frontiers | Frontiers in Conservation Science

OPINION
published: 10 May 2022
doi: 10.3389/fcosc.2022.844286

Counterfactuals to Assess Effects to Species and Systems From Renewable Energy Development

Todd E. Katzner[1], Taber D. Allison[2], Jay E. Diffendorfer[3], Amanda M. Hale[4], Eric J. Lantz[5] and Paul S. Veers[5]*

[1] U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise, ID, United States, [2] Renewable Energy Wildlife Institute, Washington, DC, United States, [3] U.S. Geological Survey, Geosciences and Environmental Change Science Center, Denver, CO, United States, [4] Biology Department, Texas Christian University, Fort Worth, TX, United States, [5] National Renewable Energy Laboratory, Golden, CO, United States

Keywords: biodiversity, wind energy, climate change, counterfactual, solar energy

OPEN ACCESS

Edited by:
Christos Mammides, Frederick University, Cyprus

Reviewed by:
Matthew E. Aiello-Lammens, Pace University, United States
Johann Koeppel, Technical University of Berlin, Germany

****Correspondence:***
Todd E. Katzner
tkatzner@usgs.gov

Specialty section:
This article was submitted to Global Biodiversity Threats, a section of the journal Frontiers in Conservation Science

Received: *27 December 2021*
Accepted: *22 March 2022*
Published: *10 May 2022*

Citation:
Katzner TE, Allison TD, Diffendorfer JE, Hale AM, Lantz EJ and Veers PS (2022) Counterfactuals to Assess Effects to Species and Systems From Renewable Energy Development. Front. Conserv. Sci. 3:844286. doi: 10.3389/fcosc.2022.844286

INTRODUCTION

Renewable energy production, mostly via wind, solar, and biofuels, is central to goals worldwide to reduce carbon emissions and mitigate anthropogenic climate change (IPCC, 2014; Pörtner et al., 2021). Nevertheless, adverse impacts to natural systems, especially fatalities of wildlife and alteration of habitat, are key challenges for renewable energy production (Allison et al., 2019; Katzner et al., 2019).

Because of the magnitude of these challenges, extensive effort has been invested in surveys and science to understand the environmental effects of renewable energy on species and systems. Nevertheless, these impacts have not been formally compared relative to counterfactual conditions (Bull et al., 2021; Coetzee and Gaston, 2021), i.e., those occurring in the absence of renewable energy. As such, cumulative ecological impact assessments required by many regulating agencies typically only consider the adverse impacts of renewables, without evaluating whether mitigative effects of current and planned build-out (e.g., Larson et al., 2020) will offset their adverse impacts to species and natural systems (Allison et al., 2014). Accordingly, these critical decision processes have an insufficient perspective to foster fully informed decisions, and, for some species or systems, renewable energy could lead to more profound impacts than those it is intended to prevent. Furthermore, because of this approach and, despite the well-studied benefits to society of renewable energy development (IPCC, 2014), the ecological value of renewable energy is often premised on the plausible but untested assumption that its negative effects to natural populations and systems are less consequential than the negative effects in alternative scenarios with less renewable energy and greater climate change.

A more comprehensive framing of the counterfactual in cumulative ecological impact assessments would evaluate, for each species or system, the incremental effects of renewables over their full life cycle against the incremental effects they provide by mitigating climate change. This framing is important because a given species or system may see net positive or net negative effects from either renewables or climate change. Furthermore, cumulative impact assessments could identify optimized tradeoffs that balance, for each species or system, the effects of both climate change and renewable energy.

COUNTERFACTUALS FOR RENEWABLES

Although the term "counterfactual" is only recently adopted by ecologists and conservation biologists, the concept is used in many related fields (Baylis et al., 2016), and its core ideas are, in fact, familiar. Counterfactual thinking is an approach to impact assessment (Ferraro, 2009) whereby scenarios in which an action is taken and an impact measured are compared to a hypothetical or an unobserved scenario in which an alternative action, or no action, is taken (Kimmel et al., 2021). That said, the exact meaning of the word is inconsistently applied in conservation biology. For example, one definition requires that the counterfactual conditions do not exist (Bull et al., 2021). However, the term also has been applied to situations where real controls are compared to real treatments (Brandt et al., 2019; Santika et al., 2019; Jellesmark et al., 2021; also called "matches" Coetzee and Gaston, 2021). The first definition is particularly useful for large scale conservation questions—such as evaluating the actual impact to global wildlife populations from renewable energy development—where conducting an experiment is difficult or impossible (Coetzee and Gaston, 2021). In these situations, impact assessment may be achieved by defining counterfactual conditions based on modeling of, and assumptions about, hypothetical scenarios (Kimmel et al., 2021).

