Attachment A

Copies of Comment Letters Received on the Initial Study

From: Michael McWalters <mmcwalters@earthlink.net>
Sent: Sunday, September 25, 2016 12:08 PM
To: Berry, Whitney
Subject: Alviso Top Golf Part 2

Hello Whitney,
Are you the correct person to write my concerns to? Here is a list of my concerns.

I live in the manufactured home park (labeled 2) for sound and noise. I've read many things regarding Top Golf, all of them have complaints of NOISE. Top Golf in Alexandria, SLC, Kansas City and Roseville have huge complaints regarding noise. The one is Austin sells $525,000 a month in alcohol. That is a ton of money, which this site has a new land owner and most likely will close as the new land owner wants to redevelop the land. Alexandria will most likely close and be moved as the noise is a concern to many and the land owner will not renew the lease with top golf. How will Top Golf and the City of San Jose make sure that I'm not going waking up by a live band or loud music at 11pm?

Since Mayor Sam Liccardo sits on the VTA board I would expect that only 200 parking spaces should be available and EVERYONE ELSE CAN TAKE THE VTA AND BUS to attend Top Golf. That's what your department is striving for. I am opposed to 1400 parking places, its obnoxious. Take the bus or light rail. Planning rams this car issue in apartments and now it's time to move it to big business.

Traffic is also a concern, how will they manage DRUNK PEOPLE and DRUNK DRIVERS? Let's face it, this is a NIGHTCLUB/BAR and ENTERTAINMENT CENTER where alcohol is served and people DO AND WILL get drunk. Will there be additional police in our area to address the issue of DUI? In addition Mayor Sam Liccardo was opposed to a girly bar for executives in downtown San Jose. He stated that it was too close to schools. Let's not forget that San Jose has CLOSED MANY BARS in downtown over the past decade. One being SJ Live, for drunken behavior and fights broke out. Isn't it odd that San Jose no longer wants BIG BAR in downtown so you will toss them out in Alviso. Where a limited number of complaints will come in. If this is built SAN JOSE WILL DIVIDE US. This is better suited for the Coyote Valley.

Our manufactured home park currently receives a MAX OF 5.0 MB/S FROM AT&T INTERNET. How pathetic is that in Silicon Valley? When this object is built, I am 100 percent sure that all utility, phone and other lines will be buried. We are currently 600 feet from this site. I know fiber optic is currently in Alviso, but AT&T will not provide us with faster internet. Will this company deliver fiber optic to our park, if not we will than we will be the only area in Alviso with slow DSL service. I feel discriminated against. Who can I talk to regarding this issue? I can even give the owner of our park to this person.

My last concern. I am very disappointed that I haven't received any information regarding this proposed project or any paperwork from the planning department. I've received stuff in the mail from SJ Planning Dept. regarding the Trommwell Crow and the other developer, but NO PAPERWORK WAS SENT TO ME REGARDING THIS PROJECT. I've also left a message with District 4 Fred Buzo regarding my disappointment.

Sincerely,

Michael McWalters
2052 Gold Street #36
Alviso, Ca 95002
408-262-4406
408-209-9814

From: Betsy Stern <betsysternmusic@gmail.com>
Sent: Tuesday, October 11, 2016 5:01 PM
To: Berry, Whitney
Subject: Response to Mitigated Negative Declaration for TopGolf at Terra Project

Dear Ms. Berry,

I am responding to the Mitigated Negative Declaration for TopGolf at Terra Project.

In reference to Appendix I, 2.6.4 NEIGHBORHOOD STREETS, where is the mitigation that will protect the pedestrians (especially the children and parents) going to and from George Mayne Elementary School while, in addition to increased traffic due to the physical presence of TopGolf, TopGolf will be serving alcohol from 9:00 am until 2:00 am, and this will have a direct impact on the increase in traffic accidents. Although the sale of alcohol itself doesn't fit into an MND, the impact of drunk driving does -- to the environment and to people.

The rezoning of this property to allow for an entertainment center that serves alcohol from 9:00 am to 2:00 am and is directly across the street from an elementary school is absolutely unconscionable.

Yours sincerely,

Betsy Stern

County of Santa Clara
Parks and Recreation Department

298 Garden Hill Drive
Los Gatos, California 95032-7669
(408) 355-2200 FAX 355-2290
Reservations (408) 355-2201
www.parkhere.org

17 October 2016

Whitney Berry
Department of Planning, Building, and Code Enforcement
City of San Jose
200 East Santa Clara Street, 3rd Floor Tower
San Jose, CA 95113

Subject: PDC16-013, GPT16-001 Topgolf at Terra Project

The County of Santa Clara Parks and Recreation Department (the Department) has reviewed the proposed Topgolf at Terra Project. The proposed project includes changing the Planned Development Rezoning from the CIC Combined Industrial Commercial and R-M Multiple Residence Residential Zoning Districts to the CIC (PD) Planned Development Zoning District (PDC16-013). In addition to this amendment, the proposed project would amend the Alviso Specific Plan development standards for building heights (GPT16-001).

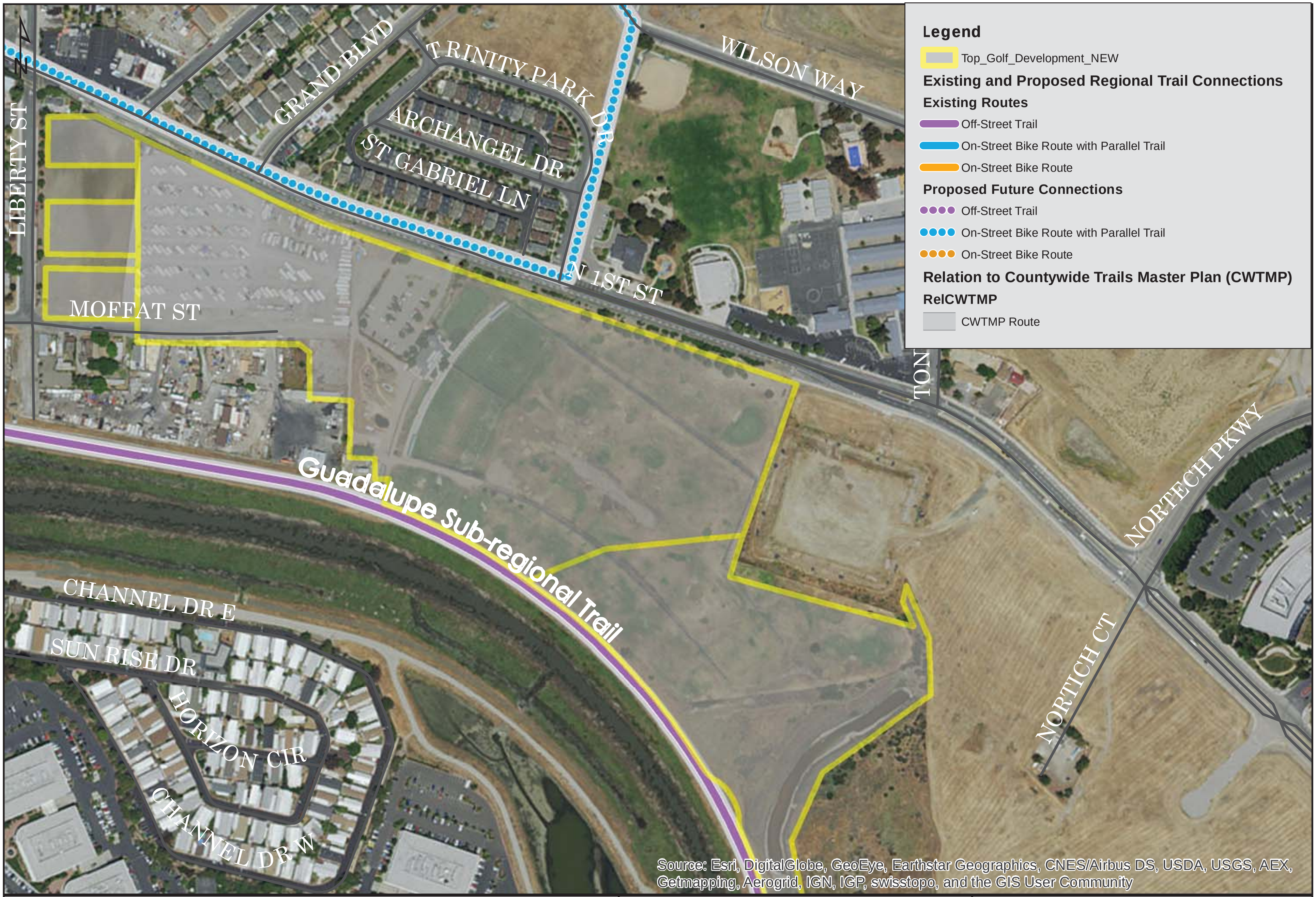
The developed Regional Trail S3 (*Guadalupe Sub-Regional Trail*) spans west of the project site, while a proposed San Francisco Bay Trail with an on-street bike route spans north of the project site. The approval of the proposed land use designation change and amendment to the Alviso Specific Plan will not adversely impact the existing adjacent recreational and commuter trails within the *Countrywide Trails Master Plan.*

PDC16-013 and GPT16-001 change does not impact the Trails Element of the Parks and Recreation Chapter of the 1995 General Plan. The Department has no further comments.

