Bennun, L., van Bochove, J., Ng, C., Fletcher, C., Wilson, D., Phair, N., Carbone, G. (2021). *Mitigating biodiversity impacts associated with solar and wind energy development. Guidelines for project developers.* Gland, Switzerland: IUCN and Cambridge, UK: The Biodiversity Consultancy.

Biodiversity impacts associated to onshore wind power projects here

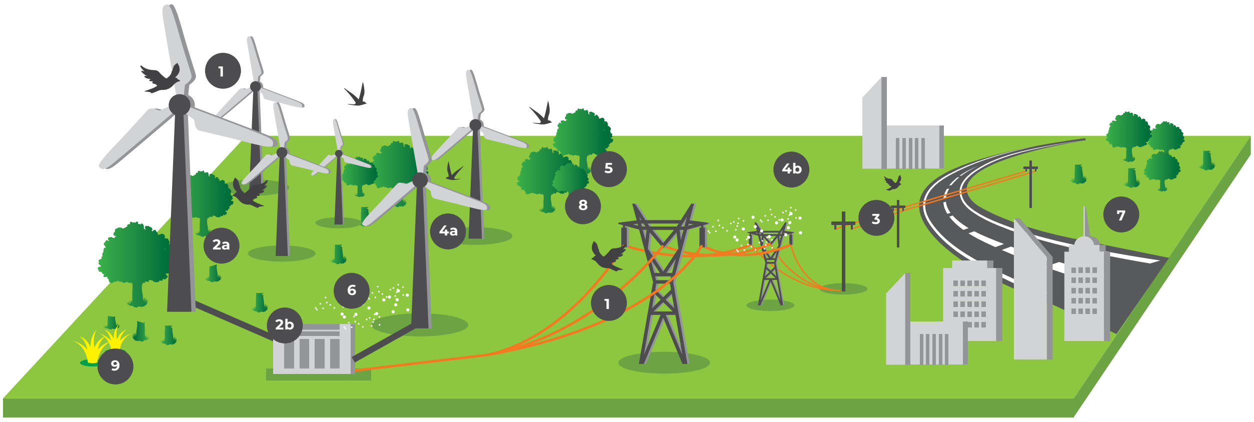
Studies on biodiversity impacts of onshore wind have focused mainly on birds, bats and natural habitats, with limited understanding of impacts to other taxa, including non-flying mammals.

Wind energy developments can affect birds and bats through direct mortality and through loss and degradation of their habitat, and this effect is well-documented for both species groups. The ability to predict fatality levels is more advanced for birds than bats, while there is comparatively little knowledge on population-level impacts for either birds or bats. This is particularly the case for the tropics and sub-tropics where diversity is high, and wind power is expanding rapidly.

Terrestrial species are generally affected by changes in the structure and function of their habitat, and these changes may be both from the wind farm or associated infrastructure. Few examples exist linking the operation of wind farms to direct impacts on terrestrial species, and impacts are likely to be location and species specific. However, barrier effect, noise, vibration, shadow flicker and electromagnetic field generation, and increased fire risk (due to increased anthropogenic activity), may directly impact terrestrial species.

Ecosystem service impacts may include a loss of, or restrict access to, locally important provisioning services, such as livestock grazing or agricultural land, or loss of cultural values, including visual impacts on the landscape. The level of these impacts will vary globally with the local intensity of, for example, land transformation, small-scale agriculture or reliance on non-timber forest products. Figure 5.2 illustrates an overall view of the impacts of onshore wind developments on biodiversity, and Table 5-1 presents a more detailed list of specific impacts on birds, bats and natural habitats. For more detailed information, read the IUCN ***Mitigating biodiversity impacts associated with solar and wind energy development Guidelines for project developers***.

