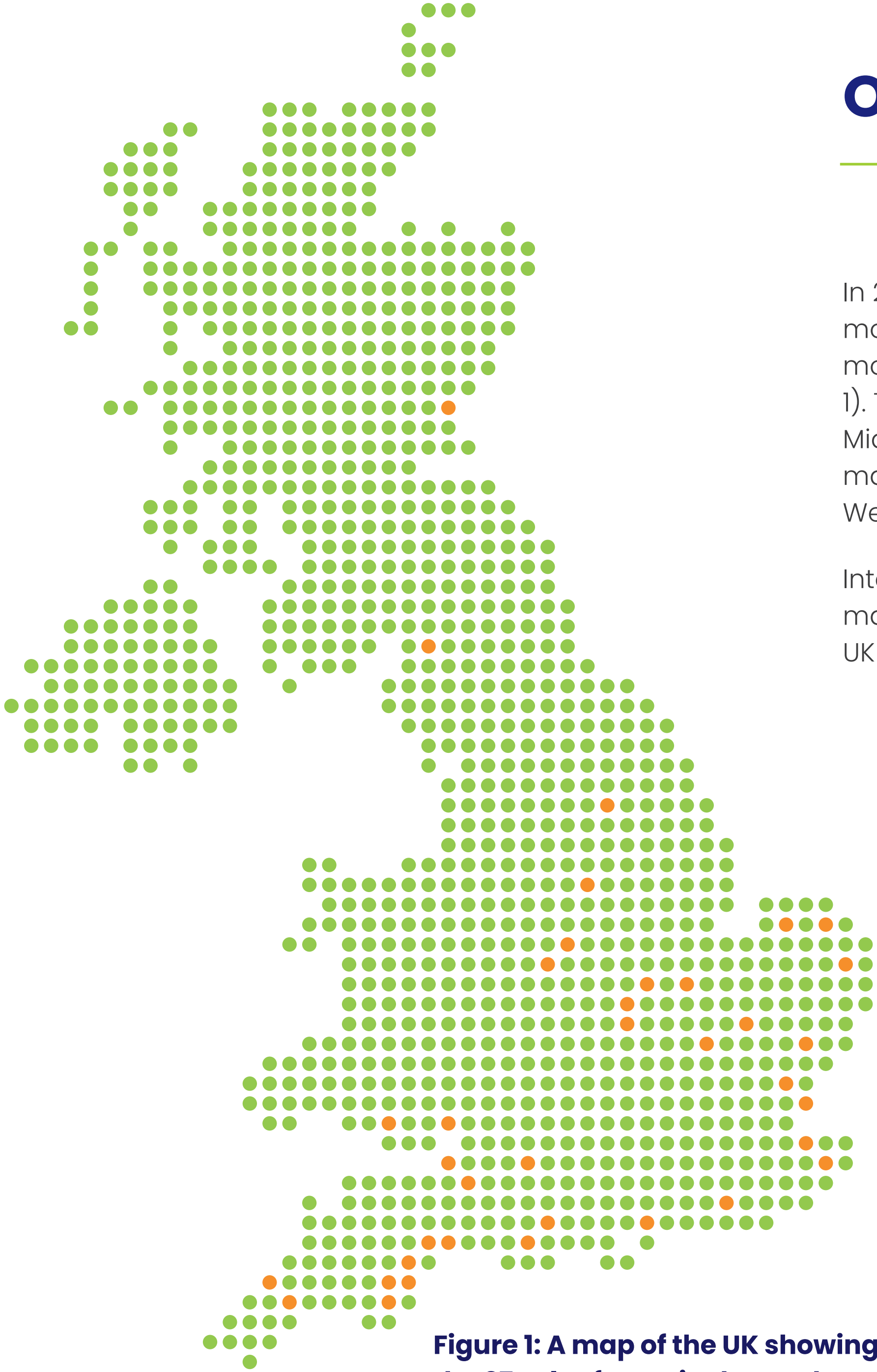


**Figure 1: A map of the UK showing the 37 solar farms in the UK that submitted monitoring data in 2022**

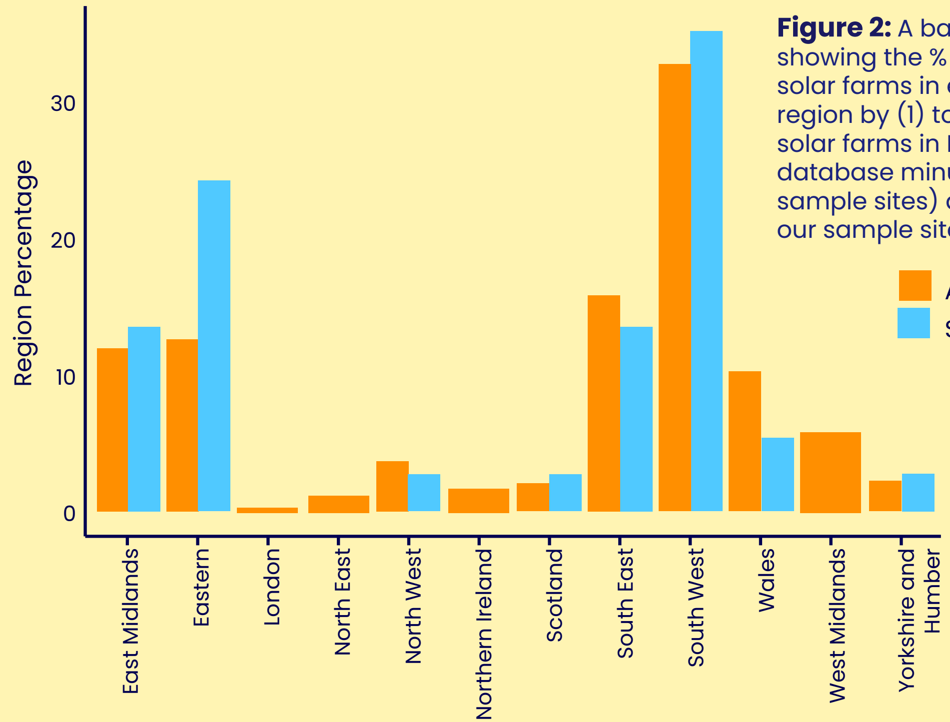



**Figure 2:** A barchart showing the % of solar farms in each region by (1) total (all solar farms in REPD database minus our sample sites) and (2) our sample sites

The size of the sites, based on the MWh output, ranged from 2.3 to 49.9 MW, with a mean of 19.62 MW; this differs from the national average, which ranges from 0.15 to 75 MW, with a mean of 7.3 MW. The national average is likely to be lower due to the number of very small solar farms and as the proliferation of 5MW sites historically. The smaller sites are also less likely to be subject to mandatory monitoring within planning applications, which may increase the average size of the monitored sites.

Management of operational solar farms varies greatly. Their management was graded from one to five, depending on the sites' focus on biodiversity (Figure 3).

Of the sites surveyed, only one site fell into Category 1, being the most optimal management for wildlife. This is likely to reflect issues with collecting grass arisings and removing them from the site or the complexity of removing sheep from a site during the summer months. Encouragingly, only one site fell into Category 4, being the least wildlife-focused management. The majority of sites were categorized as 2 (43%) and 3 (51%).

Of the 37 sites, the majority (73%) were managed through cutting, with 27% being managed through a combination of cutting and sheep grazing.