The Recreation Department appreciates the opportunity to provide comments. If you should have any questions or concerns, please contact me, commercial 408.355.2228 or by email Cherise.Orange@prk.sccgov.org.

Sincerely,

Cherise Orange
Cherise Orange
Associate Planner



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

SANTA CLARA COUNTY PARKS

This map generated by the County of Santa Clara Department of Parks and Recreation. The GIS files were compiled from various sources. While deemed reliable, the Department assumes no liability.

Title: Topgolf @ Terra Project	Comments: No impact to CTMP
Date: 17 Oct 2016	Created By: C Orange

Scale: 0 0.0125 0.025 0.05 Miles

STATE OF CALIFORNIA—CALIFORNIA STATE TRANSPORTATION AGENCY EDMUND G. BROWN Jr., Governor

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DISTRICT 4
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October 17, 2016

04-SCL-2016-00049
SCL237216
SCL/237/PM R6.5
SCH# 2016092036

Ms. Whitney Berry
Department of Planning
City of San Jose
200 E. Santa Clara Street, Tower 3
San Jose, CA 95113

Dear Ms. Berry:

Terra @ Topgolf Project – Mitigated Negative Declaration

Thank you for continuing to include the California Department of Transportation (Caltrans) in the environmental review process for the above-referenced project. In tandem with the Metropolitan Transportation Commission's (MTC) Sustainable Communities Strategy (SCS), Caltrans new mission signals a modernization of our approach to evaluating and mitigating impacts to the State Transportation Network (STN). We aim to reduce vehicle miles traveled (VMT) by tripling bicycle and doubling both pedestrian and transit travel by 2020. Our comments are based on the Mitigated Negative Declaration (MND). Please also refer to the previous comment letter, dated January 19, 2016, on this project and incorporated herein.

Project Understanding

The proposed project is located immediately adjacent to the north of State Route (SR) 237, on the east side of the Guadalupe River, and south of N. 1st Street. It would replace Pin High Golf Center, an existing driving range and golf facility located on the eastern portion of the site at 4701 N. 1st Street, as well as remove a recreational vehicle storage area located on the site's western portion. The proposed project will consist of the following:

- A 13.5-acre Topgolf entertainment complex in the southern portion of site, which would comprise of 125 hitting bays, an outdoor field enclosed by netting, and a 3-story structure with a full-service restaurant, a bar, lounges, corporate/event meeting space, and a family entertainment area. Additionally, these Topgolf facilities are anticipated to be open as late as 2:00 AM and would be supported by an adjacent 460-space paved parking lot.
- A 200-room hotel spanning 6.8 acres on the western portion of the site.
- A retail component consisting of five structures totaling 100,000 square feet (or 100 KSF).

- 5.8 acres of undeveloped land on the southeast corner of the project site would remain undeveloped.

Lead Agency
As the lead agency, the City of San Jose (City) is responsible for all project mitigation, including any needed improvements to the STN. The project's fair share contribution, financing, scheduling, implementation responsibilities and lead agency monitoring should be fully discussed for all proposed mitigation measures.

Traffic Impacts
1. N. 1st Street/SR 237 Overpass: The MND states that the project will add a third northbound left-turn lane from N. 1st Street onto the westbound (WB) SR 237 on-ramp. The on-ramp should also be widened, so it can provide enough storage on the SR 237 on-ramp. The project should provide analysis for the above operation for Caltrans review and comments.

2. Ramp Capacity: A ramp-capacity analysis should be performed on the Great America Parkway/SR 237 on-ramp for both the eastbound (EB) and WB side of SR 237. If the queue on these ramps back up onto the City streets, then mitigation is necessary to widen the ramps.

3. Queue Analysis: Please provide the 95th percentile queue analysis for the following intersections:

   - Great America Parkway/SR 237 WB off-ramp.
   - Great America Parkway/SR 237 EB off-ramp.
   - Great America Parkway/Gold Street Connector.
   - N. 1st Street/SR 237 WB off-ramp.
   - N. 1st Street/SR 237 EB off-ramp.
   - N. 1st Street/Hoglar Way.

   If the findings of the analysis result in queues that extend onto the freeway that extend beyond the through lane storage between intersections or left-turn pocket storage, then the project should fully mitigate these impacts.

4. Freeway Segment Analysis: The 2,300 vehicle per hour per lane (vhl) capacity stated in the report for Freeway Segment analysis is too high, based on passenger car equivalent volume. If this capacity is used, then all of the count volumes need to be adjusted to passenger car equivalent volumes.

5. Figure 2.0-2 Vicinity Map: The Vicinity Map of the Initial Study Report has SR 237 mislabeled as SR 87. Please correct the Figure to accurately depict the State facility as SR 237.

Vehicle Trip Reduction
Transportation Demand Management (TDM) programs should be documented with annual monitoring reports by an onsite TDM coordinator to demonstrate effectiveness. Suggested TDM

strategies include working with the Santa Clara Valley Transportation Authority (VTA) to decrease headway times and improve way-finding on bus lines to provide a better connection between the project, the Great America Station, and regional destinations and providing:

- Membership in a transportation management association.
- Transit subsidies and/or EcoPasses to all employees.
- Ten percent vehicle parking reduction.
- Transit and trip planning resources.
- Carpool and vanpool ride-matching support.
- Carpool and clean-fuel parking spaces.
- Secured bicycle storage facilities.
- Bicycles for employee uses to access nearby destinations.
- Showers, changing rooms and clothing lockers.
- Fix-it bicycle repair station(s).
- Transportation and commute information kiosk.
- Outdoor patios, outdoor areas, furniture, pedestrian pathways, picnic and recreational areas.
- Nearby walkable amenities.
- Kick-off commuter event at full occupancy.
- Employee transportation coordinator.
- Emergency Ride Home program.
- Bicycle route mapping resources and bicycle parking incentives.

Please refer to "Reforming Parking Policies to Support Smart Growth," a MTC study funded by Caltrans, for sample parking ratios and strategies that support compact growth. Reducing parking supply can encourage active forms of transportation, reduce regional VMT, and lessen future traffic impacts on SR 237 and other nearby State facilities. These smart growth approaches are consistent with the MTC's Regional Transportation Plan (RTP)/SCS goals and would meet Caltrans Strategic Management Plan.

Traffic Impact Fees
Given the project's contribution to area traffic and its proximity to SR 237, the project should contribute fair share traffic impact fees toward the Caltrans sponsored planned construction of the auxiliary lanes on both EB and WB sides of SR 237 between the Zanker Road interchange and the N. 1st Street interchange. Also, the project should contribute to the SR 237 Express Lanes Project. These contributions would be used to lessen future traffic congestion and improve transit in the project vicinity.

Voluntary Contribution Program
We encourage the City to participate in the VTA's voluntary contribution program and plan for the impact of future growth on the regional transportation system. Contributions by the City funding regional transportation programs would improve the transportation system by reducing congestion and improving mobility on major roadways throughout the San Francisco Bay Area.

Bridges, Trestles, Culverts and Other Structures in Riparian Environments
Some project level activities may affect riparian flow patterns upstream of bridges, trestles, culverts or other structures for which Caltrans holds responsibility. Please ensure your project level environmental documents include hydrological studies to determine whether such impacts will occur, and to identify appropriate mitigation measures.

Habitat Restoration and Management
Project level activities related to habitat restoration and management should be done in coordination with local and regional Habitat Conservation Plans, and with Caltrans where our programs share stewardship responsibilities for habitats, species and/or migration routes.

Sea Level Rise
The effects of sea level rise may have impacts on transportation facilities located in the project area. Executive Order (EO) S-13-08 directs State agencies to plan for potential impacts by considering a range of sea level rise scenarios for the years 2050 and 2100. Higher water levels may increase erosion rates, change environmental characteristics that affect material durability, lead to increased groundwater levels and change sediment movement along shores and at estuaries and river mouths, as well as affect soil pore pressure at dikes and levees on which transportation facilities are constructed. All these factors must be addressed through geotechnical and hydrological studies conducted in coordination with Caltrans.

Encroachment Permit
Please be advised that any work, staging, or traffic control that encroaches onto the State right-of-way (ROW) requires an encroachment permit that is issued by Caltrans. To apply, a completed encroachment permit application, environmental documentation, and five (5) sets of plans clearly indicating State ROW must be submitted to: David Salladay, District Office Chief, Office of Permits, California Department of Transportation, District 4, P.O. Box 23660, Oakland, CA 94623-0660. Traffic-related mitigation measures should be incorporated into the construction plans prior to the encroachment permit process. See this website for more information: www.dot.ca.gov/hq/traffops/developserv/permits.

Should you have any questions regarding this letter, please contact Brian Ashurst at (510) 286-5505 or brian.ashurst@dot.ca.gov.

Sincerely,

Lisa Carboni

for PATRICIA MAURICE
District Branch Chief
Local Development - Intergovernmental Review

c: Scott Morgan, State Clearinghouse
Robert Swierk, Santa Clara Valley Transportation Authority (VTA) – electronic copy

m|r|wolfe
& associates, p.c.
attorneys-at-law

October 17, 2016

By E-mail
Acknowledgement of Receipt Requested

Whitney Berry, Environmental Project Manager
Department of Planning, Building and Code Enforcement
City of San José
200 E. Santa Clara Street
San José, CA 95113
Email: Whitney.Berry@sanjoseca.gov

Re: Proposed Mitigated Negative Declaration for Topgolf @ Terra Project; File No. GPT16-001

Dear Ms. Berry:

Please accept the following comments on the above-referenced mitigated negative declaration, submitted on behalf of Organizacion Comunidad de Alviso ("OCDA"). OCDA is an unincorporated association of residents, citizens, property owners, taxpayers, and electors residing in the Alviso community of San José, who will be directly affected by any adverse environmental impacts that the Topgolf project ("Project") may generate.