Because of the many assumptions required about unknown futures, modeling counterfactuals for large-scale conservation biology questions presents challenges. However, these challenges have been overcome in closely related fields. For example, counterfactuals are used in the rapidly emerging field of climate change attribution (Mengel et al., 2021), and scenario-based approaches including counterfactuals and sensitivities are common in energy system modeling (Cole et al., 2020). Similarly, Brook and Bradshaw (2015) used a multicriteria decision making analysis to illustrate the relative cost-benefit value of different energy types. Because their counterfactual analysis clearly explained alternative scenarios, it also was useful as the foundation for robust debate (Diesendorf, 2016; Hendrickson, 2016; Henle et al., 2016). Recently, counterfactuals have been used to assess population-level impacts to wildlife from renewable energy development (Katzner et al., 2020; Conkling et al., 2022), and to understand effects on bird populations from climate change (Sæther et al., 2019). Thus, combining these two types of models should be eminently feasible with modern technical tools. Moreover, the uncertainty and fidelity of the modeling processes used to generate counterfactual insights would be expected to improve with focused study, time, and improved computational power. Finally, counterfactuals are beneficial because, as these studies demonstrate, they can provide decision-makers a more complete, transparent, and nuanced set of opportunity costs, allowing exploration of working, and perhaps untested, assumptions.

As an example of how this approach could be used to understand ecological impacts of development of renewable energy, consider diurnal birds of prey. Raptors are negatively affected by renewables via fatalities, especially collision with wind turbines, and by habitat loss, at both wind and solar energy facilities (Watson et al., 2018; Kosciuch et al., 2020; Diffendorfer et al., 2021). Effects of climate change are less dramatic but equally important, for example acting through shifts in range and phenology (Paprocki et al., 2015; Therrien et al., 2017). For this group of species, one could frame the counterfactual as "how many diurnal raptors of species x will be killed in a future in which renewable energy production is implemented in a widespread manner to fully mitigate climate change, vs. a future in which renewable energy production is less widespread and climate change is only partially mitigated." Furthermore, if framed this way, it would be possible to evaluate multiple counterfactuals (Bull et al., 2021). For example, the question could be extended such that either numbers or demography of a given species could be compared under incrementally changing scenarios, from a scenario with no renewable energy and substantial climate change, to a scenario with 100% of the expected build-out of renewable energy and substantially less climate change. Such an approach would provide a powerful and scientifically important tool to assess the relative costs and benefits of build-out of renewables at a cumulative scale.

A comprehensive assessment of the multiple costs and benefits to diurnal raptors, or to other species, that is framed in this manner would identify the scenarios of renewable energy buildout in which species and populations are most likely to remain stable. Furthermore, there is considerable nuance to this comparison because, regardless of the focal taxonomic group, some species are more likely to be affected than others, and the spatial and technological characteristics of the buildout will impact each species differently. An analysis of multiple counterfactuals, therefore, not only could identify which species are most likely to require management or mitigation actions in the face of increasing numbers of renewable energy facilities, but also help to frame the scope and focus of those actions. We expect that if such an analysis were performed, most species would be more adversely affected by predicted climate change than by fatalities associated with expansion of renewables, but for a few species, the predicted impacts of renewables would be greater than those of climate change.

DISCUSSION

The counterfactual framework we propose here focuses on species- and system-specific costs and benefits. Such an analysis will be informative even if it does not include the many social, political, and environmental costs and benefits of renewable energy. For example, in the case of the diurnal raptors noted above, the primary laws in the U.S.A. that address fatalities occurring at renewable facilities were written in 1918 (Migratory Bird Treaty Act) and 1940 (Bald and Golden Eagle Protection Act), well before renewable energy was widely used and well before the significance of climate change was recognized. This is likely the case for laws protecting wildlife in many countries around the world. In part because of the way these laws were written, managers and stakeholders currently grapple separately with the impacts of climate change and of renewable energy. A counterfactual analysis would provide a context in which managers could explicitly link climate, renewables, and wildlife population dynamics, generating a more nuanced understanding of their interaction and thus a path forward for solving problems in existing legal frameworks.