1. **Optimal management for wildlife, conservation cutting or grazing, no herbicide use, arisings removed, diversity of habitats**
2. **Conservation cutting or grazing applied, arisings left in situ, spot treatment of herbicides, diversity of habitats**
3. **Site cut or grazed throughout season, some habitats present, wider use of herbicides**
4. **Site cut or grazed throughout season, no other habitats present, wider use of herbicides**
5. **Site unmanaged or 'other'**

**Figure 3: Categorised approach to monitoring ecology on solar farms**

**Sheep grazing, H.Blaydes, Lancaster University, Wiltshire**

Orchids, Á.Remazeilles, Clarkson & Woods, Plymouth

# Botany

A total of 802 botanical quadrats were assessed across the 37 sites in 2022. A mixture of 1m x 1m and 2m x 2m quadrats were used across sites. At most sites, five quadrats were taken directly below the solar panels (“Under”; a total of 275 quadrats), five were taken from between the panel strings (“Between”; a total of 282 quadrats) and five were taken outside the main footprint of the solar panels but within the field margins or security fencing (“Outside”; 189 quadrats). Some sites had additional quadrats taken where there were other important habitats which were set aside for biodiversity (“Biodiversity”; 52 quadrats).

Where possible, quadrat locations were fixed, and precise grid references recorded, with the aim of future monitoring taking place in the same locations to make temporal comparisons of botanical diversity within each site.

## Botanical Diversity

Within the sites surveyed in 2022, a total of 178 vascular plant species were recorded, including 42 species of graminoid (grass/ sedge/rush), 119 broadleaved herbaceous plants and 17 “Other” plant species (including woody plants, climbers and ferns).

The most abundant plant group found across all quadrats on all sites were grasses. Yorkshire fog *Holcus lanatus* was by far the highest-recorded species, found in 66% of all quadrats, over twice as much as the second highest recorded species, cocksfoot *Dactylis glomerata* (recorded in 28% of all quadrats). Other abundant species included perennial ryegrass *Lolium perenne*, red fescue *Festuca rubra* and creeping bent *Agrostis stolonifera*, all of which were recorded in over 20% of all quadrats. White clover *Trifolium repens* was the highest-recorded broadleaved species, identified in 15% of all quadrats, with creeping thistle *Cirsium arvense* the next most abundant, recorded in 14% of quadrats.

Creeping buttercup *Ranunculus repens* was recorded in 13% of quadrats, followed by birdsfoot trefoil *Lotus corniculatus*, dandelion *Taraxacum officinale* and ribwort plantain *Plantago lanceolata* (all recorded in over 10% of quadrats).

On average, a total of 32 species were recorded across each site, ranging from a minimum species diversity of 10 to a maximum species diversity of 52. In terms of quadrat locations, "Under" quadrats had an average of 11 species, "Between" quadrats had an average of 16 species "Outside" quadrats had an average of 19 species and the "Biodiversity" quadrats had the highest average of 21 species, as can be seen in Figure 4. This shows that the presence of the panels does effect botanical diversity, likely through changing the amount of sun/rain reaching the ground. This is more profound directly under the panels and to a lesser extent between the panel strings.

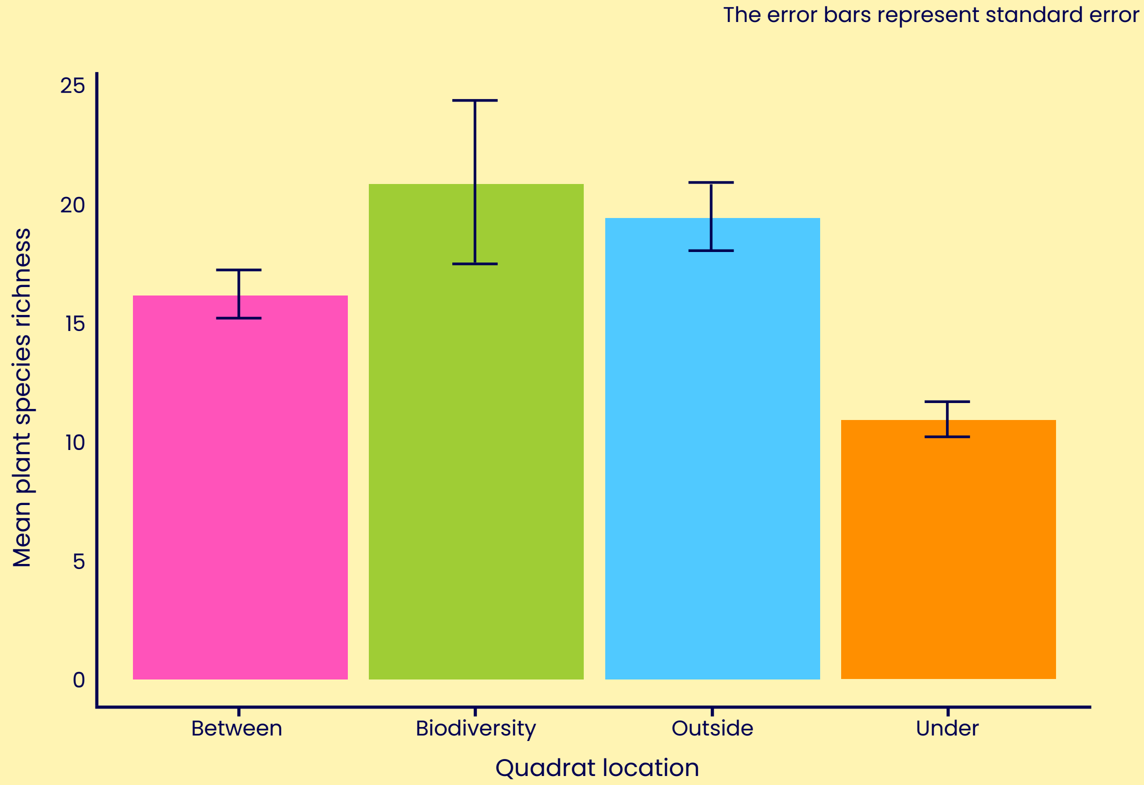



**Figure 4: Mean plant species richness across quadrat locations**

# Case Study

## Wildflower meadow at Langenhoe Solar Farm and pollinator response

**Langenhoe is a 21.5 MW solar farm close to Colchester, constructed in 2015. The site is owned by NextEnergy Solar Fund (NESF) and was selected as one of eight exemplary sites for biodiversity by NextEnergy Capital's (NEC) Biodiversity Team.**

**Wychwood Biodiversity, NEC and WiseEnergy collaborated to develop and implement a biodiversity enhancement plan with enhanced measures bespoke to the site. These included three wildflower strips, bug hotels, hibernacula, and scrub planting for nightingale *Luscinia megarhynchos* habitat.**

**Three strips were sown with wildflowers in September 2017, totalling 0.5 Ha, using Emorsgate's EM4 for clay soils. These strips have developed into botanically diverse wildflower areas managed by cutting and collecting every year in September. This measure goes above and beyond standard grassland management to ensure the wildflowers are sustained for the asset's lifetime.**

**The entire Langenhoe site is surveyed annually in alignment with SEUK methodology, including botany, selected pollinators (bumblebees and butterflies), and breeding birds.**

**Compared to the rest of the site, the abundance of bumblebees and butterflies within the wildflower areas has been significantly greater. Figure 5 shows the results from the 2021 survey, with x 6 higher abundance for bumblebees and x 5 higher for butterflies in the wild flower areas. This indicates that wildflower strips are important foraging habitat for pollinators, and likely to provide valuable habitat for small mammals, birds and reptiles too.**

