SUPPORTING INFORMATION

METHODS

The Animal Behavior Society Conservation Committee (ABS-CC conducted a multi-phase research prioritization process to identify key animal behavior questions needed for a better understanding about the effects of the impact of solar power facilities on wildlife conservation.

Research Question Creation and Selection Process: Online Survey

The question creation and selection process followed similar research prioritization exercises undertaken on other conservation-related topics (e.g. Sutherland et al. 2009, 2014; Greggor et al. 2016). The process involves input from a large number of stakeholders initially through an open-ended questionnaire, followed by an intensive in-person session with a smaller group that adhered to an iterative Delphi process (Rowe & Wright 1999; Sutherland et al. 2011) to prune, prioritize and refine the question list. When done well, the process limits the input from any given individual, to better capture the sentiments of the group as a whole.

We created an online survey via GoogleForms to collect the starting list of relevant questions (see Supporting Information 2). Diverse stakeholders were targeted, to gain input from those involved in solar power generation, academics in animal behavior, ecology and conservation, and professionals in wildlife conservation. The survey primarily asked respondents to identify research goals in which animal behavior can be used to identify or mitigate the impacts of solar facilities. Responses were kept anonymous, but individuals were asked to provide their area of expertise, level of knowledge about solar power facilities, level of knowledge about the integration between animal behavior and conservation biology, as well as their country of residence and of work (see Table S1 for breakdown of participants). The survey was approved by the Humboldt State University Institutional Review Board (IRB# 18-161).

The survey was advertised on Twitter, sent out via email on personal and professional networks and promoted by the Animal Behavior Society (ABS). A total of 81 people responded while the survey was open (April 2019 - July 2019) and they included respondents that work in academia, wildlife conservation research, wildlife management, and environmental consulting (Table S1) with some working in more than one of these fields. Members of the ABS-CC then removed redundant questions and any responses that did not align with the topic. This filtering process resulted in 57 unique questions relevant to animal behavior, and an additional 32 questions that did not directly involve behavior and were not further analyzed. The 57 relevant questions were then divided into two categories: “understanding impacts” and “designing solutions”, with the “understanding impacts” category further sub-divided into four sub-categories (Table S2).

Research Question Selection and Prioritization Process: Workshop

The research prioritization process was continued at a one-day workshop run by the ABS-CC as part of Behaviour 2019 (a joint meeting of the Animal Behavior Society and the International Ethological Conference in Chicago, Illinois, USA) on July 23, 2019. A

total of 46 people attended the workshop participants: 16 academics/professionals/post-doctoral researchers, 15 graduate students, and 15 students. Workshop participants were placed into eight groups made up of a moderator (an ABS-CC member) and a balanced mix of academics, professionals, graduate and undergraduate students.

The workshop had four phases: background presentations, first round of prioritizing, second round of prioritizing and discussion. We began with presentations by Drs Thomas Dietsch and Peter Sanzenbacher, US Fish and Wildlife Service biologists and experts on the impacts of solar power on wildlife. Their presentation, “Wildlife-solar interactions: Understanding and responding to impacts from an emerging clean-energy industry” provided background information about solar power facilities and known impacts on wildlife.

At the start of first round of prioritizing, each group received a list of 5-7 research questions (either from the understanding impacts or designing solutions categories, Table S2). Each member of a group was asked to individually rank the questions as “gold” (high priority and must be included, if any), “silver” (important but possibly not necessary) and “throw out” (those of low priority). After ranking, they decided as a group which questions are priority questions and should move onto the second round. While discussing, groups were also allowed to rephrase, combine and write new questions. At the end of the first round, each group’s priority list was then compiled into a master list that consisted of 31 questions (23 “understanding impacts” and 8 “designing solution questions”; Table S3). Most of these questions came from the original list (with some rephrasing) and 5 were new questions; Table S3). This master list was then made available electronically to all groups to be used in the second round of prioritization.

During the second round of prioritization, each group was asked to select approximately four “understanding impact” questions and two “designing solution” questions. Questions were selected through group discussion and rephrasing was allowed. Each group’s selected list of prioritized questions was collected and recorded by ABS-CC members.

