

Potential ecological impacts of ground-mounted photovoltaic solar panels in the UK

An introduction and literature review

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1 Introduction

- 1.1 As the number of solar parks in the UK increases, there is growing interest in the interaction of wildlife with ground-mounted photovoltaic (PV) solar panels. To date, a relatively low number of research papers have formed the basis for considerable discussion on the subject, and in some cases these have informed guidance relating to PV solar parks in the UK. This report reviews readily available papers that have received the greatest attention from the media, ecologists and conservation bodies, and planners. The research that has been reviewed includes papers on potential interactions between PV solar panels and invertebrates, birds and bats.
- 1.2 The aim of this review is to identify potential ecological issues (based on research undertaken to date), and identify current gaps in our knowledge. It should be noted that some sources were not available for consideration. We advocate a careful and considered approach when making ecological recommendations and planning decisions, given the limited body of available research.

Background

- 1.3 Solar energy is an increasingly important source of renewable energy in the UK. Figures released by the Department of Environment and Climate Change (DECC) suggest that total solar PV capacity grew by 1.0 GW between July 2012 and June 2013, bringing total installed capacity to 2.4 GW, approximately 12% of the renewable capacity in the UK (DECC, 2012; DECC, 2013a). In May 2012 the government announced that their updated renewable energy road map will include solar and that up to 22GW is an achievable ambition by 2020 (DECC, 2012).
- 1.4 Solar energy can be utilised in a number of ways, including:
- Solar thermal systems – using solar energy to heat water or air which is then used to heat buildings.
 - Concentrated solar systems – concentrating sunlight to superheat a fluid, which is then used to boil water, which in turn runs a generator and produces electricity.
 - Photovoltaic (PV) systems – solar cells convert sunlight directly into electricity, by harnessing the current produced by electrons being knocked off the atoms of photosensitive materials such as Selenium.
- 1.5 In the UK the most common type of solar installations are PV systems, sometimes combined with thermal. As yet, concentrated solar systems are not being installed in the UK. A report released by the Committee of Climate Change (CCC) states that concentrated solar systems are not suitable for use in the UK, as the technology requires intense sunlight and little cloud (CCC, 2011).
- 1.6 As the cost of PV panels decreases, technology improves and the demand for renewable energy continues to rise, it is likely that the current trend in increasing solar applications will continue. Although the reduction in Carbon emissions associated with an increase in renewable energy will benefit the environment in the wider sense there is, as with every development, a need to assess the ecological implications of this increase, and give appropriate consideration to wildlife policy and legislation.
- 1.7 The scope of any ecological assessment will depend on the type of development proposed. In this case, there are different ways of installing solar panels, which will each have particular ecological effects to a lesser or greater extent. In the UK photovoltaic/thermal solar panels can be installed in several forms (DECC, 2013b; Li *et al.*, 2013):
- Domestic – principally fixed on the roofs of domestic buildings. PV installations of this type can be as large as 4kW capacity.
 - Building mounted – PV systems on commercial/non-residential typically range from 4kW to 100kW capacity, although larger buildings can accommodate larger arrays up to 5MW.

- Building Integrated – there is a growing market for building materials that have a PV component built into them, such as roofing tiles.
- Ground-mounted – these generally supply power at a grid distribution level. They often span over a large area, with the land required for a 1MW fixed tilt array with security fencing currently being approximately 2.4 ha.

- 1.8 This review discusses some ecological considerations associated with the interaction of wildlife with ground-mounted PV panels. Ground-mounted PV panels have the potential to cause the highest impact on nature as they are installed on land which may have at least some value to wildlife. The other forms of installation are all reliant on an existing structure, and are likely to be limited in their ecological impacts for this reason (Dale *et al.*, 2011).
- 1.9 The potential impact of ground-mounted PV panels on some wildlife groups has been the subject of media interest in recent years. However, although there have in some cases been high numbers of media articles and some published guidance, these have generally been based on the findings of single experiments. There seems to be limited research available on the impacts caused by the installation of large solar arrays but this does not mean that the limited research available should be stretched to fill the gaps.
- 1.10 This article reviews the studies that have received the greatest amount of interest; these are principally concerned with aquatic invertebrates, birds, and bats.