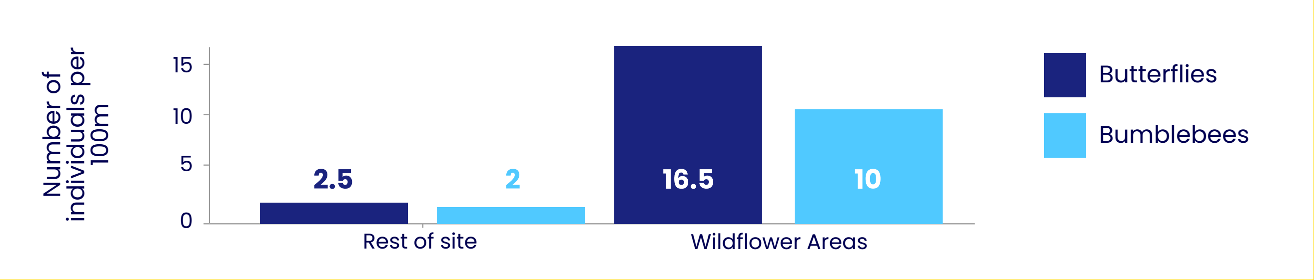



**Figure 5: The abundance of butterflies and bumblebees in wildflower areas on Langehoe Solar Farm (2021)**

**Wildflowers meadow, C.McQueen, Wychwood Biodiversity, Langenhoe**

# Injurious weeds

Within botanical surveys on solar farms, special consideration is paid to those species which are classed as "injurious weeds". Under the Weeds Act 1959, common ragwort *Jacobaea vulgaris*, broad-leaved dock *Rumex obtusifolius*, curled dock *Rumex crispus*, creeping thistle and spear thistle *Cirsium vulgare* are all classed as injurious weeds and require management to prevent them spreading onto adjacent land.

Although all of these species can provide important food sources for invertebrates, they are generally more aggressive plants which can lead to a decrease in species richness throughout a sward and problems with agricultural crops on adjacent land if they are allowed to proliferate.

Overall, 24% of all quadrats contained injurious weeds, with creeping thistle the most frequently recorded (present in 14% of all quadrats), with broadleaved dock the next most frequently encountered (7% of quadrats) and common ragwort (5%), curled dock (2%) and spear thistle (1%) being encountered the least.

Surprisingly, the "Biodiversity" and "Outside" quadrats had, on average, a higher abundance of injurious weeds, as can be seen in Figure 6, with a mean cover of 7% (range 0-50%) and 5% (range 0-68%) recorded respectively.

Common Ragwort, H.Blaydes, Lancaster University, Dorset

Quadrats beneath the panels had a higher percentage of bare ground recorded with a mean of 16% (range of 0-96%). Comparatively, the mean percentage of bare ground for the other quadrats were below 5%.

Injurious weeds do not require active control when they are not spreading to land outside of the solar farm and are not causing maintenance issues. By undertaking regular botanical monitoring of sites and understanding the spread of these species, we are able to see whether there are certain plants or specific areas within each solar farm which may require management before becoming a more expensive and difficult problem.

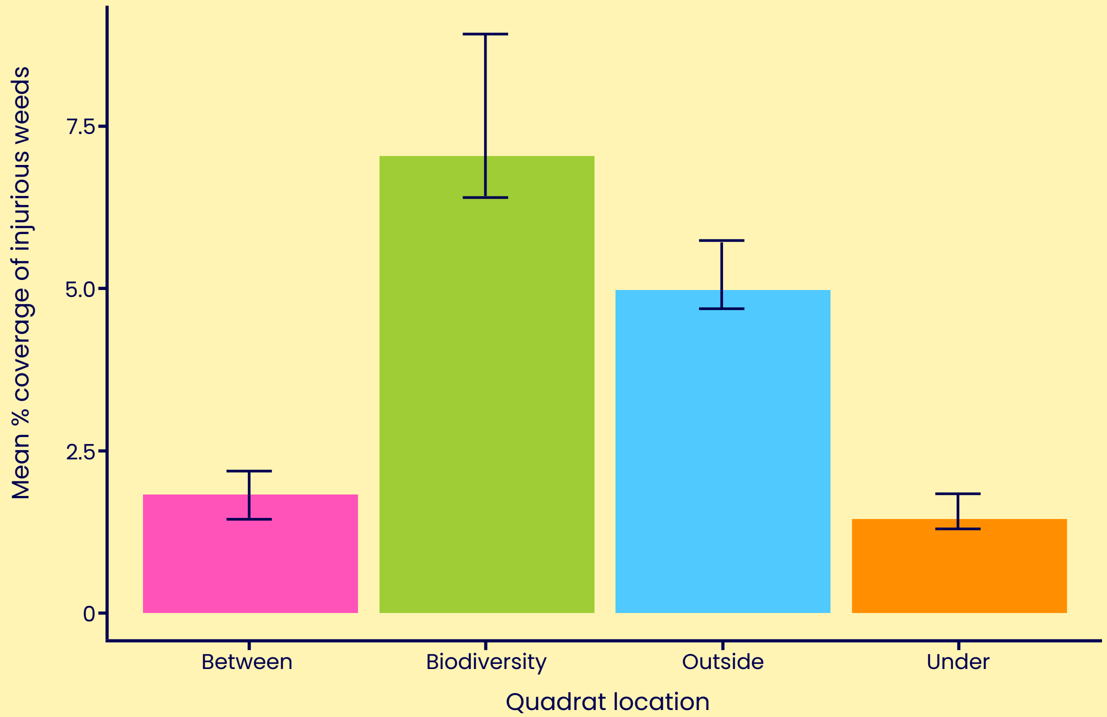



**Figure 6: Percentage cover of injurious weeds by quadrat location**

Small skipper Butterflies on a thistle, H.Blaydes, Lancaster University, Staffordshire

# Invertebrates

The low-intensity of management on solar farms, as well as the range of habitats present, can support a variety of invertebrate species. Previous studies have shown that solar farms can offer enhanced habitat for bumblebees[1], however, the relationship between solar farm developments and invertebrates is still poorly understood.

In 2022, bumblebees and Lepidoptera (butterfly/day flying moth) transects were carried out on 30 solar farms. These surveys are thought to be a good representation of pollinators in general but do not require intensive sampling or an experienced entomologist. In general, 10 transects measuring 100 m were carried out on each site, however, this varied slightly depending on site size (a range of 9 to 26 transects were conducted on each site). Across all sites, 437 transects were walked. Most were walked between the strings of panels ("Between" – a total of 248 transects), although some were focused on field margins ("Outside" – a total of 157 transects) or areas beyond the footprint of the solar farms (but within the lease area) which were managed specifically for biodiversity ("Biodiversity" – a total of 29 transects).

We counted a total of 3,764 individual invertebrates of 31 different species during transect walks across all of the sites, with 28 species of Lepidoptera and 5 species of bumblebee observed. The most commonly recorded species by far was the meadow brown butterfly *Maniola jurtina*, with an impressive total of 1,810 individuals counted. After this was the red-tailed bumblebee *Bombus lapidarius* (358 individuals) and small skipper butterfly *Thymelicus sylvestris* (313 individuals). Although these are fairly widespread species, some notable species were recorded, including 9 sites where small heath butterfly *Coenonympha pamphilus* was recorded – this is a species of principal importance under the NERC Act as it has shown recent declines. Cinnabar moth *Tyria jacobaeae* was also recorded on 7 sites, which is widespread but declining, so it is also a species of conservation concern.