The eight groups overlapped in prioritized questions; most questions were listed twice or more. The final list was comprised 24 questions (Table S4). Note that even this list included some questions that were very similar, varying only in wording. Three priority research themes emerged from this final list of questions (Table S4), which are further explored the manuscript (Table 1).

References

Table S1. Demographics of the online survey “Impacts of Solar Power on Wildlife Conservation” (n = 81 respondents). *First selection (some respondents also selected a second and third field in addition to the first selection).

		Percent respondents
Field of work*	Applied wildlife conservation research	35%
	Academia	31.2%
	Wildlife conservation management	21.2%

	Environmental consulting	6.2%
	Other	6.2%
Expertise in integrating Animal Behavior and Conservation Biology	5: Extensive - my work is directly involved with making these connections	32.5%
	4	35%
	3	27.5%
	2	2.5%
	1: None - I have never considered this connection	2.5%
Familiarity with Solar Power Facilities	5: Extensive - my work is directly involved with solar power facilities	7.5%
	4	17.5%
	3	36.25%
	2	20%
	1: None - I have never encountered, studied or worked with solar power facilities	18.75%
Geographic Location	USA	79%
	Canadian	6%
	Germany	3.75%
	United Kingdom	3.75%

Table S2. Compiled questions originated from the online survey. Questions are divided into two categories: understanding impacts and designing solutions.

	Understanding impacts
#	*--Baseline assessments and Construction impacts*
1	How do species using the area where solar panel construction is planned behave in the face of road construction, deforestation, shade effects, contamination, and fragmentation?
2	Do the potential impacts of solar facilities accrue over time, or does the initial construction phase have the most impact?
3	How does the wildlife species behaviors change to the new footprint during construction and then after on a micro and macro scale?
4	What anti-predator behaviors do species exhibit in habitats where want to place facilities? And does anti-predator behavior allow species to persist in face of landscape change?
5	How much disruption is initiated by construction of large solar facilities?
6	What are the activity patterns and spatial use patterns of species before building facilities?
	--Maintenance impacts
7	Are there mowing trends that might interfere with regular emergence/nectaring/pollinating behaviour around solar panels?
8	How facilities be designed and managed to minimise the negative effects on behavior?
	--Long term impacts
9	Are the effects on individual behavior long-term or short-term? Do individual behavioral changes have community-level impacts?
10	What are species responses to various human activities and novel structures associated with solar farms?
11	Do species have the ability to acclimate to habitats altered by solar farms?
12	How does animals' behaviour around solar facilities affect communities and ecosystems?
13	Relative to the different types of solar facilities, what species are directly and indirectly affected, how are these effects expressed, and what are the population-level effects?
14	Relative to the different types of solar facilities, how are animal movements affected (attraction, avoidance, indifference), and how do these effects on movement ecology pair with those of other alternative energy development in a particular region?
15	How do species respond to: permanent habitat destruction; microclimate changes; increased lighting; increased habitat fragmentation due to fencing; pesticides?
	--Species-specific impacts
16	What are the effects of solar panels on gopher tortoise movement and burrow occupancy?
17	Are those species that show adaptation to humans and their structures also benefiting by solar facilities, and how?
18	What are the responses of burrowing species to artificial burrows?
19	What behaviors do birds exhibit when near habitat impacted by solar facilities?