We have reviewed the initial study and proposed mitigated negative declaration ("IS/MND") together with its various technical appendices. As explained below, the City's proposed reliance on a MND for this large-scale retail/hotel/recreational project in lieu of a full environmental impact report ("EIR") is improper. Evidence contained in (or missing from) the IS/MND shows that the Project – the first of its kind in the City -- may have one or more significant environmental impacts notwithstanding the mitigation measures identified in the MND. Under these circumstances the California Environmental Quality Act ("CEQA") requires the City to prepare and circulate an EIR before it may lawfully approve the Project.

I. Traffic Impacts

The Transportation Impact Analysis ("TIA") appended to the IS/MND states that existing (i.e., baseline) traffic conditions were based on traffic counts obtained from the City. Although most of the counts were taken in 2015 or 2016, some are as old as 2013 (*see* pp. 208 - 211 of the Appendix I PDF comprising counts for North First and Tasman). Other counts date from 2014 (*see* Appx I PDF pages 257-258; 260 -261; 263-266, comprising respectively counts of Great America Parkway with SR 237 westbound ramps, Great America Parkway with eastbound SR 237 ramps and Vista Montana with West Tasman). Still other count data is of indeterminate age – 2014 or older (pp. 178, 183, 228, 259, and 262, comprising respectively data for the key intersections of N. First with SR 237 westbound ramps, N. First with SR 237 eastbound ramps, N. First with Montague Expressway, Great America with SR 237 westbound ramps and Great America with SR 237 eastbound ramps; dates on these sheets are dates on which data was entered into data base or extracted from data base; actual count date is indeterminately older).

The TIA should have used growth factors to update older count data to approximate current levels. No such adjustment is documented. As the City should aware, North San Jose has seen substantial new development in recent years, and reasonable growth factor adjustments (or new counts) are thus essential to fair representation of existing conditions in this area. It is also noteworthy that Levi's Stadium, which has major effects on weekday as well as weekend traffic in the area, did not open for events until July, 2014. If the existing conditions data base is understated, the analysis is skewed to minimize disclosure of project traffic impacts. Please circulate a revised TIA that reflects current traffic count data, or growth-adjusted earlier data before taking any action to approve the Project.

The TIA's trip generation analysis, documented in Appendix I, Table 10, used the average trip generation rate for shopping centers from ITE *Trip Generation, 9th Edition* to estimate the gross trip generation (trip generation before reductions for internalization and passerby attraction) for the Project's retail component. However, trip generation varies by shopping center size with very large centers having lower than average generation per square footage, small ones having greater than average generation per square foot. Because of this, the ITE document advises use of the regression equation provided in the document rather than the average rate. The retail floor area in the Topgolf Project falls in the area where actual generation by the regression equation is greater than the average rate. Please update the trip generation analysis accordingly.

The TIA's trip generation analysis assumes that 25 percent of the daily and PM peak trips to the Project's retail component would be attracted from existing traffic passing the site. While this is ordinarily a conventional assumption, it is inappropriate with respect to this Project for two reasons. First, the limited amount of traffic passing the site makes attracting 25 percent of the Project's retail traffic from regular passers-by unsustainable. Second, the retail to be developed on the site is unlikely to be attractive to passers-by given the socioeconomics of the local community who comprise the passerby traffic.

The TIA reports that under the original assumption of 117,000 square feet of retail space, the Project was found to cause a significant impact on a freeway segment. After reducing the retail component by 7,000 square feet, the TIA finds a reduction in overall PM peak generation of about 20 net trips (after discounting for internalization and passers-by), thereby avoiding the freeway impact. Had the TIA properly accounted for the gross PM peak retail trip generation and for realistic passer-by attraction, the result would have been substantially more trips generated per 1,000 square feet, such that the removal of just 7,000 square feet would not eliminate the freeway impact.

The TIA also indicates that the Project could add 21 to 28 percent to traffic on Gold Street. The Project traffic assignment on Appendix I, Figure 8 shows the project adding 136 trips to Gold Street in the PM peak, which is a 20.4 percent increase in the existing Gold Street PM peak traffic of 666 shown on Appendix I, Figure 6. But if the Project trip distribution route information displayed on Appendix I, Figure 7 is combined with the project trip generation information contained on Appendix I, Table 10, Project trips could add some 32 percent to traffic on Gold Street. And if the gross retail trip generation and passer-by attraction had been properly estimated as detailed in the points above, the percent increase on Gold would be even greater.

The TIA also includes an analysis of Project impacts on Alviso neighborhood streets, finding that the Project would increase average daily trips on Gold Street at Moffatt Street by 21 percent, and on North Taylor Street between Gold and Liberty Streets by 28 percent. The TIA then identifies various "potential transportation improvements." The listed improvements, which include installation of bulb-outs, speed feedback signs, roundabouts, raised crosswalks and the like, are not identified as mitigation measures in the IS itself. The TIA in essence has found potentially significant traffic impacts on Alviso neighborhood streets and recommended mitigation measures for them, that the IS/MND has failed to disclose. At a minimum, the IS/MND should be updated to specify these measures as binding mitigation measures that the Project applicant and/or the City will be required to implement if the Project is ultimately approved.

In sum, the City should correct the foregoing flaws and inconsistencies in a revised TIA circulated for further public review and comment.

II. Air Quality Impacts

The Project uses CalEEMod to calculate Project emissions. The model appears to rely on unsubstantiated input parameters to estimate Project emissions. For example, the CalEEMod output files for the Hotel/Retail portion of the Project model the parking lot with 178 spaces, but then assigned a lot acreage of zero to this land use (Appendix A, p. 55). Meanwhile, according to figures presented in the IS/MND itself, the surface parking lots are in fact a part of the total lot acreage (IS/MND, p. 13, p. 39). As such, the parking lot land use should have an acreage assigned to it in the CalEEMod model. By failing to include this, pollutant emissions, such as fugitive dust and VOCs, from grading and asphalt paving have been underestimated. Please correct this omission in a revised initial study.

The IS/MND finds a potentially significant air quality impact from emissions of NOx during Project construction. (IS/MND p. 65.) It then claims this impact would be reduced to a less than significant level with mitigation measure MM AQ-1.1, which provides: "[a]ll diesel-powered construction equipment larger than 50 horsepower and operating on site for more than two (2) continuous days shall meet U.S. EPA particulate matter emissions standards for Tier 4 engines or equivalent" (IS/MND, p. 65). The IS/MND does not, however, explain or document the feasibility of this mitigation measure. The assumption that a combined total of 75 pieces of construction equipment for both the TopGolf Complex and Hotel/Retail components of this Project will be equipped with Tier 4 engines is dubious, given that current regulations do not require construction fleets to consist of solely Tier 4 equipment, and that retrofitting older equipment with Tier 4 engines is extremely expensive. Please explain how the City plans to enforce this mitigation measure.

The IS/MND calculated average daily construction emissions by averaging annual emissions over 396 workdays. (Table 4.3-4, IS/MND, p. 65). This averaging period appears to be based on the CalEEMod default schedule used to model the TopGolf Complex. At the same time, construction of the Retail/Hotel component of the Project was done using a Project-specific construction schedule provided by the applicant, which assumes construction over 300 work days. However, the annual emissions from both the TopGolf Complex and the Retail/Hotel are spread over a 396 day averaging period instead of using a 396 day averaging period for the TopGolf Complex and a 300 day averaging period for the Hotel Retail Component, and adding the average daily emissions with each other. By using a larger averaging period to estimate the Retail/Hotel average daily emissions, the Project's average daily construction emissions are underestimated. Please address this inconsistency in a revised Air Quality analysis.

III. Health Impacts from Diesel Exhaust Emissions

The IS/MND includes a health risk assessment ("HRA") in Appendix A for exposing nearby sensitive receptors to hazardous pollutant emissions during Project construction. Specifically, the ISCST3 dispersion model was used to predict concentrations of diesel particulate matter (DPM) and PM2.5 at affected sensitive receptor locations. The ISCST3 output files do not appear to have been provided, however. This makes it impossible for the public to verify the accuracy or legitimacy of the various assumptions that the dispersion model relied upon. Because the public is entitled to review and comment upon all technical information relied upon in the IS/MND (CEQA Guidelines § 15072(g)(4)), please circulate the ISCST3 for a minimum 20-day review period before any action is taken to approve the Project.

The IS/MND does not include a HRA for the Project's operational phase. Diesel-powered delivery truck trips associated with the hotel and retail land uses of the Project will undoubtedly produce significant quantities of DPM emissions, exposing nearby sensitive receptors in Alviso to a potentially significant direct and/or cumulative health risk. The City should prepare and circulate a HRA that evaluates the Project's individual and cumulative operational health risks prior to taking action to approve the Project.