When looking at the locations of the transects, there were fewer bumblebees and Lepidoptera recorded within the sites when the surveyor walked between the panel strings ("Between" transects had a mean of 48 with a range of 0-195) and more on the edges of the solar farm ("Outside" transects had a mean of 74 with a range of 7-229). The biodiversity area surveys were similar, however, fewer transects were walked in these areas which may have affected the results ("Biodiversity" transects had a mean of 72 with a range of 3 - 266).

In addition to structured transect walks, ad hoc sightings of invertebrates were recorded on all 37 sites as the surveyor walked around the solar farm. When taking into account the walked transects and ad hoc sightings of invertebrate species, a total of 66 species were identified, with 11 species of bee, 32 species of butterfly/moth, as well as various damselflies, dragonflies, grasshoppers, crickets, wasps and ladybirds. The species recorded at each site varied greatly, with the minimum number of invertebrates recorded being 3 on one solar farm and the maximum being 38 on another site (although it should be noted that weather may have affected these results).

We looked at some of the potential drivers behind these differences and found that abundance (mean invertebrate count) and species richness were associated with management that was more focused on biodiversity. Both species-richness and the count of invertebrates was higher on sites with a higher focus on management for wildlife (Management Category 2; no Category 1 sites were surveyed for invertebrates) and lower on sites with less focus on management for wildlife (Management Category 3; with only one site surveyed that fell under Category 4), as can be seen in Figure 7. When looking at species richness, there were statistically significant differences between the management categories.

In the standardised methodology, we introduced a nectar productivity survey. Using existing data to describe the nectar productivity of various plant species, alongside the botanical data[2] collected as part of this report, we have been able to estimate how much nectar each solar farm produced in a year.

Firstly, the nectar production of each botanical quadrat on a site was calculated. Quadrats were separated by location within the solar farm (directly under panels, between panels and in the margins) and an average nectar production value was calculated for each location, within each site. The total area of these habitats was then calculated for the entire solar farm and the quadrat data extrapolated to give the nectar production for all three habitats over the entire solar farm. This gave a total mean nectar productivity estimate (kg/year) for each site.

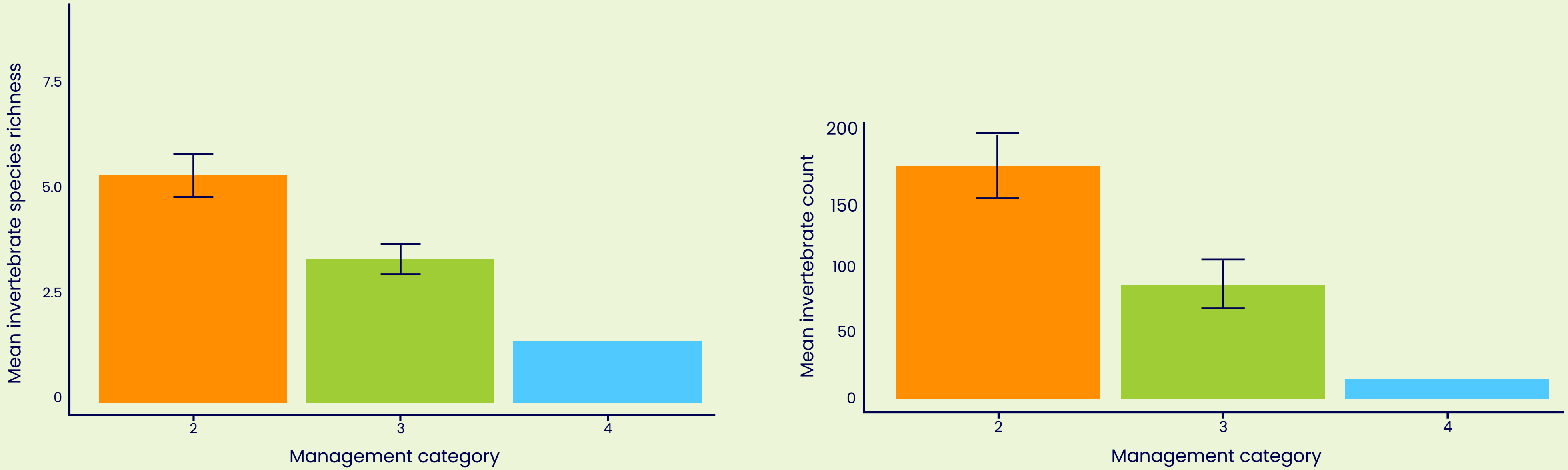



**Figure 7: On the left: Invertebrate species richness (number of different species). On the right: Species abundance (total number of individuals counted) by management category.**

The nectar productivity on each site varied greatly with a minimum of 1.7 kg/year to a maximum of 2,169 kg/year, showing that certain solar farms can offer a significant resource for invertebrates (although nectar production is also, of course, linked to the size of the site). Unsurprisingly, solar farms with higher nectar productivity accommodated significantly higher bumblebee/Lepidoptera species richness and abundance, as shown in Figure 8. This is particularly interesting in an agricultural setting, where surrounding arable or pasture land may provide nectar resources for just a short period until the crop is cut; therefore, solar farms may offer a longer-term resource supporting larger numbers of local pollinators which may in turn enhance pollination services to nearby crops.

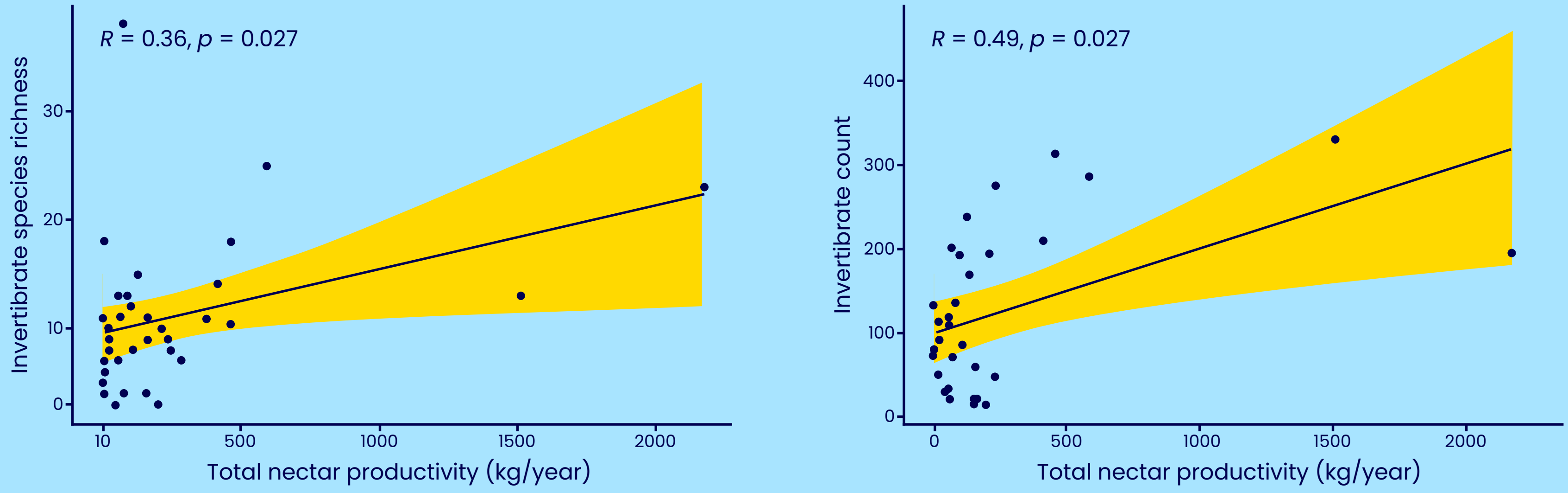



**Figure 8: Left: The relationship between nectar productivity and invertebrate diversity. Right: Invertebrate abundance.**