Figure 5.2 Potential impacts of onshore wind developments on biodiversity. Please see Table 5-1 for details on each impact type



1. Bird and bat collisions with turbines blades and / or transmission lines, as well as possibly barotrauma
2. Habitat loss through clearance or displacement of land for construction of, (a) wind turbines and (b) associated facilities
3. Bird and bat mortality through electrocution on distribution lines
4. Barrier effects to to animal movement from, (a) closely-spaced turbines, (b) roads, and transmission lines.
5. Trophic cascade effects affect predator-prey dynamics and ecosystem function
6. Pollution (e.g. dust, light, noise and vibration, solid/liquid waste)
7. Indirect impacts from displaced land-uses, induced access or increased economic activity
8. Associated ecosystem service impacts
9. Introduction of invasive alien species

Table 5-1 Summary of the impacts of onshore wind and associated facilities on birds, bats and natural habitats. The significance of particular potential impacts will be context-specific

No.	Impact type	Project stage	Description and examples
1	Bird and bat collisions with turbines blades and/or transmission lines	Operation	Birds flying in the turbine rotor swept zone are potentially at risk of collision and serious injury or death. In the United States, for example, the median annual fatality estimate at wind energy facilities is 1.8 birds per MW,[1] while in South Africa and Canada the estimated mean annual fatality is 4.6 and 8.2 birds per turbine per year, respectively.[2] As these are median values, poorly sited wind energy facilities can have considerably higher fatalities. The diversity of birds killed by turbines can also be high. A four-year study of 20 wind farms in South Africa found mortality of 130 species from 46 families, totalling 30% of bird species recorded at and around the wind farms. Species accumulation models suggest that this may be as high as 42%.[3] Collisions with the (thin and hard to see) earth wire of transmission lines may lead to significant fatalities for some species such as bustards.[4] For bats, most studies to date on turbine collision risk are in the north temperate zone. In North America, carcasses were dominated by migratory, foliage- and tree-roosting bat species, with fatalities increasing at: (i) low wind speeds; and (ii) before and after passage of storm fronts.[5] The majority of species killed by turbines are adapted for foraging insects in open spaces, high above the ground and far from vegetation.[6] Mortality was usually the highest during low wind speeds and increased with turbine tower height and rotor diameter.[7] As for birds, collision risks are both for resident and migratory species. While barotrauma (injury caused by sudden pressure changes) has been hypothesised as a major source of bat mortality at wind turbines,[8] it does not appear to be an important source of bat mortality.[9]

1 AWWI (2019).
2 Perold et al. (2020); Ralston Paton et al. (2018); Zimmerling et al. (2013).
3 Perold et al. (2020).
4 Mahood et al. (2017).
5 Arnett et al. (2008).
6 Denzinger & Schnitzler (2013); Thaxter et al. (2017).
7 Rydell et al. (2010).
8 Baerwald et al. (2008).
9 AWWI (2019).

2	Habitat loss through clearance or displacement	Construction/ operation	The physical footprint of wind power turbines and access roads is usually relatively small. However, some species avoid wind farms, resulting in displacement and effective loss of habitat. Avoidance of turbines varies between species and locations, with avoidance distances also scaling with the size of the turbine.[10] Installation of wind turbines in Portugal resulted in black kites (*Milvus migrans*) avoiding 3%–14% of their previously used habitat in the area.[11] The response of bats to turbines differs across species and locations. Bats may actively avoid turbines or may be attracted to feed around them.[12] For example, forest clearance could affect bats through loss of roosting and foraging habitat. At the same time, the construction of roads and turbine arrays could create new foraging habitat for species that prefer foraging along forest edges and gaps.[13] The response to the presence of wind farms appears to be species-specific, with some species showing varying levels of avoidance.[14] Such species include both large mammals, such as the European roe deer (*Capreolus capreolus*), and smaller mammals such as the European hare (*Lepus europaeus*) and red fox (*Vulpes vulpes*).[15] In Portugal, wolves were found to avoid denning near wind farms by distances up to 6.4 km. Such responses can lead to significant cumulative impacts if wind farms are located in areas of limited breeding habitat; there can also be further impacts to the trophic cascade.[16] For example, a study on California ground squirrels (*Spermophilus beecheyi*) observed increased anti-predator behaviour near turbines.[17] Such behavioural changes may decrease foraging efficiency and lead to a shift in population dynamics (see row no. 5 'Trophic cascades').
3	Bird and bat mortality through electrocution on distribution lines	Operation	Electrocution rates at the pylons (or poles) of low- or medium-voltage lines can be high and disproportionately affect some species that use pylons of low-voltage lines as perches when hunting or for nesting. An annual mortality rate of around 0.7 birds per pole was estimated as a result of electrocution on a distribution line in southern Morocco.[18] Electrocutions may be partially responsible for the decline of some long-lived species. For example, electrocution of Egyptian vulture (*Neophron percnopterus*) over a 31-km stretch of powerline in Sudan is thought to have resulted in sufficient deaths to partially explain their population decline.[19] Electrocutions are rarely significant at the pylons of high-voltage transmission lines. There is limited evidence of risks to bats, although electrocution of large bat species, particularly fruit bats, has been identified as an issue associated with distribution lines.[20]