IV. Noise Impacts

The Noise Assessment appended to IS/MND does not appear to have evaluated the Project's cumulative traffic noise impacts in the manner required by CEQA. Under CEQA, a legally adequate cumulative impact analysis requires an agency first to determine whether will be a significant cumulative noise impact from the Project in combination with other past, present, and future projects in the vicinity, i.e., whether all relevant projects together will generate noise exceeding the City's noise standards at the affected locations. *See* CEQA Guidelines, § 15130; *Communities for a Better Environment v. California Resources Agency* (2002) 103 Cal.App.4th 98. If the agency in fact finds a significant cumulative impact, it must then *separately* determine whether the project's contribution to that impact is "cumulatively considerable." *Id.* The IS/MND's Noise Assessment does not adhere to this mandatory two-step approach.

We would note that the Noise Assessment indicates that traffic noise levels at 7 affected roadway segments already exceed the City's residential noise standard of 60 dB, and will continue to do so with the Project. This suggest there is already a significant cumulative noise impact, thus triggering a duty to ascertain, using specific significance thresholds, whether the Project's contribution to it in the future is cumulatively considerable. The City should prepare and circulate a legally adequate cumulative traffic noise analysis before taking any action to approve the Project.

V. Conclusion

Under CEQA, an agency may rely on a negative declaration or mitigated negative declaration only if there is no substantial evidence whatsoever that a project may have a significant environmental impact. CEQA Guidelines, § 15064(f)(3). While a fair argument of environmental impact must be based on substantial evidence, CEQA places the burden of environmental investigation on government rather than the public. "If a local agency has failed to study an area of possible environmental impact, a fair argument may be based on the limited facts in the record. Deficiencies in the record may actually enlarge the scope of fair argument by lending a logical plausibility to a wider range of inferences." *Sundstrom v. County of Mendocino* (1988) 202 Cal.App.3d 296, 311.

Here, the foregoing deficiencies, errors and omissions render the IS/MND inadequate to support approval of the Project under CEQA. The City should prepare a full EIR that contains new/revised analyses discussed above before taking any action to approve the Project.

Thank you for your consideration of this comments and concerns.

Yours sincerely,

M. R. WOLFE & ASSOCIATES, P.C.

Mark R. Wolfe
On behalf of Organizacion Comunidad de Alviso

MRW:sa
cc: OCDA

3189 Salem Drive
San Jose, CA 95127
(408) 835-1795
adaemarquez@gmail.com

October 17, 2016

City of San Jose
200 East Santa Clara Street
San Jose, CA 95113

Dear Ms. Berry:

In regards to Topgolf IS/MND File No. PDC16-013, *Planned Development Rezoning from the CIC Combined Industrial Commercial and R-M Multiple Residence Residential Zoning Districts to the CIC(PD) Planned Development Zoning District to allow up approximately 110,000 square feet of commercial/retail space, a 200 room hotel, approximately 72,000 square feet of indoor/outdoor recreation use (Topgolf) and late night use. File No. GPT16-001: General Plan Text Amendment to amend the Alviso Specific Plan to change the development standards for height under the "Village Area Guidelines for Commercial Development" to include a maximum allowable building height of 65 feet in certain areas and a maximum allowable non-building structure height of 170 feet in certain areas.*

An EIR should be prepared per CEQA for the following inadequacies and lack of quantitative analyses:

1. **GHG's : This project does not conform to the General Plan and therefore cannot use the Greenhouse Gas Reduction to replace a separate analysis.**

Per The City of San Jose Greenhouse Gas Reduction Strategy[1]: The City chose the *Establishment of a GHG Reduction Target (updated December 2015) per* BAAQMD CEQA Guidelines (May 2011) thresholds for assessing the required reduction in GHG by the year 2020: Meeting the plan efficiency threshold of 6.6 metric tons of CO2 equivalent per service population per year (MT CO2e / SP / year)." However, the IS/MND does not disclose thresholds for their analysis of greenhouse gases. In addition, the IS/MND fails to disclose the following information:

a) The IS/MND does not disclose the environmental baseline for greenhouse gases in the City of San Jose;
b) Does not disclose existing GHG's emissions around the project's perimeter and cumulative GHGs impacts. The document is inadequate by disclosing qualitatively only "Existing On-Site Emissions" of the Golf Center, RV storage area, on-site electricity and transportation. Per CEQA, what are other sources in Alviso emit greenhouses gases, both stationary and mobile sources, approved projects, and future projects?

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[1] http://www.sanjoseca.gov/index.aspx?NID=3687

c) Does not provide quantitative analysis of GHG's of the project for approximately 110,000 square feet of commercial/retail space, a 200 room hotel, approximately 72,000 square feet of indoor/outdoor recreation use (Topgolf), separately and cumulatively.

d) The City of San Jose per CEQA section 15065, must prepare an EIR to disclose the cumulative impacts of this project and other projects in Alviso:

   a. The project has the potential to achieve short-term environmental goals to the disadvantage of long-term environmental goals.

   b. The project has possible environmental effects that are individually limited but cumulatively considerable. "Cumulatively considerable" means that the incremental effects of an individual project are significant when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects. (CEQA Statutes and Guidleines, 2016)

e) Disclose quantitatively, how much this project will reduce GHGs by implementation of the Greenhouses Gas Reduction Strategy for the hotel, retail, and the Topgolf?

This project fails to comply with the Reduction Strategy, "This Diagram was specifically designed to minimize greenhouse gas emissions along with other environmental impacts by guiding the City's future growth in a form which will reduce the need for automobile travel while also promoting transit use, bicycling and walking as alternative means of mobility instead of automobiles." Disclose how the City will "maximize the future share of transit, pedestrian and bicycle use as transportation modes, focusing almost all new employment and residential growth in areas with a high degree of transit access, proximity to services and designed in a way to foster those transportation modes" per the City's Strategy. GHG analysis must show evidence significant impact will not occur (Mejia v. City of Los Angeles (2005) 130 Cal. App. 4th 322).

2. **Air Quality Impact Analysis is inadequate for the following reasons per BAAQMD CEQA Guidelines Updated May 2011 as cited in this IS/MND.**
   - **a.** Inconsistent information for the duration of construction, square footage of the hotel, and the amount of parking spaces in the project description and the technical report Appendix A. Therefore, the IS/MND provides inaccurate analyses and significance levels for construction and TACs to sensitive receptors, elementary school, youth center, library, park, and residents.
   - **b.** In the IS/MD, please disclose impacts to sensitive receptors from mobile sources and cumulative sources per CEQA from existing, approve, and future projects.
   - c. Disclose air quality analysis with correct project description for Community Risk and Hazard Impacts; and cumulative air quality impacts on human health per BAAQMD CEQA.

(Children's Environmental Health Protection Act (Senate Bill 25, Escutia, Chapter 731, Statutes of 1999, Health[2] and Safety Code Sections 39669.5 et seq.)[3]. The Air Quality and the Hazards sections do not disclose this project is specifically subject to BAAQMD's **Regulation 11, Rule 2**

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[2] This tract either contains or is nearby **15** hazardous waste generators. The hazardous waste percentile for this census tract is **88**, meaning the number and type of hazardous waste generators and sites is higher than **88%** of the census tracts in California. http://oehha.ca.gov/calenviroscreen

[3] This tract either contains or is within a kilometer of **10** Groundwater Cleanup site(s). The cleanups percentile for this census tract is **82**, meaning the number and type of groundwater threats is higher than **82%** of the census tracts in California. The data was downloaded and analyzed in Spring 2014] [This tract either contains or is nearby **19** solid waste facilities. The solid waste percentile for this census tract is **100**, meaning the number and type of facilities is higher than **100%** of the census tracts in California.] (2014) http://oehha.ca.gov/calenviroscreen

(Asbestos Demolition, Renovation, and Manufacturing) and California Code of Regulations, Section 93105.[4]

> **Construction Emissions:** *"A total of up to 50,000 cubic yards (c.y.) of fill would be imported to the site. The project would require minimal cut on the site, mostly limited to the removal of existing paved surfaces, which would result in the off-haul of up to 20,000 tons of materials. The project proposes weekend (Saturday-Sunday) construction hours, 9:00 AM to 5:00 PM, as part of their Planned Development (PD) Permit. The duration of construction for all project elements would be roughly 24 months." (p.11)*

However, according to Appendix A, *"The project would require up to 50,000 cubic yards (cy) of soil import for the hotel/retail component, which was entered into the model. The anticipated 20,000 tons of demolition for the hotel/retail component was also entered into the model. In addition, 25,000 cy of asphalt is anticipated during the paving phase and was entered based on 16cy per truck. The anticipated construction schedule assumes that the project would be built out over a period of approximately 18 months beginning in 2017, or an estimated 396 construction workdays (assuming an average of 22 construction days per month).(p.5)*

- The IS/MD fails to disclose accurate information on construction emissions and duration which will expose sensitive receptors: George Elementary School, Alviso Library, Alviso Community Center, the park, and families of Alviso to TAC's, PM's, and hazardous materials that exceed thresholds such as, asbestos, TPH, pesticides, arsenic, lead, beryllium and cadmium, and VOCs.
    - Technical Report Appendix A; (p.10) Explain why meteorological data set of 1996-2000 was used for dispersion modeling to predict concentrations of DPM and PM2.5 near sensitive receptors? A current environmental baseline must be used for CEQA analysis.
    - The TAC's from construction emissions of residential cancer risks 47.9 in one million for infant exposure and 0.8 in one million for adult exposure exceeds BAAQMD thresholds. However, this must be reanalyzed with current baseline data and for George Mayne elementary school. PM2.5 thresholds exceed also for residential receptor location, but current baseline is needed as well.
    - For cumulative construction risk: Appendix A incorrectly identified N. Taylor Street/N. 1st Street as 1,000 feet from the project site and nearby receptors.
    - The Technical Report did not analyze significant **cumulative impacts** of "*the total of all past, present, and foreseeable future sources within a 1,000 foot radius (or beyond where appropriate) from the fence line of a source, or from the location of a receptor, plus the contribution from the project*" for TACs and PM $_{2.5}$/PM $_{10}$(BAAQMD, 2011, p. 5-15). Please correctly disclose and analyze the correct roadways with traffic volumes (North First Street and Highway 237), correct distance for stationary sources, and correct PM2.5, PM10, cancer and non-cancer risks, and adequate mitigation measures per BAAQMD for operational impacts.