Green hay bale being delivered, G.Parker, Wychwood Biodiversity, Creacombe


Green hay being spread by hand, G.Parker, Wychwood Biodiversity, Creacombe

# Case Study

## Creating a wild flower meadow within Creacombe solar farm using green hay

**Creacombe solar farm was built in 2019. This 5 MW solar farm was developed by the team behind Eden Renewables, who created a sophisticated biodiversity management plan for the site. Creacombe is now owned by CORE and Yealm Community Energy, whose joint goal is to make it an exemplary site for biodiversity.**

**Following construction, the entire site was seeded with native fine grasses, which are slow growing and conducive to wildflower spread. Then, five areas were selected for seeding wildflower meadows. In August 2020, Wychwood Biodiversity established 4 of the meadows using Emorsgate's seed mix and for the fifth – the largest of all – used green hay from a local wild flower meadow.**

**The landowner has a 1 Ha wildflower meadow 2 miles from Creacombe and this was cut, baled and transported to the solar farm within the same morning. Two large round bales were split and spread onto cultivated ground. The green hay was spread evenly by hand and left in place through the Winter.**

**The wildflowers established well, with red clover *Trifolium pratense*, yellow rattle *Rhinanthus minor*, birdsfoot trefoil *Lotus corniculatus*, two species of plantain, oxeye daisy *Leucanthemum vulgare* and smooth cat's ear *Hypochaeris radicata* all establishing in year 1. The resulting wildflower meadow is botanically rich and is a valuable foraging habitat for pollinators, small mammals and birds.**


Wildflower meadow, G.Parker, Wychwood Biodiversity, Creacombe

Wheatear on solar panel, C.Mackenzie, Wychwood Biodiversity, Unknown



# Birds

A total of 91 bird species were recorded from both ad hoc sightings and structured bird surveys in 2022. Of the bird species recorded, 20 were BTO Red Listed Species of Conservation Concern and 26 were BTO Amber Listed[3].

Figure 9 shows that a diversity of birds were recorded; the species assemblage was largely typical of farmland habitats with the exception of some water birds, such as oystercatcher *Haematopus ostralegus* and reed warbler *Acrocephalus scirpaceus*.

Overall, an average of 25 different bird species were recorded on each site. As with all other elements of this report, the data were highly variable, with some sites having as many as 42 different bird species whilst others had as few as four.

Wood pigeon *Columba palumbus* was by far the most recorded species and the most commonly recorded Bird of Conservation Concern (it is Amber listed), recorded on 94.6% of sites. As the UK's most common pigeon, their abundance is not unexpected. Linnets *Linaria cannabina* were the most recorded Red listed species, observed on 56.8% of sites.

We looked at the effects of management and botanical diversity on bird species richness. The results show that sites which were managed with a focus on biodiversity (Category 2) tended to be more diverse in terms of species richness (as shown in Figure 10), although this was not statistically significant. No surveys were conducted on Category 1 sites and there was not enough data for sites with management Category 4 to be able to compare (although interestingly, the single site included in the study showed very high numbers of species!).

There also was a positive relationship between botanical diversity and bird diversity as seen in Figure 11 , which is likely due to an increase in food resources both through vegetation, seeds and invertebrate prey.