2 Research Review

Aquatic Invertebrates

- 2.1 At present there is very little information regarding the possible adverse effects that the presence of PV solar panels in the countryside could have on aquatic invertebrate populations. In 2010, Horvath *et al.* released a paper about the possible attractiveness of solar panels to aquatic invertebrates, from experiments conducted next to a river (from which the invertebrates emerged) in the Hungarian Duna-Ipoly National Park. The authors found that the homogenous black panels used in that particular study reflected horizontally polarized light at a higher percentage than water. It was postulated that the studied panels may therefore appear more attractive to aquatic insects than water bodies. As polarized light appears to be one of the most important sensory cues used by aquatic invertebrates when identifying water bodies, which may be used as egg-laying sites, artificial sources of highly polarised light could potentially impact aquatic invertebrate populations by inducing egg-laying in locations where survival is unlikely (Schwind, 1991; Horvath and Varju, 1997)
- 2.2 In the paper by Horvath *et al.* (2010) experiments were carried out to test the attractiveness of solar panels to mayflies, caddis flies, dolichopodids, and tabanids. The experiment found some evidence that mayflies (Ephemeroptera), stoneflies (Trichoptera), dolichopodid dipterans, and tabanid flies (Tabanidae) were attracted to solar panels and did exhibit egg-laying behaviour above solar panels more often than above surfaces with lower degrees of polarisation. Specific counts of eggs on solar panels were not undertaken during this experiment and it was assumed by the authors of the paper that eggs were laid following observation of egg-laying behaviours.
- 2.3 The research investigated the attractiveness of panels that reflect highly polarised light rather than their ecological impacts. The results of the research leads the authors to the conclusion that some consideration would be appropriate in the siting and design of solar panels where important populations of aquatic invertebrates are likely to be present locally. This recommendation is quoted in a European Commission news alert (European Commission, 2011) and in a briefing note released by the RSPB (RSPB, 2011).
- 2.4 The potential attraction of invertebrates to highly polarised reflected light occurs with many man-made surfaces, such as, asphalt roads, parked cars and glass buildings (Kriska *et al.*, 1998; Wildermuth, 1998; Kriska *et al.*, 2006; Kriska *et al.*, 2008). It would therefore be difficult in some locations, without very careful experimental design, to determine if population changes were due to polarised light from a solar park or other man-made features. Furthermore, in order to assess the impacts of a solar park, other variables affecting aquatic invertebrates would also need to be monitored and taken into account, such as the water quality of existing water bodies, which can have substantial effects on invertebrate species populations and diversity (Sundermann *et al.*, 2013).
- 2.5 It is unclear whether impact susceptibility varies between still water and fast flowing water species although it could be hypothesised that the likelihood of an ecological effect occurring (if one does occur), would be greater in close proximity to still and slow-moving water habitat as the solar array may superficially appear to be a slow moving or standing water-body as oppose to a riverine habitat.
- 2.6 An additional observation made by Horvath *et al.* (2010) was that for polarising surfaces that were broken by a white border or grid, the occurrence of egg laying behaviours was reduced. The study found that "*The highly and horizontally polarising surfaces that had non-polarising, white cell borders were 10- to 26-fold less attractive to insects than the same panels without white partitions*". Moreover, the polarisation of light by these broken surfaces appeared from the results to be less than water. As most existing and proposed solar parks in the UK employ grid-formed panels with anti-reflective films it is possible that the reflection of polarised light from these surfaces is already substantially reduced.

Birds

- 2.7 One of the most high profile issues regarding birds and solar parks in recent years has been the effect of light reflected from mirrored heliostats¹, which can singe a bird's wings. Most of the articles available draw upon one document, by McCrary *et al.* (1986) which reports on bird mortality at the Solar One facility in the Mojave Desert, California. This is a concentrated solar system, which uses mirrors to concentrate sunlight onto a central tower containing a fluid which is heated and subsequently used to heat water which powers a turbine. As previously mentioned this type of solar park is not installed in the UK at the moment.
- 2.8 McCrary *et al.* (1986) found that during approximately 40 weeks of survey, 70 bird fatalities were recorded, which were caused by either collision with solar park infrastructure or burning at standby points. The most frequent form of avian mortality was due to collision (81%), the majority of these collisions being with the mirrored heliostat panels. This stands to reason, as birds commonly collide with other highly reflective infrastructure such as windows and buildings (Klem, 1990; Dunn, 1993; Erickson *et al.*, 2001). McCrary *et al.* (1986) also reports that there were thirteen instances of burning recorded in the heliostat standby points (small, temporary, areas of the sky on which the reflection from the heliostats are focussed during maintenance, testing, etc.) apparently due to birds flying through the heated air. The study concludes that the low number of mortalities from burning is due to the infrequent use of the standby points, and their varying intensity when being used. From the results shown by McCrary *et al.* it is fair to assume that by conducting maintenance at times of low light intensity, these incidents could be avoided.
- 2.9 To reiterate, the study applies to large concentrated solar arrays, which are unlikely to be used in the UK. The burning observed cannot occur at photovoltaic solar parks as concentrating reflected light is not part of the design. PV solar panels are designed to absorb as much light as possible, and most are coated with an anti-reflective film for this reason. There is ongoing research to better develop anti-reflective films that will increase the efficacy of solar panels (Achtelik *et al.*, 2013; Li *et al.*, 2013). In addition, the grid-like panel design means that any reflection could be fragmented, a principle applied to windows in order to reduce collision events (Klem, 2009; Sheppard, 2011).
- 2.10 It is possible that bird collisions with PV solar parks could also occur. There is some mention in the media and grey literature of water birds confusing large solar arrays with water bodies; and of collisions with solar panels at large-scale PV solar parks, but no relevant research or monitoring reports were found during the data search for this review. The solar parks to which the articles refer are extremely large projects, built in the desert on a migratory flight path for water birds. It is difficult to directly compare the impacts of such solar parks with those existing or proposed in the UK due to large differences in scales and habitat.
- 2.11 There are a number of accounts of birds nesting on the structures that support solar panels including a personal observation by Hernandez *et al.* (2014). This could result in a local increase of some bird species, which could increase the possibility of collision events. It is also reasonable to hypothesize that some ground-nesting birds would be attracted to solar parks due to the availability of a safe nesting area, as the security fencing around the solar parks may deter ground predators (Smith *et al.*, 2010).
- 2.12 The potential impacts of any type of development on sensitive areas that are important for birds should be considered. However the extent and significance of impacts caused by solar parks would be extremely difficult to quantify at the current time due to the lack of research.
- 2.13 The RSPB's briefing note (2011) comes to the same conclusions: "If correctly sited (so as not to impact on sensitive species) and with appropriate land/habitat management and other mitigation measure employed, the deployment of solar might be of benefit to birds in the wider countryside. There is no scientific evidence of fatality risks to birds associated with solar PV arrays. Collision is most likely to be a risk for waterfowl, which may be attracted to PV panels (though there is little evidence for this)."