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[4] NOTES: *Communities for a Better Environment v. California Resources Agency (2002) 103 Cal. App. 4th 98. Regarding the use of regulatory standards and thresholds of significance, the court invalidated a State CEQA Guidelines requirement for Lead Agencies to rely on adopted environmental standards to determine significance. The court held that this requirement conflicted with CEQA's standard for determining whether to prepare an EIR whenever it can be fairly argued on the basis of substantial evidence that a project may have a significant environmental impact. Oro Fino Gold Mining Corp. v. County of El Dorado (1990) 225 Cal.App.3d 872.*

- The IS/MND and technical report fails to disclose quantitative reduction of mitigation measures to protect sensitive receptors in Alviso from both construction, stationary, and mobile sources.
- The technical report and the IS/MND also failed to disclose the cumulative exposure of ROG, NOx,, and local CO from this project, approved projects, and future projects in the General Plan and other amendments, mobile sources from Highway 237, and existing stationary sources. [5](CCR §15355, §15130) (PRC §21083(b), CCR §15065) T**he City must prepare an EIR to disclose Substantial Adverse effects of Human per CEQA.**[6]

3. **Hydrology Project Description and Mitigation Measures:** The IS/MND's significance levels for all hydrological impacts concluded "Less than Significant Impact" in the checklist and "Impacts Evaluation". The document fails to disclose Mitigations are required per CEQA. The project description chapter does not disclose details of the design features and best management practices. For example, *"Project-specific Low Impact Development Measures would be determined as part of the PD Permit Process; Detailed design of any detention area(s) would be subject to review and approval during the project PD permit process (pp.10-11).* Therefore, the Hydrology chapter must identify the mitigations required to adequately conclude reduction of the project impacts (*Lotus v. Department of Transportation (2014) 223 Cal.App.4th 64).* The purpose of CEQA is to inform the decision-makers and informed public participation (CEQA Statutes and Guidelines, 2016).
4. **Transportation:** The project requires an EIR to fully disclose the cumulative impacts of this project's daily 6,915 daily new vehicle trips in Alviso, plus approved and future projects and mitigations measures. The Transportation chapter includes inadequate mitigation measures that fails to disclose how much of the project's percent contribution to the North San Jose Area Traffic Impact Fee (TIF), the timeline for payment and improvements in the Alviso community specifically or exactly where the improvements will occur, monitoring and reporting responsibility, consequences if the fees are not paid to the City, etc. For example, the document states that this "project's cumulative traffic represents 25% or more of the increase in total traffic volume from background traffic conditions to cumulative conditions". Intersection 5: N. First Street & SR 237 Westbound Ramps (LOS E, PM peak hour) (p.220). Furthermore, *"A significant cumulative impact is deemed mitigated to a less than significant level by the City of San Jose if the measures implemented would restore the intersection LOS to background conditions or better at non-protected intersections (p.220)."* Since the IS/MND only includes the "payment of the TIF would represent a fair share" as mitigation measure, an EIR is required to disclose an unmitigated significant impact, when the traffic impact fee mitigation will paid, the timeline for improvements in Alviso, and monitoring and reporting. The families and children in

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[5] A project would have a significant **cumulative impact** if the total of all past, present, and foreseeable future sources within a 1,000 foot radius (or beyond where appropriate) from the fence line of a source, or from the location of a receptor, plus the contribution from the project, exceeds the following: Non- compliance with a qualified Community Risk Reduction Plan;
An excess cancer risk levels of more than 100 in one million from all local sources ; a chronic hazard (non-cancer) index greater than 10 from all local sources ; 0.8 μg/m3 annual average PM2.5 from all sources. (BAAQMD, 2011, p. 2-2)

[6] BAAQMD **operational thresholds of significance (project)**: Compliance with Qualified Community Risk Reduction Plan OR (TAC and PM)) An excess cancer risk level of more than 10 in one million, or non-cancer risk greater than 1.0 HI from a single source would be significantly cumulatively considerable contribution;
Ambient PM2.5 increase: > 0.3 μg/m3 annual average from a single source would be significant
Zone of Influence: 1,000-foot radius from property line of source or receptor

Alviso are entitled as City of San Jose residents to full disclosure per CEQA. (CCR §15355, §15130) (PRC §21083(b), CCR §15065).

In January 2017, SB 1000 (Leyva) will require General Plan updates to identify disproportionately environmental impacted communities and implement an Environmental Justice element. Alviso is a unique community, the residents are disproportionately impacted by numerous environmental impacts such as TAC's, PM2.5, Union Pacific Railroad, Highway 237, South Bay Asbestos/NPL site, methane vapor from numeorus surrounding landfills[7], diesal generators, Calpine Energy Plant, SJWPCP, Midpoint@237 Office and Industrial Project's trucks, and many other proposed projects. According to BAAQMD (2011), diesel PM from mobile sources is the most predomoniate TAC in the Bay Area which accounts for over 80% of the inhalation cancer risk in the Bay Area. I hope that with the implementation of SB 1000 *Planning for Healthy Communities Act*, vulnerabale communities in the City of San Jose, like Alviso, will finally be acknowledged and receive equitable enviromental protection and informed public participation accessibility.

Thank you,
Ada E. Márquez

SIERRA CLUB
FOUNDED 1892

Santa Clara Valley
Audubon Society

SAN FRANCISCO BAY
CITIZENS COMMITTEE TO
COMPLETE THE REFUGE

COMMITTEE FOR
GREEN FOOTHILLS

October 17th, 2016

Whitney Berry, Environmental Project Manager
City of San Jose
Whitney.Berry@sanjoseca.gov

RE: Initial Study/Mitigated Negative Declaration for the Topgolf@Terra Project (Project)

Dear Ms. Berry,

Santa Clara Valley Audubon Society (SCVAS), the Citizens Committee to Complete the Refuge (CCCR), and the Loma Prieta Chapter of the Sierra Club (SCLP) are local environmental organizations focused on the conservation of our natural resources and biological diversity. Our members appreciate birds and wildlife along the Bay and creek corridors, and are always concerned when development proposals are adjacent to the Don Edwards National Wildlife Refuge, the Bay, or creek corridors. We believe the project will impose significant and unavoidable impacts to the Alviso community, to migratory birds, and to our members who enjoy recreation on the Guadalupe Creek Trail.

The project proposes to redevelop the site with a Topgolf entertainment complex, a 5 story 65-ft tall hotel and retail space. The proposed Topgolf entertainment complex would be located on the southern portion of the site and would include a three-story structure reaching up to 54 feet in height that would be enclosed on the north, east and west sides. The south side of the structure, facing the Guadalupe River Trail and the river, will be open to the environment. The building includes roughly 120 hitting bays which would face south toward a 5.2-acre lighted artificial turf field enclosed by poles and netting that would reach up to 170- feet in height at a setback of 100-ft from Guadalupe River and the Creek Trail. Each hitting bay can accommodate up to six players at a time. Hitting bays include seating, television screens and overhead speakers providing amplified music. The facility would also include a full-service restaurant, bar, lounges, rooftop entertainment area, corporate/event meeting space, and a family entertainment area with games. Entertainment will be offered every day, morning to 2AM in the morning. Thus, the Topgolf can be reasonably expected to attract thousands of visitors every day (employees, restaurant, bar and events visitors, and several groups of up to 6 people at each of 120 bays each day).

The surrounding land uses include sensitive ecological features (creek, bay) and a plethora of sensitive land-uses that accommodate sensitive receptors: George Mayne Elementary school (500+ students), Alviso Branch Library, Residences (including a mobile home park), and the

Guadalupe Creek Trail where people go to exercise and to enjoy nature. Most of the Project area is currently ruderal open space, is dark at night, and is relatively quiet. If the Project is permitted, tall buildings, expansive parking, overwhelming netting, excessive noise, traffic, light, and air pollution will impose significant and unavoidable operations-related impacts to the creek corridor and to nearby residents and sensitive receptors, changing the character of the Alviso community forever.

We believe an Environmental Impact Report (EIR) must be prepared for the Project to allow full study of the project specific and cumulative impacts, offer and evaluate alternatives. It is likely that decision makers will have to make a declaration of overriding considerations to allow the project to proceed as described.

<u>The project is incompatible with the Alviso Master Plan (Plan)</u>

The Alviso Master Plan was the result of a lengthy public process that engaged the entire Alviso community and multiple stakeholders for years (a 24-participants task force, multiple public meetings, 5+ years of planning). The Plan aimed at “full build-out” to year 2020 and beyond stating, “It is important to set forth a vision now to avoid piecemeal development and to better respond to potential development pressure within the community”. **Clearly, the Alviso Master Plan was created with the exact intent of preventing speculative projects such as the Topgolf@Terra.**

When the Alviso Specific Plan was developed, height considerations were an integral part of the discussion. The intent was to preserve the unique characteristics of Alviso, and it was agreed upon that taller building and structures did not fit in with the character of the community. The Plan’s objectives allowed for economic development, but also included:

- Maintain the small town character, strong community identity, and neighborhoods
- Allow for new development at, or at least compatible with, the scale and intensity of existing development within specific areas
- Beautify Alviso
- Preserve and protect Alviso’s strong natural amenities, including the Guadalupe River, Coyote Creek, and baylands.