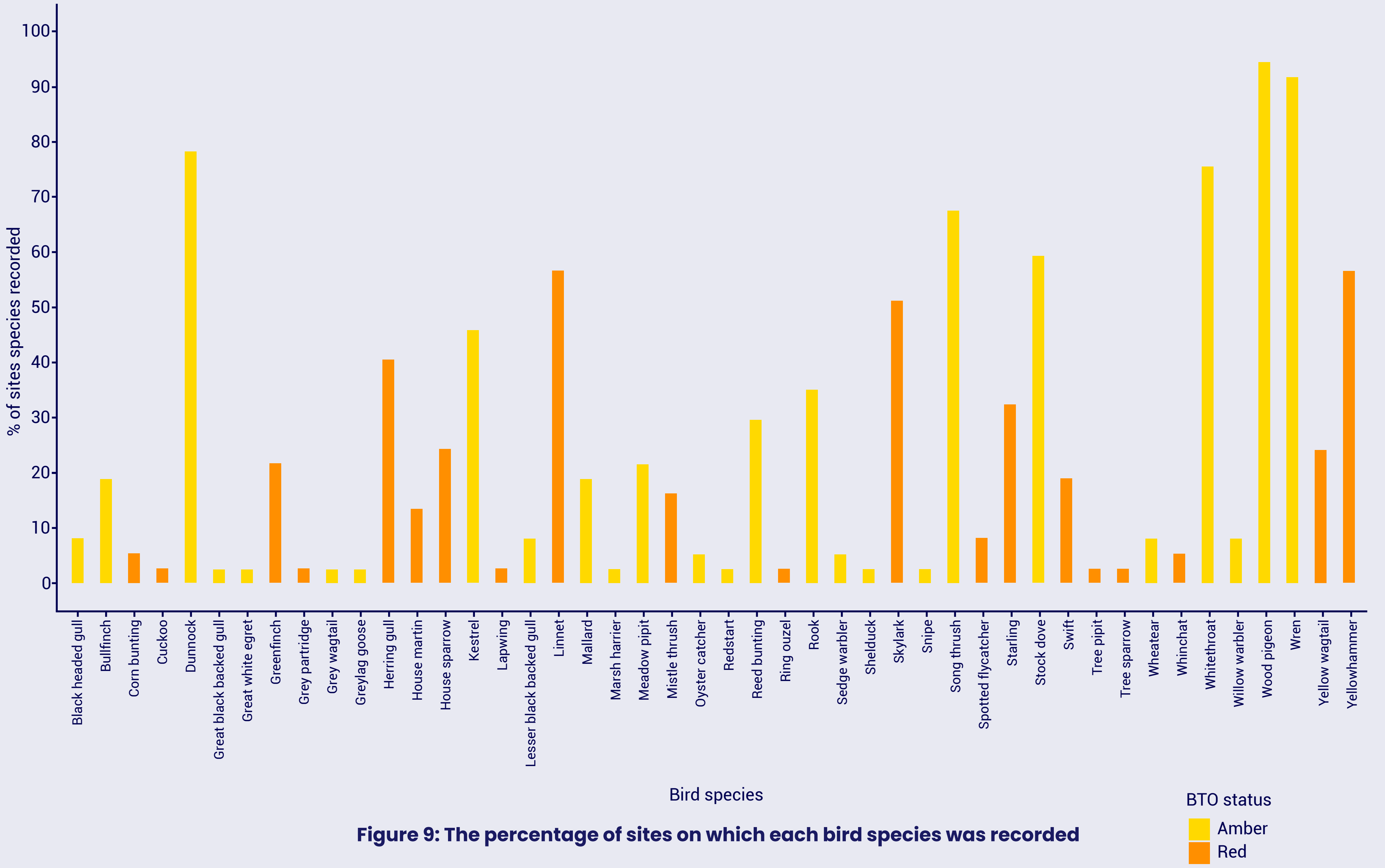



**Figure 9: The percentage of sites on which each bird species was recorded**

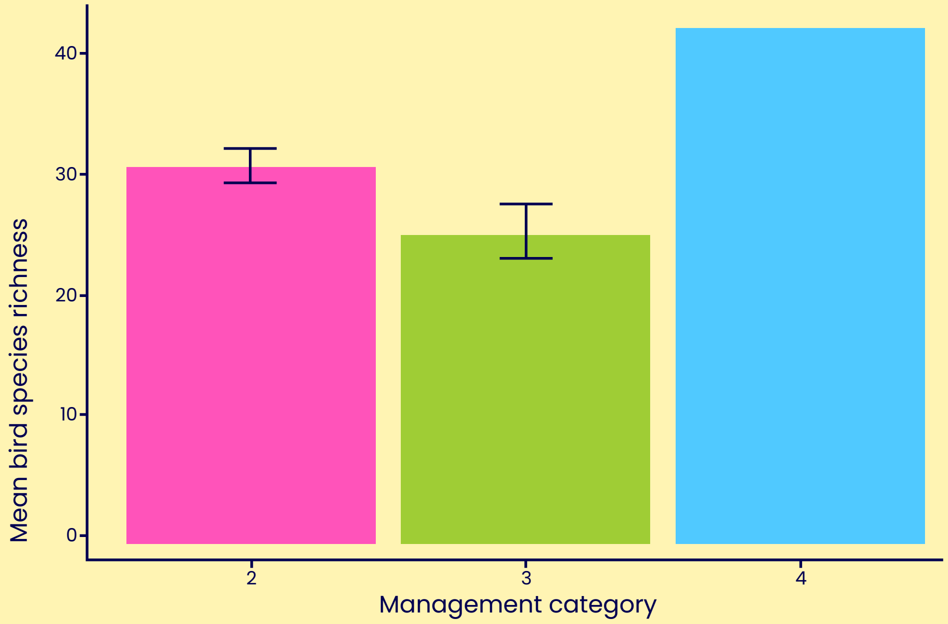



**Figure 10: Bird species richness by management category. Bars for categories two and three represent mean values and error bars represent standard error. The bar for category four represents bird species richness from one site only and therefore there are no error bars due to insufficient data.**

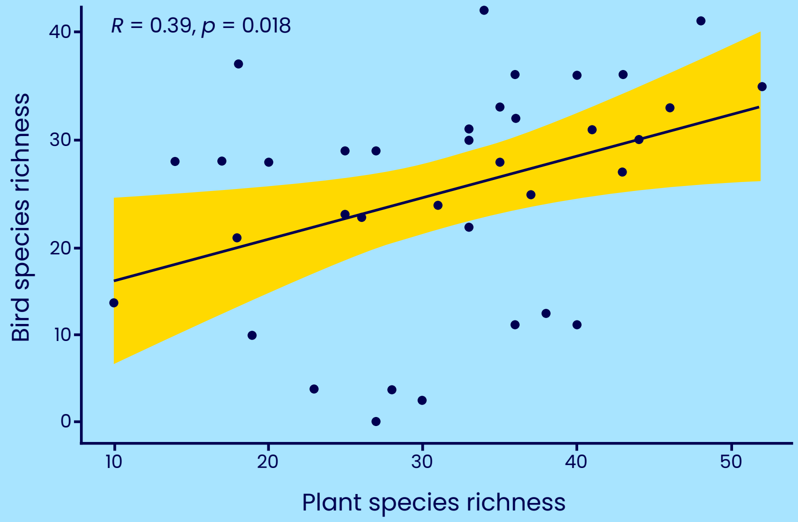



**Figure 11: The relationship between bird and botanical diversity**

Skylark Nest, H.Montag, Clarkson & Woods, Unknown

# Skylarks

Skylarks are species of conservation concern (Red listed), and have become a recent subject of discussion due to the potential impacts of displacement of nesting sites associated with solar farm development.

Skylarks were recorded singing above panels on 19 sites (51.4% of sites) monitored in 2022. It should be noted that although hearing skylarks sing is an indicator of potential breeding activity, it does not confirm the birds are nesting on site. However, continued occurrence of these species within solar monitoring is encouraging.

Skylarks require long unbroken sight-lines for nesting, so the installation of solar panels could displace nesting pairs. Buffers of retained habitats around the solar farm are also likely to be incompatible with the requirements of nesting skylarks, unless very large, undisturbed and managed to promote the required sward height. Despite breeding bird surveys being undertaken on 22 sites (59% of the sites), no evidence of actual skylark nests were found within the solar farms. There is no conclusive evidence of skylark nests within an active solar farm in the UK to date. Skylarks have, however, been recorded many times foraging for invertebrates amongst the grassland within solar arrays and even feeding recently fledged young. It is possible, therefore, that development sites with suitable grassland might even provide a nursery habitat where nesting takes place on adjacent farmland.

An approach for mitigating and compensating for skylark nesting displacement associated with solar farms has been recently published in the Chartered Institute of Ecology and Environmental Management (CIEEM) magazine[4]. This remains an important area where further research is required and we would be interested in obtaining more data or observations on how ground-nesting birds interact with solar farms.

# Case Study

## Encouraging threatened birds at Sawmills solar farm

**Sawmills is a 6.6 MW solar farm at Ashcombe, near Dawlish in Devon. The solar farm was developed by the team behind Eden Renewables in 2015 with an ambitious biodiversity management plan and is now owned and managed by Foresight.**

**This solar farm falls within the UK range of the cirl bunting *Emberiza cirlus*, the UK's rarest resident farmland bird. To enhance the site for this species, hedgerows were managed to increase volume and density and a wild bird seed mix was sown to provide seed through the winter months.**

**These measures appear to have been successful, as cirl buntings have been observed on site in three separate years during annual breeding bird surveys.**

**The site has also been successful in attracting other birds of conservation concern, including mistle thrushes *Turdus viscivorus*, song thrushes *Turdus philomelos*, linnets *Linaria cannabina*, skylarks *Alauda arvensis* and yellowhammers *Emberiza citrinella*.**

**Overall, the bird diversity observed at the site has nearly doubled since the solar farm was built (see Figure 12 below). Survey results from Sawmills demonstrate that with appropriate management, solar farms can benefit threatened species as well as our more common wildlife.**

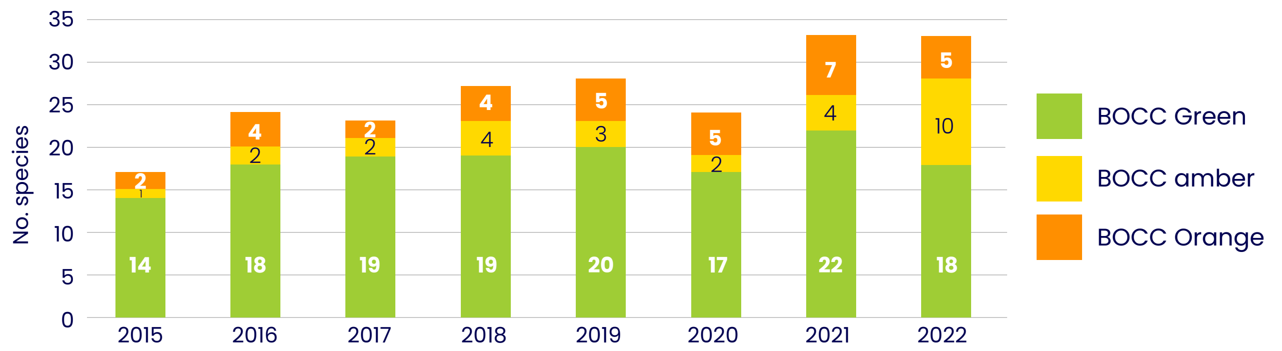



**Figure 12: Total number of bird species for BOCC status between 2015 and 2022 at Sawmills solar farm**


Male Roe Deer, M.Kos, unknown

# Mammals

As the ecologists carried out the surveys, they also made notes of any mammals they observed, or saw signs of (such as scat, footprints, hairs, etc). It is often stated that solar farm security fencing prevents access for larger mammals, however, we found that this was certainly not the case and the fencing usually had many gaps and squeeze-holes beneath it, offering access to a range of species.