Developing new data and insights covering a wider array of impacts across infrastructure lifecycles is critical to informed decision-making and to serving the objectives of society and decision-makers. Ultimately, a full accounting of the net effects to species and natural systems of renewables will require incorporating analyses of multiple counterfactuals that could guide projected near-term and large-scale build-out. Doing so will require new models, analytical tools, and theories for evaluation of the ecological costs and benefits of both renewable energy and climate change.

AUTHOR CONTRIBUTIONS

The core concepts underpinning this article arose from a discussion among all authors. TK led writing of the manuscript. All authors contributed to both the original manuscript and revisions, and all authors approved the submitted version.

FUNDING

Funding was provided by the authors' institutions and the Wind Energy Technologies Office. This work was authored (in part) by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308.

ACKNOWLEDGMENTS

The views expressed in the article do not necessarily represent the views of the DOE. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a non-exclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

REFERENCES

Allison, T. D., Root, T. L., and Frumhoff, P. C. (2014). Thinking globally and siting locally – renewable energy and biodiversity in a rapidly warming world. *Clim. Change* 126, 1–6. doi: 10.1007/s10584-014-1127-y

Allison,T. D., Diffendorfer, J. E., Baerwald, E. F., Beston, J. A., Drake, D., Hale A. M., et al. (2019). Impacts to wildlife of wind energy siting and operation in the United States. *Issues in Ecol.* 21, 2–18.

Baylis, K., Honey-Rosés, J., Börner, J., Corbera, E., Ezzine-de-Blas, D., Ferraro, P. J., et al. (2016). Mainstreaming impact evaluation in nature conservation. *Conserv. Lett.* 9, 58–64. doi: 10.1111/conl.12180

Brandt, J. S., Radeloff, V., Allendorf, T., Butsic, V., and Roopsind, A. (2019). Effects of ecotourism on forest loss in the Himalayan biodiversity hotspot based on counterfactual analyses. *Conserv. Biol.* 33, 1318–1328. doi: 10.1111/cobi.13341

Brook, B. W., and Bradshaw, C. J. (2015). Key role for nuclear energy in global biodiversity conservation. *Conserv. Biol.* 29, 702–712. doi: 10.1111/cobi.12433

Bull, J. W., Strange, N., Smith, R. J., and Gordon, A. (2021). Reconciling multiple counterfactuals when evaluating biodiversity conservation impact in social-ecological systems. *Conserv. Biol.* 35, 510–521. doi: 10.1111/cobi.13570

Coetzee, B. W., and Gaston, K. J. (2021). An appeal for more rigorous use of counterfactual thinking in biological conservation. *Conserv. Sci. Pract.* 3, e409. doi: 10.1111/csp2.409

Cole, W., Corcoran, S., Gates, N., Mai, T., and Das, P. (2020). *2020 Standard Scenarios Report: A U.S. Electricity Sector Outlook*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-77442. https://www.nrel.gov/docs/fy21osti/77442.pdf. doi: 10.2172/1721757

Conkling, T., Vander Zanden, H., Allison, T., Diffendorfer, J., Dietsch, T., Duerr, A., et al. (2022). Vulnerability of avian populations to renewable energy production. *Royal Soc. Open Sci.* 9:211558. doi: 10.1098/rsos.211558

Diesendorf, M. (2016). Subjective judgments in the nuclear energy debate. *Conserv. Biol.* 30, 666–669. doi: 10.1111/cobi.12692

Diffendorfer, J. E., Stanton, J. C., Beston, J. A., Thogmartin, W. E., Loss, S. R., Katzner, T. E., et al. (2021). Demographic and potential biological removal models identify raptor species sensitive to current and future wind energy. *Ecosphere* 12, e03531. doi: 10.1002/ecs2.3531

Ferraro, PJ. (2009). "Counterfactual thinking and impact evaluation in environmental policy," in *Environmental Program and Policy Evaluation: Addressing Methodological Challenges. New Directions for Evaluation*, eds M. Birnbaum and P. Mickwitz, Vol. 122, 75–84.