The Project is not compatible with these objectives: it does not beautify Alviso (rather the opposite), degrades the small town character, is incompatible with the scale and intensity of existing development, and harms Alviso’s natural amenities along the Guadalupe River as well as the birds and wildlife at the Don Edwards National Wildlife Refuge, a major bird migratory destination only a half mile away from the project site.

Therefore, the proposed text amendment to the Alviso Master Plan(section 3.2.5, page 12[1]) that

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[1] Page 55: Village Area Guidelines for Commercial Development, Section 5 Development Standards, Subsection A. (added language is underlined)

allows **tall buildings (up to 65-feet) and 170-foot tall structures (poles, netting) must be considered a potentially significant and unavoidable impact to land use.**

Mitigation for the impact on landuse should be considered (i.e. elimination of this aspect of the proposed Project).

The aesthetic impacts of the proposed Project are significant and unavoidable

The MND states, in one sentence, that the proposed Project will have no aesthetic impacts. This finding seems to overlook the fact that the Project will include structures up to 170 feet in height. This would be far higher than any other nearby structure and should be considered a significant impact.

Tall golf netting such as this can has a significant visual impact to the environment, and often elicit pronounced negative response from the public[2][3][4]. For our members who frequent the Guadalupe Creek Trail, the Bay Trail, and the Don Edwards National Wildlife Refuge, the proposed 170-ft poles and netting (and the noise-generating, tall buildings) will violate the sense-of-place end enjoyment of recreation and bird watching north of HWY 237, along the River and the Bay. While the existing 90-ft tall fences are not visually pleasing, replacing them with 170-ft netting creates a much stronger imposition and further degrades the enjoyment of sky, vistas and nature.

Thus, the 170-ft tall poles and netting will impose significant, unavoidable aesthetic impacts. The finding that the impacts are less than significant is not justified. Instead, the visual impact of this high a structure should be further analyzed and found to be a significant impact. Lowering the height or, better yet, eliminating this aspect of the Project altogether should be considered as mitigation.

The change to the Envision 2040 General Plan must be vetted in Citywide community outreach

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Height: 40 feet, 2 stories above flood elevation. For properties on the west side of North First Street between Liberty and Tony P. Santos Streets, the maximum allowable building height shall not exceed 65 feet, 5 stories above flood elevation. Non-building structural uses, including structures on top of or attached to buildings, such as but not limited to, energy saving devices, wireless communication antennae, net poles, and other associated structures through the development project review shall establish a specific height, not to exceed the maximum allowable height of 170 feet on sites with non-residential or non-urban land use designations.

[2] http://www.loudountimes.com/news/article/new_topgolf_location_will_open_this_september441

[3] http://www.daytondailynews.com/news/local/west-chester-new-topgolf-almost-county-tallest-building/bNxanFgh8tF65HdQrsZbRO/

[4] http://www.sfgate.com/bayarea/article/New-Golf-Fences-Driving-North-Bay-Residents-Crazy-2980615.php

due to Growth Inducing Impacts

The proposed text amendment to the Alviso Master Plan (section 3.2.5, page 12) applies by extension the Envision 2040 General Plan. It is reasonable to expect that such a substantial change (from a height limit of 40 feet to that of 170 feet) – a change that changes the skyline of North San Jose all the way to the downtown area - should have visually-significant growth-inducing impacts, encouraging other property owners in the City of San Jose to seek modifications that would allow them to exceed existing height limitations for various structures on rooftops etc. This is a potentially significant impact and should be acknowledged.

Furthermore, there was no outreach to the entire San Jose community regarding this change to the Envision 2014 General Plan. An amendment of such citywide significance should be communicated in a transparent, citywide process.

Cumulative impacts

The project IS/MND fails fully evaluate cumulative impacts of project-related noise and air quality criteria pollutants during operations.

Section 15355 of the CEQA Guidelines states: "Cumulative impacts" refers to two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts.

(a) The individual effects may be changes resulting from a single project or a number of separate projects.

(b) The cumulative impact from several projects is the change in the environment which results from the incremental impact of the project when added to other closely related past, present, and reasonably foreseeable probable future projects. Cumulative impacts can result from individually minor but collectively significant projects taking place over a period of time.

Important direction to the practical use of this definition is found in Section 15130 of the CEQA Guidelines: “As defined in Section 15355, a cumulative impact consists of an impact which is created as a result of the combination of the project evaluated in the EIR together with other projects causing related impacts.”

Several projects are currently in the process of permitting, or have been recently permitted, or are under construction in Alviso in the immediate vicinity of the project site:

Alviso near / along North First Street
PD13-039 Trammel Crow Distribution Center
PDC15-016: Residence Inn by Marriott & Fairfield Inn and Suites by Marriott Project
PDC14-004, PD14-007: Midpoint at 237 Office and Hotel Project

C14-010: 237 at North First St. Homewood Suites Hotel

America Center Area (Gold St/237 access)
PDC 15-058 & PD15-053: America Center Phase III Project (Build 192,350 sq ft. office building and expand existing garage.)
PDC15-016: Residence Inn and Fairfield Inn & Suites America Center Court Project (aka Marriott Hotels)
PDC15-058 and PD15-053 America Center Planned Development Zoning and Planned Development Permit and Subsequent Environmental Impact Report (SEIR). Zanker Road/McCarthy Blvd access
C15-054: Cilker Property, Rezoning from A/PD to LI (Light Industrial)

The IS/MND fails to evaluate the Project's cumulative impacts associated with the projects identified above.

Cumulative Air Quality impacts require additional analysis
Air pollution impacts on sensitive receptors from hundreds of weekday and weekend car trips during operations of the Project should be evaluated cumulatively, combined with the impacts of air pollution from Hwy 237, truck trip operations at the Trammel Crowe Distribution Center and car trips to and from the newly constructed and planned hotels and office buildings in the vicinity.

The IS/MND proposes that the Project will not result in a cumulatively considerable net increase of any criteria pollutant for which the project region is classified as non-attainment under an applicable federal or state ambient air quality standard including releasing emissions which exceed quantitative thresholds for ozone precursors. The IS/MND states (page 68), "As described above in the response to checklist question "b", the project would not result in a considerable net increase of any criteria pollutant with implementation of mitigation measures." But offers no mitigation measures for operation-related air pollution.

These cumulative impacts are significant and potentially unavoidable and likely to affect the health of the students and teachers of the George Mayne elementary school, visitors to the Alviso Branch Library, residences of nearby residences and the Summerset Mobile Home Park across the Guadalupe River from the Project Site.

Please provide a comprehensive analysis in an EIR to fully study, disclose and mitigate cumulative operations-related air quality impacts. Please offer mitigations including a Traffic Management Plan.

Noise impacts are likely to prove significant and unavoidable

The IS/MND inadequately addresses the significance of noise impacts on the community of Alviso. There should be an analysis of noise impacts from the Project after it is developed, both on a project specific and cumulative levels. The proposed Project will generate noise into the evening, within close proximity to Alviso residents and to sensitive species in the Alviso area. The MND for the project specifically points out that "late night use" would be part of the Project (MND, page 1). These noise impacts should be explained and mitigation adopted if needed.

Sensitive Receptors

The IS/MND defines sensitive receptors to the project, "an existing residence located on the southern corner of N. First Street and Liberty Street, adjacent to the northwest boundary of the site. Residences are also located across N. First Street, Liberty Street, and Moffat Street from the site. Additionally, George Mayne Elementary School is located across N. First Street from the site."[5] The IS/MND's analysis must include the Alviso Branch Library as a sensitive receptor. Additionally, people who utilize the Guadalupe Park Trail and guests of nearby hotels should also be included as sensitive receptors.

Noise monitoring survey, average inadequate, effects of noise

The IS/MND states, "a noise monitoring survey was completed at various locations near the site on Wednesday December 16, 2016 and Thursday December 17, 2016"[6]. As these dates have not yet occurred, we ask that this statement be clarified.

It seems that the proposed noise monitoring survey did not include the George Mayne Elementary School or the Alviso Branch Library as study locations. In order to measure the full impact of the Project, a noise monitoring survey must include the Alviso Branch Library and George Mayne Elementary School and should be completed during days that the elementary school is in session, outdoors and in a classroom.

The noise monitoring survey measured the "Ldn...the average energy level intensity of noise over a given period of time such as the noisiest hour".[7] Results from the noise monitoring survey show that the average ambient noise was measured between 65 dB and 66 dB at the residences on North First Street.[8] The maximum noise was measured between 74-88 dB during daytime hours and 71-81 dB during nighttime hours at the residences on North First Street.[9]

Noise levels of above 55 decibels outside and 45 decibels indoors have been shown to be preventing and interfering with activities and creating feelings of annoyance, leading to observable impairments in reading comprehension and memory skills in children[10][11]. San Jose's

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[5] Initial Study 4.12.1.2 page 164

[6] Initial Study 4.12.1.1 page 162

[7] Initial Study 4.12.1.1 page 162

[8] Initial Study Table 4.12-1 page 164

[9] Initial Study Table 4.12-1 page 164

[10] Textbook of Children's Environmental Health, edited by Philip J. Landrigan, Ruth A. Etzel. page 386. 2014

[11] Clark, C. & Stansfeld, S. A. (2007). The effects of transportation noise on health and cognitive development: A review of recent evidence. Journal of Comparative Psychology, Vol 20(2-3), 145-158.