¹ An instrument consisting of a mirror moved by clockwork, for reflecting the sun's rays to a fixed point. During times when this energy is not needed, during maintenance for example, sunlight is reflected towards 'standby points', which are predetermined areas of open sky.

Bats

- 2.14 The impact of solar parks on bats has not attracted as much interest within the media. There has been some concern that there may be collision fatalities due to bats mistaking solar panels for water, and this is referred to in Natural England's technical advice note TIN101:
- 2.15 "Very little research has been conducted to date, but one laboratory study undertaken by Bjoern Siemers and Stefan Greif [sic] (2010) showed that bats attempted to drink from the panels and occasionally collided with them. If the plates were vertically aligned they often crashed into them when attempting to fly through them. Juvenile bats are expected to be more prone to this behaviour."
- 2.16 The paper by Greif and Siemers (2010) aimed to investigate an innate recognition of water bodies by bats. For this they observed the behaviour of 15 species of bat towards smooth and rough panels of wood, metal and plastic placed on a sand-covered floor. They observed that bats appeared to only attempt to drink from the smooth surface and not from the rough one. This suggests that the bats were mistaking the panels in this environment for water. However, there are a number points made in this paper which suggest that this mistake may not be made with solar panels in natural conditions (a hypothesis that was not tested in this experiment):
- The experiment was conducted in both low light levels and in complete darkness. The authors observed an increase of 60% in attempts at drinking from smooth panels in complete darkness. From this Greif and Siemers (2010) concluded that bats integrate information from several senses when forming a perception of their environment.
 - The experiment relied on bats needing to drink, and therefore the bats had water withheld from them during the day and were released into the flight room in the condition they would be in after roosting for the day. In the wild, light levels at emergence could be relatively high, depending on the species of bat, so other senses (such as sight) may not be as limited as they were in the flight room.
 - The bats did not have access to water during the experiment, and therefore they could not 'choose' between the plate and water; they just kept attempting to find somewhere to drink.
- 2.17 It is also worth noting that the panels of metal, wood and plastic were aligned horizontally on the floor, rather than vertically. There is also no mention of the bats colliding with the panels, although the authors note that on rare occasions, bats accidentally landed on the smooth plate, but continued to behave as though it was water after this.
- 2.18 Greif and Siemers (2010) conclude that bats have an innate ability to echolocate water, by recognising the echo from smooth surfaces, and that bats may therefore perceive all smooth surfaces as water. The authors do not suggest that bats will be negatively affected by this mistake. A more recent paper by Russo *et al.* (2012) assesses the ability of bats to tell the difference between water and smooth surfaces in the wild. An existing water trough used by bats was covered with Perspex and another left open. A third existing water trough was half covered in Perspex, with the other half left open. There was no difference in numbers of bats visiting each trough. However, in this experiment, the authors found that having had a number of failed drinking attempts from the Perspex side of the trough the bats would either return to drink from the water side of the trough or leave the site in search of water elsewhere. There was no mention of bats colliding with the Perspex.

3 Discussion

- 3.1 Some of the reports and ongoing monitoring mentioned in reviewed articles could not be located during this review, which restricts our ability to fully assess the potential impacts of ground-mounted PV solar panels. Notwithstanding this, the amount of research and monitoring data that are currently available appears to be too limited to allow definitive conclusions to be drawn.
- 3.2 From the research that we have reviewed, it is likely that the majority of concerns that have been discussed in the media are not well-founded or particularly relevant to the UK; or are based on scientific experiments that were not specifically designed to evaluate ecological impacts. It may be possible to make some sensible and logical recommendations in respect of survey and mitigation measures, based on the research available, but such recommendations should be reviewed on a site by site basis. It should also be taken into account that impacts on wildlife, and the significance of any such impacts, may be dependent on a number of variables, including a site's setting and proximity to sensitive populations of protected or otherwise notable species.
- 3.3 This review of available research suggests that the ecological impacts of ground-mounted solar panels in the UK are relatively limited and location-specific. The objectives and design of surveys and the development of ecological recommendations at ground-mounted PV parks should be considered in this context and on a case-by-case basis, to ensure that any design restrictions or mitigation / compensation measures are justified and effective.

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