20	Is fish behavior impacted by run-off or changes in land use?
21	Is habituation to humans a good predictor of which species may be highly affected by the increased human disturbance?
22	How do bats respond to tilted even surfaces of solar power facilities (since they collide with vertical even surfaces because the echo is reflected)?
	--Mechanisms of impact
23	What are the environmental cues that attract animals to solar facilities and are there any changes to attraction depending on the time of year or day?
24	What factors, and relative to the type of solar facility, serve to attract wildlife (e.g., ambient light, heat, cover, prey resources, etc.)?
25	For large, mobile animals, how do the various types of solar facilities serve as attractants, are animal avoiding them or indifferent, and why/how? Similar questions could be posed for insect fauna.
26	How might certain flora or landscape features typical of solar facilities attract serve as attractants, and what are the consequences for species responding (e.g., foraging, predation, reproduction, direct or indirect mortality)?
27	What species, if any, are affected by neophobic responses to solar facility establishment, and how?
28	How/will predators wait at entry points of fences?
29	Are solar fields mistaken for water bodies by migratory birds?
30	Is there individual variation in how individual animals respond to panels?
31	What cues affect landing aquatic fowl?
32	How do animal perceive solar facilities in the surroundings?
33	How do species (or individuals with in species) vary in their reactions to different disturbances caused by solar power facilities such as displacement?
34	How does noise pollution from solar facilities affect species?
35	Do solar power facilities cause sensory disturbance?
36	Are birds attracted to solar power facilities because of the increased abundance of insects over them?
37	Are raptors attracted to solar power facilities because of increased perching habitat?
38	Do reflections actually attract or deter species from these facilities?
39	What causes animals to stray into the path of solar energy collecting dishes where temperatures are dangerously high?
	--Impacts on movement
40	How do solar facilities overlap with species' (across taxa) home ranges?
41	How does facility type and area affect habitat connectivity and foraging corridors used by different species?
42	How is migration behavior impacted by solar facilities?

43	What is the minimum size of corridors needed for wildlife movement in solar facilities?
44	Do animals move through fences around the facilities?
45	How do solar power facilities interfere with dispersal?
46	How do solar power facilities interfere with foraging?
47	How do animals use and move in and around existing installations?
	-Designing solutions
48	How best to manage vegetation and construction to encourage small mammals (for example) or discourage (avoid bird collisions from polarized light pollution) animal use at solar facilities?
49	Is it possible to design a deterrent or repellent (sound? Visual?) to deter flight near solar facilities?.
50	Where can solar facilities be situated to avoid disrupting normal behaviors such as breeding, movement, foraging in and near altered habitat?
51	How might we mitigate cover, temperature, and light effects to prevent the creation of ecological traps for species that might not have otherwise occupied the preconstruction site?
52	Will species, such as tortoises and burrowing owls occupy, survive, and reproduce in artificial burrows established in an industrial complex?
53	How might predator exploitation of solar facility sites be managed so as to reduce tap effects?
54	How might site fencing be modified to allow animal movements?
55	What measures can be used to dissuade birds from entering areas where they might be at risk? (e.g. CSP Tower Facilities)
56	What sensory modalities are animals using that could be exploited to repel animals from dangerous solar tech equipment?
57	How can animals be kept away from such equipment long-term? (e.g. deterrents resilient to habituation?)

Table S3. Research questions prioritized during the first round of prioritization of the ABS-CC Conservation Behavior Workshop Behavior 2019.

New Number	***Understanding impacts***	Originating from Table S2 Number(s) or New Question

1	How do species using the area where solar panel construction is planned behave in the face of road construction, deforestation, shade effects, contamination, and fragmentation?	1
2	How does the wildlife species behaviors change to the new footprint during construction and then after on a micro and macro scale?	3
3	What are the activity patterns and spatial use patterns of species before building facilities?	6
4	How does species composition change pre to post construction?	New
5	Relative to the different types of solar facilities, what species are directly and indirectly affected and how does it change animal behavior, the population level effects and the community/ecosystem level impacts?	13
6	How do species respond to: permanent habitat destruction; microclimate changes; increased lighting; increased habitat fragmentation due to fencing; pesticides?	15
7	What are the effects of solar panels on gopher tortoise movement and burrow occupancy?	16
8	How far does the impact on behavior of the facilities go?	19
9	Is fish behavior impacted by run-off or changes in land use?	20
10	How do bats respond to tilted even surfaces of solar power facilities (since they collide with vertical even surfaces because the echo is reflected)?	22
11	How/will predators wait at entry points of fences?	28
12	Do solar power facilities attract/deter wildlife?	23-27 & 29-31
13	What species are attracted/deterred?	23-27
14	What are the factors attracting/deterring?	23-27
15	What are the consequences of the attraction/deterrence?	23-27
16	How do animal perceive solar facilities in the surroundings?	32
17	Do solar power facilities cause sensory disturbance?	35
18	Do reflections actually attract or deter species from these facilities?	38
19	What causes animals to stray into the path of solar energy collecting dishes where temperatures are dangerously high?	39
20	How is movement behavior impacted by solar facilities?	42
21	How do solar power facilities interfere with foraging of prey populations?	46
22	How does facility type and area affect habitat connectivity and foraging corridors used by different species and how does that affect fitness and mortality in different species?	41
23	How do solar power facilities overlap with species home ranges?	40
	Designing solutions	
24	Is it possible to design a deterrent or repellent (sound? Visual?) to deter flight near solar facilities?.	49