Envision San Jose 2040 General Plan Comprehensive Update, Noise Background Report, 2009 states, “Sleep and speech interference is therefore possible when exterior noise levels are about 57-62 dBA DNL with open windows and 65-70 dBA DNL if the windows are closed” and “When the DNL increases to 70dBA, the percentage of the population highly annoyed increases to about 12 percent of the population.”[12]

Given its location near the George Mayne elementary school, the proper measure for the Project’s noise impact to sensitive receptors should be the **noise generated during operation hours**, when music is ongoing and guests are active. This is because children who live near the project will be affected during the school day, afternoon activities, homework preparation, evening relaxation, and bedtime. They will not be able to escape to the Alviso Park or library, since the noise will invade these places as well. For an accurate analysis of the impact of noise, Project specific noise impacts should be analyzed for the operation hours only (no averaging with quiet-time hours.

Cumulative Noise Analysis

The IS/MND failed to include a study of the cumulative noise generated by the activities, traffic, construction, and aircraft noise surrounding the project site. Further, the MND only includes noise impacts generated during the construction phase of the project and fails to analyze noise impacts during operation hours.

Noise generation from Topgolf@Terra operations, including traffic related noise as well as outdoor music and noise generating guest activities (cheering, thumping) must be analyzed cumulatively with noise generated by traffic and nearby activities, including the upcoming operations of the Trammel Crow Distribution Center (for example, trucks traffic, backing up and beeping at the nearby Distribution Center). The study and analysis should focus on the George Mayne elementary school since it is located between the Distribution Center and the Project site, but cumulative impacts should also be evaluated for other sensitive receptor locations.

Conclusion (Noise)

The failure to adequately analyze and mitigate noise impacts after the project is built (operation hours) and cumulative noise impacts means that potentially significant and unavoidable impacts to sensitive receptors have not been disclosed. The City must prepare an Environmental Impact Report to provide transparency and inform the public and decision makers of noise impacts.

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[12] Envision San Jose 2040 General Plan Comprehensive Update, Noise Background Report, 2009, page 3 (https://www.sanjoseca.gov/DocumentCenter/Home/View/511)

The noise generation and cumulative noise impacts are significant to the extent that the project may not accomplish compliance with the City of San Jose's General Plan Envision 2040 GOAL EC-1, 1.1, Goal EC-1 – "Community Noise Levels and Land Use Compatibility: Minimize the impact of noise on people through noise reduction and suppression techniques, and through appropriate land use policies". The obvious mitigation would be to restrict the hours of operation to eliminate noise during the school hours, and at night. We recommend that the Topgolf portion of the Project not operate after 9 PM.

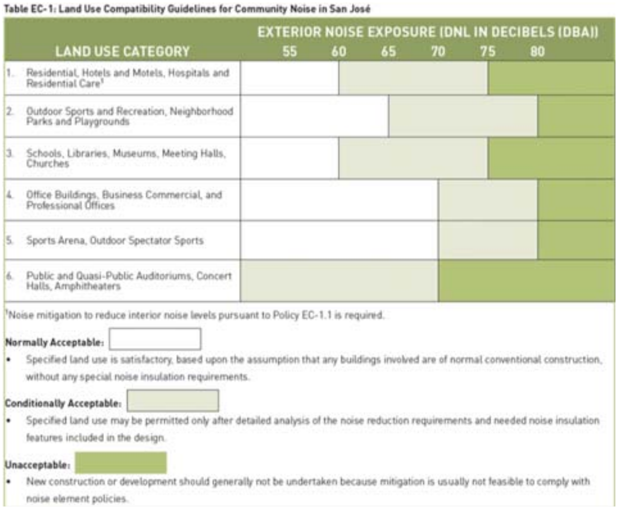

Table EC-1: Land Use Compatibility Guidelines for Community Noise in San José

LAND USE CATEGORY	EXTERIOR NOISE EXPOSURE (DNL IN DECIBELS (DBA))						
	55	60	65	70	75	80	
1. Residential, Hotels and Motels, Hospitals and Residential Care[1]	☐	☐	▨	▨	▨	🟩	🟩
2. Outdoor Sports and Recreation, Neighborhood Parks and Playgrounds	☐	☐	☐	▨	▨	▨	🟩
3. Schools, Libraries, Museums, Meeting Halls, Churches	☐	☐	▨	▨	▨	🟩	🟩
4. Office Buildings, Business Commercial, and Professional Offices	☐	☐	☐	☐	▨	▨	🟩
5. Sports Arena, Outdoor Spectator Sports	☐	☐	☐	☐	▨	▨	🟩
6. Public and Quasi-Public Auditoriums, Concert Halls, Amphitheaters	▨	▨	▨	▨	🟩	🟩	🟩

[1] Noise mitigation to reduce interior noise levels pursuant to Policy EC-1.1 is required.

Normally Acceptable: ☐
- Specified land use is satisfactory, based upon the assumption that any buildings involved are of normal conventional construction, without any special noise insulation requirements.

Conditionally Acceptable: ▨
- Specified land use may be permitted only after detailed analysis of the noise reduction requirements and needed noise insulation features included in the design.

Unacceptable: 🟩
- New construction or development should generally not be undertaken because mitigation is usually not feasible to comply with noise element policies.

Biological impacts

Congdon's tarplant

Impact Bio-1 identifies potentially significant impacts to Congdon's Tarplant, and offers to mitigate by establishing other populations of the plant onsite. What evidence does the City have that such mitigation can be successful? Can the City produce any documents providing substantial evidence that this mitigation would reduce the impact to less than significant? In particular, are there documents from previous projects that used the same mitigation successfully?

Nesting Birds

Many of the bird speciess that nest in this area are ground or shrub nesting birds. Pre-construction nesting bird surveys (and burrowing owl surveys) should include the entire project site, and not be limited to trees.

Netting and birds

Since 1987, the San Francisco Bay Bird Observatory (SFBBO, an avian research organization) operates the Coyote Creek Field Station at Coyote Creek, at a similar distance from the Bay to the location of the Project site. Research at the station is based on the use of mist-nets to capture birds in the creek corridor, banding the birds with uniquely numbered, federally-issued bands, and analyzing the data to study the bird community of the region and migration patterns.

The attached SFBBO Species List indicates that 249 species protected by the Migratory Bird Treaty Act, including multiple rare and endangered species, breed or otherwise use habitat of lower Coyote Creek and most likely, Guadalupe River. The list also identifies 52 species that are currently listed by a government agency, by the State of the Birds 2016 report or by the National Audubon Society. These include Federal and California threatened and endangered migratory species such as the Willow Flycatcher and Swainson's Hawk. In addition, note State and Federal Species of Special Concern such as Burrowing Owl, San Francisco Common Yellowthroat, Nuttel’s Woodpecker, Painted Bunting, Loggerhead Shrike, and Long-billed Curlew.

The City of San Jose recognizes the importance of the lower Guadalupe River corridor for bird migration in its 2010 General Plan Envision 2040 in Goal ER-7 – Wildlife Movement and the City’s Riparian Corridor ordinance. Goal ER-7 states,

- In the area north of Highway 237 design and construct buildings **and structures** using bird-friendly design and practices to reduce the potential for bird strike for species associated with the baylands or the riparian habitats of lower Coyote Creek. (emphasis added).

The MND acknowledges that the 170-ft tall netting is a potentially significant impact to birds (Impact Bio-7). The proposed mitigation (MM BIO-7.1) is borrowed from methods used to reduce collision of large birds with powerlines. These mitigations are not likely to reduce the risk for millions of night-flying migratory passerines and shorebirds that visit the Don Edwards National Wildlife Refuge or fly through near the Bay and along the Guadalupe River. Even for day flying birds, these deterrents require a much closer spacing than 15-feet for many bird species.

It is our expert opinion that the risk to migratory birds remains significant after mitigation (see also attached expert opinion from Dr. Christine Sheppard, American Bird Conservancy).

Light may attract birds

We are concerned with the potential negative impacts of light that this project will impose upon nearby sensitive habitats. The project site is located 100 feet away from the Guadalupe River and about half a mile away from the Don Edwards National Refuge. Due to the close proximity of these sensitive areas, light emitted from Topgolf may have significant negative impacts on birds and wildlife.

Our primary concern is that night-flying migratory birds may become attracted to the light, causing increased collisions with the 170-ft tall netting.[13] (see attached opinion from Dr. Christine Sheppard, American Bird Conservancy).

In accordance with the Alviso Master Plan, new development should be designed “as not to create glare or other negative impacts to nearby sensitive habitats, including baylands, riparian corridors, and other biotic communities”[14]. The Topgolf development does not align with the Alviso Master Plan in that it will create significant glare and negative impacts on surrounding sensitive habitats.