10 See review in Hötker (2017).
11 Marques et al. (2019).
12 Cryan et al. (2014); Foo et al. (2017). Other key references : Arnett et al. (2016); Millon et al. (2015; 2018); Minderman et al. (2012).
13 Barclay et al. (2017).
14 Pearce-Higgins et al. (2012).
15 Łopucki et al. (2017).
16 Ferrão da Costa et al. (2018a).
17 Rabin et al. (2006).
18 Godino et al. (2016).
19 Angelov et al. (2013).
20 Kundu et al. (2019); O'Shea et al. (2016); Tella et al. (2020).

4	Barrier effects	Construction/ operation	Multiple wind farms in the same landscape may create barriers for bird species although such impacts have not been extensively studied. As some species do show high collision avoidance rates, it is likely that their flight paths will change, especially if there are large numbers of closely-spaced turbines in a landscape. Migratory birds are particularly affected by wind turbines as they often travel in large flocks along set routes. Any obstacles blocking their flight paths will not only cause fatalities but may force them to burn crucial energy reserves diverting their route or abandon much-needed rest stops altogether. For example, migrating raptors appear to adjust their flight trajectories to avoid new wind farms.[21] Such barrier effects may become increasingly apparent as more wind farms are developed and monitoring (including of tagged birds) improves. Barrier effects may also affect terrestrial species if wind farms are fenced, particularly large migratory mammals.
5	Trophic cascades	Operation	Changes in species abundance with the presence of wind farms can affect predator-prey dynamics and ecosystem function: the nature and prevalence of this impact is still poorly understood. One example from India showed increased lizard abundance and behavioural changes within a wind farm footprint due to the avoidance of the area by their main raptor predators.[22] The effect of trophic cascades may become better understood with long-term monitoring.
6	Pollution (dust, light, noise and vibration, solid/ liquid waste)	Construction/ operation	Construction and operations can result in water, noise, dust and light pollution impacts. Although examples of impacts related to wind developments are limited,[23] they have been widely demonstrated for other types of infrastructure development.
7	Indirect impacts	Construction/ operation	Wind power projects generally have a small physical footprint and a small complement of staff once construction is complete. Despite this, localised indirect impacts (e.g. from displaced land-uses, induced access or increased economic activity) may still be significant. In some cases, land take for wind farm developments and their associated facilities may displace other land uses such as agriculture elsewhere. Induced access through construction of roads into previously remote areas may lead to increased pollution or contamination, natural resource collection or exploitation of vulnerable species. Examples specific to wind developments are not currently available.[24]
8	Associated ecosystem service impacts	Construction/ operation	Land needed for the development of wind farms and their associated facilities could lead to reduced access to, and the loss of, important provisioning services such as areas important for agriculture or provision of natural resources. Local communities may also feel a loss of cultural values (e.g. where sacred sites are impacted), including a sense of place and belonging. Wind farms may also impact the aesthetic value of an area, in turn negatively impacting the tourism potential or land value. These associated ecosystem service impacts could have adverse effects on the well-being of local people.
9	Introduction of invasive alien species	Construction	Movement of equipment, people or components may facilitate the introduction of invasive alien species (IAS), for example through its transport in soil on machinery or attached to clothing, etc. The creation of new habitats, for instance by land disturbance during construction or by creating open spaces, may also facilitate the spread of IAS already present on the site. At the Serra da Lousã wind farm in Portugal, two new IAS were found during operational monitoring, while two IAS already present were shown to have spread along access roads and turbine pads.[25]

21 Cabrera-Cruz & Villegas-Patraca (2016).

22 Thaker et al. (2018).

23 See Perrow (2017) for discussion of impact pathways for various species groups.

24 Ledec & Posas (2003).

25 Silva & Passos (2017).