Mammals were recorded on 38% of solar farms, with six species observed or signs of their presence recorded. Signs of badger *Meles meles* were recorded on 8% of sites. Rabbits *Oryctolagus cuniculus* were observed on 16% sites, foxes *Vulpes vulpes* on 8%, roe deer *Capreolus capreolus* on 5% and fallow deer *Dama dama* on 2%. Brown hares *Lepus europaeus* were the most frequently observed species, making up 43% of the total count, and were recorded on 24% of sites. This observation has been highlighted in previous research and it appears that solar farms offer ideal habitats for this declining species of conservation concern[5].

Mammal gates were recorded as being present on 11% of sites, presumably installed for badgers to use to access the sites. We did not find signs of active use of these gates and most sites provided gaps under fencing which badgers are far more likely to use by either squeezing or digging underneath.

Mammal observations were taken from ad hoc sightings, rather than targeted surveying, and therefore, mammal presence has likely been underestimated. Moreover, common mammal species such as field voles *Microtus agrestis*, wood mice *Apodemus sylvaticus* and moles *Talpa europaea* were not observed during ad hoc sightings on solar farms, likely as they are less visible, rather than absent.

No data from bat surveys were submitted, although 24% of sites within the sample had bat boxes installed. Few of these were physically checked for the presence of bats, likely due to the health and safety risks associated with using ladders and the requirement for two ecologists to be on site.


Wildflower meadow, C.Mcqueen, Langenhoe



# Biodiversity Net Gain on solar farms

Biodiversity Net Gain (BNG) is defined as an approach to development that leaves biodiversity in a measurably better state than before the development took place. Under Part 6 of the Environment Act (2021) all new developments, including solar farms, will be designed to deliver a minimum of 10% BNG from November 2023. Solar farms considered to be of national significance (NSIP/DNS) will need to deliver the requirement from 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 of a solar farm can take as little as 2% of the total land area.

BNG is made measurable by the use of a suitable metric (most commonly Natural England's Biodiversity Metric 4.0). BNG can be calculated by an ecological consultant by comparing the baseline biodiversity units measured in the pre-development state, and comparing it 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 habitats.

Work is currently being carried out on looking at extensive botanical data within different areas of solar farms and applying this to the BNG Metric and UKHab (the habitat classifications that the metric is based on).

Several asset owners are now also 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 in order to assess its ecological value and explore ways in which this can be increased.

# Case Study

## Downing LLP Biodiversity Study

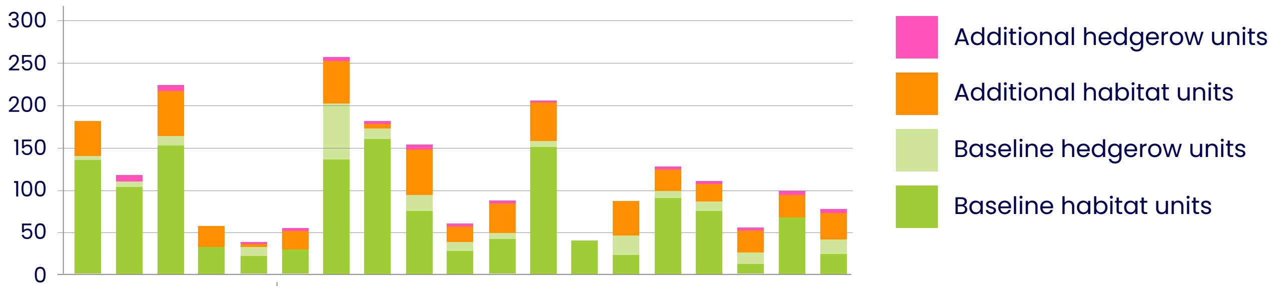
**Downing LLP is a sustainable investment manager who commissioned Clarkson & Woods to undertake a biodiversity assessment of 19 of its ground-mounted solar farm assets in 2022. The study aimed to use the Biodiversity Net Gain (BNG) metric to measure the baseline units on all 19 solar farms, and then to look at options for bespoke ecological enhancements on the sites, with a calculation of the BNG uplift as a result of potentially implementing these.**

**The study showed that across 19 solar farms, a total of 1,419 habitat units and 237 hedgerow units are currently accommodated within the sites (Figure 13). For each site surveyed, recommendations were set out to improve biodiversity such as changes in grassland management, seeding of wildflower areas, planting of hedgerows/trees and creation of wetland features (where appropriate).**

**The calculations resulting from these enhancements showed a potential uplift of 505 habitat units and 54 hedgerow units; showing that solar farms offer ideal opportunities for Biodiversity Net Gain.**

**Some sites offered greater enhancement opportunities than others and depending on the size of the site and the area within the lease agreement. For example, with some of the sites, the boundary hedgerows were outside the lease area and so could not be a focus for improvement. With many solar farms, easy gains could be made by changing the grazing/cutting regime or using fencing to restrict sheep grazing. Other sites offered opportunities for wetland creation within areas outside of the footprint of the array, where soil conditions and topography were appropriate.**

**Figure 13: Baseline and achievable additional biodiversity units for each solar farm**




Scrub on solar farm, H.Montag
Clarkson & Woods, Unknown

# Current research

**Studying ecology on solar farms continues to be an area of mutual interest and collaboration for industry and academia. Several academics across the UK are leading studies into the potential benefits and impacts of managing solar farms for biodiversity.**

## Lancaster University

Researchers at Lancaster University have been investigating the effects of ground-mounted solar farms on hosting ecosystems in the UK since 2013. The body of work has been in collaboration with other institutions including the Universities of York and Reading, and UK Centre for Ecology & Hydrology, as well as several industry and policy project partners. Their research utilises field, laboratory and modelling approaches across a wide range of environmental and biodiversity indicators. The current team of researchers are focusing on the implications for carbon sequestration, soil health, vegetation (including forage quality), pollinators, birds and a broad suite of natural capital and ecosystem service measures. They also work with industry project partners on more operational aspects, including the application of BNG to solar farms, a solar park carbon payback calculator, a solar farm management decision support tool and two recent projects examining how biodiversity could be incorporated into the financial system. On the following page are overviews of some of the projects.

## Keele University

Researchers at Keele University have recently started a longitudinal study of the new hybrid solar and wind farm on their campus. The site represents a range of technologies (solar, wind, battery storage) and despite its size at only 4ha, it provides a realistic representation of future small-scale hybrid developments.  Research has focussed on the impact of both above- and below-ground biodiversity.

The impacts on mobile species are particularly under-researched so attention has focused on mobile species such as birds, bats, small mammals, badgers, amphibians and insects. Vegetation surveys and detailed soil analyses are linked to a system of permanent microclimate sensors which monitors the changing environmental conditions across the solar field.  These collect data on light, air temperature, humidity, soil temperature and soil water content. Soil data assesses the biogeochemical cycle in terms of physical characteristics (pH, bulk density) of plant nutrients, carbon, geochemistry and soil fauna. The sub-surface water is also being analysed by geophysical methods to better understand how solar panels influence the moisture distribution patterns, thereby impacting the vegetation and soil biogeochemical cycles. Repeat surveys every 3-5 years will allow for an ongoing assessment of the effect of changing environmental conditions across the site.