25	Where can solar facilities be situated to minimize disrupting normal behaviors such as breeding, movement, foraging in and near altered habitat?	50
26	How might we mitigate cover, temperature, and light effects to prevent the creation of ecological traps for species that might not have otherwise occupied the preconstruction site?	51
27	Will species, such as tortoises and burrowing owls occupy, survive, and reproduce in an industrial complex without reduced fitness?	52
28	Should solar power facilities attempt to prevent animals from entering solar power facilities or should they work to make them more permeable (allow animals to move through)?	New
29	How might site fencing be modified to allow animal movements?	54
30	What measures can be used to dissuade animals from entering areas where they might be at risk within a solar power facility?	55
31	What sensory modalities are animals using that could be exploited to repel animals from where they might be at risk within a solar power facility?	56

Table S4. Research questions selected during the second round of prioritization of the ABS-CC Conservation Behavior Workshop (Behavior 2019). Questions in black text represent the category “understanding impacts questions” and those in blue are “designing solution questions”.

Theme	#	Research Questions
Perception of solar facilities: natural attraction or deterrence?	1	Do solar facilities attract or deter wildlife? What are the mechanisms?
	2	How do animals perceive solar facilities in the surroundings?
	3	Do solar power facilities cause sensory disturbance?
	4	What are the characteristics of solar facilities are attracting and/or deterring certain species? What species impacted? What are consequences?
	5	What sensory modalities are animals using that could be exploited to repel animals from where they might be at risk within a solar power facility?
	6	Is it possible to design a deterrent or repellent (sound? visual?) to deter flight near solar facilities?

Habitat use in and around solar facilities in resident and migratory species	7	What kind of solar facilities designs would deter animal actively near hazardous areas (of the facilities)?
	8	What impact do solar facilities have on habitat use of resident terrestrial species?
	9	How far does the impact on behavior extend into habitat?
	10	What are the species composition and their habitat use before, during and after building facilities?
	11	How is migration behavior impacted by solar facilities?
	12	How does facility type and area affect habitat connectivity and foraging corridors used by different species?
	13	How is movement behavior through corridors impacted by solar facilities?
	14	Where can solar facilities be situated to minimize disrupting normal behaviors such as breeding, movement, foraging in and near altered habitat?
	15	How and where to build new solar facilities?
	16	How can solar power facilities attempt to prevent animal from entering solar power facilities?
	17	How should solar power facilities assess habitat quality and availability to determine whether harm is minimized by full exclusion or appropriately managed access to the site?
	18	Should solar power facilities attempt to prevent animals from entering solar power facilities or should they work to make them more permeable (allow animals to move through)?
Behavioral responses to solar facilities	19	What is the change in behavior from a baseline in response to solar facilities?
	20	What are the activity patterns and spatial use patterns of species before and after building facilities?
	21	How does species' behaviors (activity patterns, spatial use patterns, foraging/predator behavior, habitat connectivity) change to new footprint during construction and then after on a micro and macro scale?
	22	How do species respond to: permanent habitat destruction; microclimate changes; increased lighting; increased habitat fragmentation due to fencing; pesticides?
	23	What are the factors influencing animal behavior around solar facilities?
	24	Relative to different types of solar facilities, what species are directly and indirectly (i.e. occupy, survive and reproduce) affected and how does it change animal behavior, the population level effect and community/ecosystem level impacts?