Animal Conservation

Animal Conservation. Print ISSN 1367-9430

EDITORIAL

Challenges and opportunities for animal conservation from renewable energy development

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doi:10.1111/acv.12067

Global climate change is among the greatest threats confronting both human and natural systems (IPCC, 2007). A substantial component of greenhouse gas (GHG) emissions is from energy production, generated via the burning of fossil fuels, especially coal, natural gas and refined petroleum. Given that reduction in global energy consumption is unlikely over the next century or so, renewable energy generation has been proposed as a low-carbon alternative to limit GHG emissions. Consequently, many national and regional governments have set targets for renewable energy manufacture and use (e.g. '20% Wind Energy by 2030' – DoE, 2008; EU, 2009). Nevertheless, despite the benefits associated with reducing carbon emissions, renewable energy development itself has important, sometimes severe, implications for the conservation of biodiversity that should not be ignored. A central challenge and opportunity for animal conservation is to understand and manage environmental problems associated with the rapid growth in renewable energy production, while simultaneously maintaining progress toward reducing dependence on fossil fuels.

There are several types of renewable, or 'green', energy production. The most prominent of these are wind, solar, geothermal and biofuels. Some sources also consider hydroelectric, tide-generated energy and nuclear fission and fusion to be renewable. Although all are truly low carbon, two (fusion and tidal energy) are largely unproven and two (fission and hydroelectric) have dramatic and well understood environmental impacts.

Extraction of different types of renewable energy has varying direct and indirect effects on wildlife. Wind energy is unusual in that it can have both direct and indirect effects that are demographically relevant. Direct effects can be dramatic and are well-studied; for example, one of the world's oldest wind energy plants, the Altamont Pass Wind Resource Area in the Diablo Mountains in California, kills >1000 raptors annually, including >60 federally protected golden eagles, *Aquila chrysaetos*; (Smallwood & Thelander, 2008). Many other avian species, including grouse, songbirds and waterbirds, are impacted by a subset of terrestrial and offshore turbines globally, for example, in Norway (Dahl *et al*., 2012), Spain (Barrios & Rodriguez, 2004) and Scotland (Madders & Whitfield, 2006). Wind turbines also kill bats, especially tree roosting species (Kunz *et al*., 2007; Arnett *et al*., 2008; Grodsky *et al*., 2011; Voigt *et al*., 2012), often in greater numbers and with greater demographic impact than is the case for birds. Perhaps the most important conservation need linked to the use of wind turbines is for continued development of models to predict and evaluate how turbine sitting decisions impact local and migratory volant animals.

Although direct effects from wind turbines are severe and newsworthy, the majority of threats to animal conservation from renewable energy development is probably indirect and caused by habitat alteration or changes in behavior due to avoidance of energy generators. Wind energy development is habitat intensive, as each turbine requires a maintained ground clearing and a service road

(McDonald *et al.*, 2009), as well as installation of electric lines to transport power to the grid (Johnson & Stephens, 2011). Such habitat clearing nearly always has consequences for wildlife population and community dynamics (Naugle, 2011) often in unexpected ways, for example, by creating open foraging habitat for species that may subsequently encounter risk from blade strike or by creating scavenging sites that can attract new predators. Because indirect effects are notoriously difficult to quantify, they remain largely understudied and underappreciated. More work is needed to quantify and catalogue existing indirect effects associated with renewable energy development. This will allow a more realistic approach to modeling indirect effects and, thereby, better predictions about how their implementation will affect wildlife.

Solar energy presents threats to wildlife primarily through indirect effects linked to habitat fragmentation and loss; it is indeed presumed that only a very few, and likely demographically irrelevant number, of animals are killed at solar facilities (Tsoutsos, Frantzeskaki & Gekas, 2005). Although solar energy is readily adapted to the built environment (e.g. on rooftops of buildings and parking areas) where the biodiversity impacts of those installations are generally assumed to be negligible, industrial-scale solar facilities can use large amounts of land and require roads and transmission lines (McDonald *et al.*, 2009; Lovich & Ennen, 2011); the arid areas where it fares best can be areas of high biodiversity and endemism. In North America, solar energy development is concentrated in the desert southwest (Fernandes *et al.*, 2010; Copeland, Pocewicz & Kiesecker, 2011). In Europe, the Southern regions have the highest regional solar potential (Šúri *et al.*, 2007), although this technology is deployed broadly throughout the continent, especially Germany (Schiermeier, 2013).

Geothermal energy is the least space intensive of modern alternative energy approaches and among all energy types trails only nuclear energy in terms of its land-use footprint (McDonald *et al.*, 2009). Although the impacts to wildlife from geothermal energy are almost completely unstudied, they are likely to be less than those of other energy sources. The few published studies focus on groundwater and atmospheric pollution (Brophy, 1997; Kristmannsdóttir & Ármannssonb, 2003). Like solar, geothermal is one of the few technologies that can also be downscaled effectively, to the extent that when suitable resources are present, it can become a useful single-household energy resource.

Biofuels pose a suite of complicated and poorly understood hazards that impact animal conservation. Biofuel production requires substantial land area (McDonald *et al.*, 2009). Conversion of habitat to biofuel crop fields is controversial due to its impacts on biodiversity and because of the fossil fuel expenditure required to sow, harvest and transport the crop and to convert it to a useable form (Fargione *et al.*, 2008; Searchinger *et al.*, 2008; Koh & Wilcove, 2008). Furthermore, conversion of existing agricultural lands to biofuel production can have substantial impacts on world food prices, a problem often of greater concern to the general public than are the impacts associated with animal conservation (Zilberman *et al.*, 2013).

The unknowns in renewable energy development present a suite of grand challenges for animal conservation. In particular, major issues that remain to be addressed include:

1. The implementation of any energy program requires inputs of energy and land to manufacture, install and maintain generators and transport the produced energy. A complete lifecycle analysis accounting for the direct costs and benefits, not only in terms of carbon, energy and pollution, but also in terms of biodiversity impacts, would enable more effective decision making about renewable energy development.
2. A complete life cycle analysis would also allow effective development of best management practices (BMPs) for each type of renewable energy extraction. BMPs for renewables are still in their infancy and there are important improvements that can be made to benefit animal conservation, for example, in sitting of wind turbines, in types of solar and wind generators deployed and in how habitat is impacted.
3. In parallel with the quantification of known direct effects, it is critical to simultaneously focus on the elephant in the room – the almost completely unknown and species-specific indirect effects to wildlife of renewable energy generation. The physiological costs and demographic consequence of renewable-specific habitat fragmentation or generator avoidance need to be more completely assessed, understood and, ultimately, incorporated into impact assessments and BMPs.
4. Finally, a central assumption of renewable energy development is that over the relatively short term (<100 years), it has lesser negative impacts on populations and ecological systems than does the burning of fossil fuels. Because renewables should change climate less but may convert more habitat than fossil fuels, it is critically important to define the set of implementation scenarios under which this assumption is and is not met.

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