## Soil health and vegetation

Soil and vegetation data were collected from more than 40 solar farms in England and Wales in the summer of 2021. The data are linked to natural capital and ecosystem services, and are currently being analysed. The results will highlight the soil and vegetation conditions within solar farms, including stocks of soil organic carbon, soil nutrient content (e.g., nitrogen, phosphorus), soil microbial community and soil physico-chemical properties (e.g., bulk density, pH), as well as the percentage plant cover, plant above ground biomass and forage quality and quantity.

**Collecting soil samples on solar farm, F.Carvalho, Lancaster University, Unknown**

## Pollinators

Pollinator surveys were also undertaken at 15 solar farms across England in 2021. Bumblebee and butterfly abundance and richness data have been linked to local and landscape scale factors to better understand the drivers of insect biodiversity across solar farms. Preliminary results indicate that a combination of on-site resources (floral diversity and abundance) and wider landscape characteristics (the amount of high-quality pollinator habitat and hedgerows in the surroundings) impact the number and diversity of insects on solar farms.

**Marbled White and Burnet on Scabious, C.Durigan, Wychwood Biodiversity, Unknown**

## Birds

This year's field research focuses on the impacts of solar farms on skylarks . The project will further our understanding of how skylarks use solar farm developments and their surroundings for foraging and nesting.

**Skylark in air, K.Lindstrom, unknown**

UNIVERSITY of York

University of Reading

UK Centre for Ecology & Hydrology

## Biodiversity Net Gain

Work is also in progress looking at botanical data collected over several years of monitoring of operational solar farms to conduct an in-depth study on how BNG relates to solar farms, with particular emphasis on how to classify habitats (including under panels) and which factors affect the habitats which eventually establish including management, age of solar farm and previous land use.

**Wildflowers on solar farm, H.Blaydes, Lancaster University, Hampshire**

## Solar park carbon payback calculator

A beta version of a solar park payback calculator, which incorporates technical and ecological carbon costs and savings, is currently being refined and verified by carbon calculator specialists, Small World Consulting.

**Ariel drone footage of a solar farm, W.Hitchcock, Above Surveying, Unknown**

## Solar Park Impacts on Ecosystem Services (SPIES) decision support tool

The SPIES tool (www.lancaster.ac.uk/spies), in collaboration with the University of York, provides insight into the effect of site management decisions on ecosystem services, grounded in a robust and transparent evidence base.

**Vegetation on solar farm, S.Cheesbrough, Independent, Dorset**

Keele University

## Biodiversity Net Gain

The site is also being used to study the realistic opportunity and timescales required to develop Biodiversity Net Gain-credit-bearing enhancements, with the aim of informing land use planning policy and site management plans. The pre-construction ecological data is often ignored once a development is complete. However, longitudinal studies allow for an analysis based on both short-term impacts from construction disturbance and long-term changes relating to new infrastructure. This in-depth, single-site approach allows a full investigation of short and long-term impacts alongside realistic monitoring of biodiversity net gain site enhancements.

Students from the MSc in Environmental Sustainability and Green Technology are conducting research into various aspects of ecological impacts and opportunities relating to ground-mounted solar on site, including investigating the impact of average light conditions found underneath panels to determine species that may be suitable for enhancing biodiversity in these spaces.

House sparrow, pxl.store

## Bats

On Keele's solar farm transect surveys and static bat monitors are being used to assess the impact of the development on the bat population and to monitor changes over time.

Common pipistrelle, Rudmer Zwerver

## Mammals

Both static wildlife cameras and small mammal trapping have been undertaken around the periphery and within the site of the solar farm. This is a longitudinal survey which aims to investigate the use of the site by mammals (such as foxes, badgers, rabbits, and stoats) and small mammals (such as mice, voles and shrews). The panels have the potential to provide shelter for small mammals. Ad hoc sightings confirm the presence of larger mammals, but little quantifiable research exists.  The static wildlife cameras have already been successful in collecting images which can be used to assess the suitability and use of such sites by these species.

**Fox at night on solar farm, E.Harrison, Keele University, Keele**

## Botanical, soil and microclimate data

Annual vegetation surveys are linked to soil and microclimate data to monitor the changes related to the presence of solar panels.  Samples are studied in control plots, in between the panels and underneath the panels. The microclimate sensor data indicates that the design of the infrastructure on the Keele field tends to create cooler and wetter conditions underneath the panels and the vegetation is slowly changing in response to these environmental variables. Experiments in growth chambers are attempting to stimulate these conditions in order to investigate which species might thrive and provide a nectar source under these panels.

**Vegetation on solar farm, A.Turner, Keele University, Keele**

**Keele solar farm, A.Turner, Keele University, Keele'**

# Innovative monitoring technologies

## Monitoring wildlife with drones

Drones are playing an increasing role in the solar sector, carrying out thermographic inspections and construction oversight. In the context of natural capital management, drones can utilise different sensors, including thermographic, visual and multispectral, to monitor and record flora and fauna across the entire solar farm quickly, accurately and to very high levels of detail. This enables high frequency and large area coverage monitoring to be carried out at a fraction of the cost of ground-based manual alternatives.

**Drone taking ariel footage of solar farm, W.Hitchock, Above Surveying, unknown**

## Innovative monitoring technologies

Innovative technologies are opening new doors to how we monitor wildlife and assess land management on solar farms. Complementary to traditional monitoring techniques (e.g quadrats) and advances in technology is now offering opportunities for enhanced data collection. In recent years, the popularity of these technologies has grown rapidly and are now being used more commonly for ecological monitoring on solar farms.

**Botanical survey, Clarkson & Woods, unknown**

## Environmental DNA Testing

The application of environmental DNA (eDNA) testing is routinely used by ecologists to test pond water for the presence of great crested newts *Triturus cristatus*. The water sample is sent to a lab which identifies any newt DNA within and confirms whether the species is present or not. However, eDNA technology has, in the past few years broadened its scope dramatically.

It is now possible to apply eDNA much more widely, for example, a single water sample from a pond or ditch and an eDNA assessment will let you know which vertebrates have been using the water. This includes birds, mammals, amphibians, reptiles and even fish. The testing process is reliable and provides results that are comparable between sites.

Similarly, it is now possible to test a single soil sample for eDNA to establish the diversity of micro- and macrofauna in it. This includes the presence of fungi and bacteria. These indicators are useful in determining soil condition and therefore would be valuable to measure through a solar farm's life.

# Looking ahead

Conducting ecological monitoring across the same solar farms, year on year, will help to identify trends and inform how best to manage them to support ecology. By doing so the solar industry can play its part in tackling climate change while addressing the ecological emergency.

In 2022, only a small proportion of sites used the standardised methodology for monitoring ecology. It is hoped that we will see greater adoption of the methodology by ecological consultancies, solar developers, asset managers and local authorities in the coming years. This will ensure a robust database to be built upon year on year, which is fully representative of the opportunities solar farms can create for increasing biodiversity.

Over the next year, we will be exploring the possibility of producing an app for field data collection. This app will seek to simplify the process of data collection, making it more accessible and promoting the reporting of data in a standardised format. Implementing the idea should increase the reliability of the data collected.

We are keen to collaborate and encourage all those within the industry (and beyond!) to get in touch if you would like to know more about the standardised approach to monitoring.

**Red Tailed Bumblebee on solar farm, H.Blaydes, Lancaster University, Hampshire**

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# Contributors

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