Hendrickson, O. (2016). Nuclear energy and biodiversity conservation: response to Brook and Bradshaw 2015. *Conserv. Biol.* 30, 661–662. doi: 10.1111/cobi.12693

Henle, K., Gawel, E., Ring, I., and Strunz, S. (2016). Promoting nuclear energy to sustain biodiversity conservation in the face of climate change: response to Brook and Bradshaw 2015. *Conserv. Biol.* 30, 663–665. doi: 10.1111/cobi.12691

IPCC (2014). "Climate change 2014: synthesis report," in *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, eds Core Writing Team, R. K. Pachauri, and L. A. Meyer (Geneva, Switzerland: IPCC).

Jellesmark, S., Ausden, M., Blackburn, T. M., Gregory, R. D., Hoffmann, M., Massimino, D., et al. (2021). A counterfactual approach to measure the impact of wet grassland conservation on UK breeding bird populations. *Conserv. Biol.* 35, 1575–1585. doi: 10.1111/cobi.13692

Katzner, T.E., Braham, M.A., Conkling, T.J., Diffendorfer, J.E., Duerr, A.E., Loss, S.R., et al. (2020). Assessing population-level consequences of anthropogenic stressors for terrestrial wildlife. *Ecosphere* 11, e03046. doi: 10.1002/ecs2.3046

Katzner, T. E., Nelson, D. M., Diffendorfer, J. E., Duerr, A. E., Campbell, C. J., Leslie, D., et al. (2019). Wind energy: an ecological challenge. *Science* 366, 1206–1207. doi: 10.1126/science.aaz9989

Kimmel, K., Dee, L. E., Avolio, M. L., and Ferraro, P. J. (2021). Causal assumptions and causal inference in ecological experiments. *TREE* 36, 1141–1152. doi: 10.1016/j.tree.2021.08.008

Kosciuch, K., Riser-Espinoza, D., Gerringer, M., and Erickson, W. (2020). A summary of bird mortality at photovoltaic utility scale solar facilities in the Southwestern U.S. *PLoS ONE* 15, 0232034. doi: 10.1371/journal.pone.0232034

Larson, E., Greig, C., Jenkins, J., Mayefield, E., Pascale, A., Zhang, C., et al. (2020). *Net-Zero America: Potential Pathways, Infrastructure, and Impacts, Interim Report*. Princeton, NJ: Princeton University.

Mengel, M., Treu, S., Lange, S., and Frieler, K. (2021). ATTRICI v1. 1– counterfactual climate for impact attribution. *Geosci. Model Dev.* 14, 5269–5284. doi: 10.5194/gmd-14-5269-2021

Paprocki, N., Glenn, N. F., Atkinson, E. C., Strickler, K. M., Watson, C., and Heath, J. A. (2015). Changing habitat use associated with distributional shifts of wintering raptors. *J. Wildl. Manage.* 79, 402–412. doi: 10.1002/jwmg.848

Pörtner, H. O., Scholes, R. J., Agard, J., Archer, E., Arneth, A., Bai, X., et al. (2021). *IPBES-IPCC Co-sponsored Workshop Report on Biodiversity and Climate Change*. IPBES and IPCC.

Sæther, B.E., Engen, S., Gamelon, M., and Grøtan, V. (2019). "Predicting the effects of climate change on bird population dynamics," in *Effects of Climate Change on Birds*, 2nd Edn, eds P. O. Dunn and A. P. Møller (Oxford: Oxford University Press).

Santika, T., Wilson, K. A., Budiharta, S., Law, E. A., Poh, T. M., Ancrenaz, M., et al. (2019). Does oil palm agriculture help alleviate poverty? A multidimensional counterfactual assessment of oil palm development in Indonesia. *World Dev.* 120, 105–117. doi: 10.1016/j.worlddev.2019.04.012

Therrien, J. F., Lecomte, N., Zgirski, T., Jaffré, M., Beardsell, A., Goodrich, L. J., et al. (2017). Long-term phenological shifts in migration and breeding-area residency in eastern North American raptors. *Auk* 134, 871–881. doi: 10.1642/AUK-17-5.1

Watson, R. T., Kolar, P. S., Ferrer, M., Nygård, T., Johnston, N., and Hunt, W. G., et al. (2018). Raptor interactions with wind energy: case studies from around the world. *J. Raptor Res.* 52, 1–18. doi: 10.3356/JRR-16-100.1

Conflict of Interest: All authors have received funding from government agencies who regulate renewable energy development and from the renewable energy industry for research on renewable energy. EL, PV, and TA are employed at organizations that specialize in the science and implementation of renewable energy. These funders were not involved in the study design, collection, analysis, interpretation of data, the writing of this article, nor the decision to submit it for publication.