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[13] Letter from Dr. Christine Sheppard, American Bird Conservancy

[14] Alviso Master Plan, Environmental Mitigation, pg 118

Loss of Open Space

Open spaces in the Alviso area are particularly important due to Alviso's proximity to the Don Edwards National Wildlife Refuge and other open space areas such as the burrowing owl preserve of the Water Pollution Control Plant, where the only relatively sizeable population of burrowing owls persists in the South Bay region. Many bird species common to the National Wildlife Refuge and creek corridors utilize the remaining ruderal and open spaces in the Alviso area for upland foraging or roosting.

When the Alviso Specific Plan was adopted, the City Council discussed a goal that, on the large open spaces in Alviso, one-third of the land should remain in open space when they are developed. At the time, Council discussed the Planning Recommendation of a 1 acre/2 acre open space ratio requirement and recommended that the Administration provide Council with information on the percentage of open space achieved at the beginning of the development process to enable Council to determine the maximum open space achievable and if no land is available, Council consider requiring financial mitigation funds in-lieu for purchase and restoration of habitat and removal of illegal fill[15].

The MND should analyze impacts to open space in Alviso due to the proposed Project. We assert that those impacts should be found significant. Mitigation for the impact should be considered, including leaving one-third of the property in open space or preserving alternate open space in the Alviso area, with management of that area designed to maximize benefits to rare plants, wetlands, and Burrowing owls, as well as for the more common species found in the Alviso area.

Potential Impacts on Aerial Activity of Emergency Services

The Initial Study fails to analyze the potential impact of the 170' net structure on local, aerial activity of emergency services as may occur in the vicinity of the Project. Helicopters from multiple agencies, commonly fly along SR 237 regarding traffic problems. It is also known that the County Sheriff's Department flies helicopters in the Alviso area to respond to boating problems along Alviso Slough and the South Bay. It is also possible that a flooding or earthquake event could produce a situation involving use of helicopters for emergency evacuation in Alviso. Nothing in the Initial Study shows that any effort was made to evaluate whether or not the height of the nets would impact these services.

We note that in the Hazards Environmental checklist in Section 4.8.2, the Initial Study responds as "No Impact" to: "Would the project: Impair implementation of, or physically interfere with, an adopted emergency response plan or emergency evacuation plan?" (P. 137, question g). In discussion, in Section 4.8.3, p. 141, we find analysis is limited to "adopted" plans with no evidence of analysis nor consideration of cross-jurisdictional public safety activity in the area.

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[15] http://www3.sanjoseca.gov/clerk/1998_CnclMins/12_07_98GPMin.htm Minutes of the San Jose City Council meeting, December 7 1008.

Further we find that Section 4.14, Public Services, fails to analyze potential interference on the aerial response actions of Public Safety organizations.

In an area where helicopter activity is common, these findings are inadequate and need to be reviewed in full Environmental Impact Report.

Our groups have reasonable concerns and have provided substantial evidence that the IS/MND has not adequately evaluated project impacts, and that mitigation measures are not sufficient. This project may impose significant, unavoidable impacts to the environment. We ask the City of San Jose to require an Environmental Impact Report for this Project in order to provide full transparency and in-depth analysis of the issues we have brought up. An EIR is also needed in order to explore alternative locations for the Topgolf@Terra project. We believe that moving the Entertainment Complex part of the project to an area that is not as environmentally sensitive may avoid most of the significant impacts to birds, wildlife and the environment, to the health and well-being of elementary school children, and to the Alviso community.

Thank you,

Shani Kleinhaus

Shani Kleinhaus, PH.D.
Environmental Advocate
Santa Clara Valley Audubon Society

Eileen P. McLaughlin

Eileen McLaughlin,
Board Member
Citizens Committee to Complete the Refuge

Michael Ferreira
Executive Committee Chair
Sierra Club-Loma Prieta Chapter

Alice Kaufman,
Legislative Advocate
Committee for Green Foothills

Attachment

AMERICAN BIRD
CONSERVANCY

Bringing back the birds

October 17, 2016

Dear Dr. Kleinhaus,

I have reviewed the material outlining the proposed Topgolf facility in the area of San Jose. My primary concern would be with the netting itself and support structures. The measures outlined are intended to reduce diurnal collisions of large water birds with power lines; I have attached a recent meta-analysis of studies on this type of device. Unfortunately, these products will not address local, smaller species, nor will they warn night-flying migrants. This is compounded they the facility's location with respect to the Guadeloupe River and a wetland area, which may be stopover sites for migrants, bringing them low enough to hit the nets.

A concentration of bright lights, as illustrated in the video http://topgolf.com/us/, could be of serious concern, especially as the area is lit until late in the evening. This might actually bring night migrants towards the facility, causing collisions with the net. The net itself likely does not present a strong enough signal to stop local birds flying towards it and this could result in birds trapped in the netting itself.

Christine Sheppard

Christine Sheppard, Ph.D.
Bird Collisions Campaign Manager
American Bird Conservancy

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Attachment

Coyote Creek Field Station Species List
Compiled by the San Francisco Bay Bird Observatory, June 17 2016

For additional details, contact:
Josh Scullen, jscullen@sfbbo.org
Dan Wenny, dwenny@sfbbo.org

Date Range

SFBBO data originate from mist-netting operations, point count surveys, and breeding bird surveys conducted between 1982 - 2015.
eBird data includes all recorded species entered as of mid-June, 2016

Data Notes

Source	SFBBO: indicates species detected during mist-netting operations, point count surveys, and/or breeding bird surveys, from 1982 - 2015 eBird: indicates species recorded in eBird for the Coyote Creek Field Station location and 3 adjacent hotspots along Coyote Creek, as of June 17, 2016

Species Code	4-letter species code Subspecies are indicated by Species Code / Subspecies Code (example: Audubon's Warbler is listed as "YRWA/AUWA") The dataset is currently sorted by this column

Status in Coyote Creek area	Resident: species are present at CCFS year-round Migrant: species pass through CCFS during spring (March - June) and/or fall (August - October) migration. Wintering: species are present at CCFS during winter months (approximately October - March) escaped: indicates species that are likely non-wild captive birds or escaped pets

California Status	SSC-1: Bird Species of Special Concern - First Priority SSC-2: Bird Species of Special Concern - Second Priority SSC-3: Bird Species of Special Concern - Third Priority Threatened: State Threatened Endangered: State Endangered
California Endangered Species List:	http://www.dfg.ca.gov/wildlife/nongame/t_e_spp/bird.html
California Bird Species of Special Concern:	http://www.dfg.ca.gov/wildlife/nongame/ssc/birds.html

State of the Birds Watch List 2016	x: On the North American Bird Conservation Initiative Watch List for 2016
	http://www.stateofthebirds.org/2016/resources/species-assessments/?__hstc=75100365.33c5c4cc061d8120eb76cb854cd70677.1466099657998.1466188824130.1466191335722.4&__hssc=75100365.1.1466191335722&__hsfp=1333291337#_ga=1.19765560.1414109025.1466099656

Audubon Watch List 2007	yellow list: rare and/or declining
	red list: highest conservation concern
	http://www.audubon.org/sites/default/files/documents/watchlist2007-technicalreport.pdf

US Fish and Wildlife Service	BCC: Bird of Conservation Concern
	BCC Focal Species: Species for which USFWS is prioritizing research and planning for conservation
	Endangered: the indicated population is on the Federal Endangered Species list
USFWS Focal Species List:	https://www.fws.gov/migratorybirds/pdf/management/BMCFocalSpecies.pdf
USFWS Birds of Conservation Concern 2008:	https://www.fws.gov/migratorybirds/pdf/management/BCC2008.pdf

Source	Species Code	Common Name	*Scientific Name*	Status at Coyote Creek Field Station	California Status	SOTB Watch List 2016	Audubon Watch List 2007	USFWS
SFBBO	ACWO	Acorn Woodpecker	*Melanerpes formicivorus*	Resident				
eBird	AGWT	Green-winged Teal	*Anas crecca*	Winter				
SFBBO	ALHU	Allen's Hummingbird	*Selasphorus sasin*	Migrant		x	yellow list	BCC
SFBBO	AMAV	American Avocet	*Recurvirostra americana*	Resident				
SFBBO	AMCO	American Coot	*Fulica americana*	Winter				
SFBBO	AMCR	American Crow	*Corvus brachyrhynchos*	Resident				
SFBBO	AMGO	American Goldfinch	*Carduelis tristis*	Resident				
SFBBO	AMKE	American Kestrel	*Falco sparverius*	Resident				
SFBBO	AMPI	American Pipit	*Anthus rubescens*	Winter				
SFBBO	AMRE	American Redstart	*Setophaga ruticilla*	Migrant				
SFBBO	AMRO	American Robin	*Turdus migratorius*	Resident				
eBird	AMWI	American Wigeon	*Anas americana*	Winter				
SFBBO	AMWI	American Wigeon	*Anas americana*	Winter				
SFBBO	ANHU	Anna's Hummingbird	*Calypte anna*	Resident				
SFBBO	ASFL	Ash-throated Flycatcher	*Myiarchus cinerascens*	Migrant				
eBird	AWPE	American White Pelican	*Pelecanus erythrorhynchus*	Winter				
SFBBO	BARS	Barn Swallow	*Hirundo rustica*	Migrant				
eBird	BBPL	Black-bellied Plover	*Plucialis squatarola*	Winter				
SFBBO	BCHU	Black-chinned Hummingbird	*Archilochus alexandri*	Migrant				
SFBBO	BCNH	Black-crowned Night-Heron	*Nycticorax nycticorax*	Resident				
SFBBO	BEKI	Belted Kingfisher	*Ceryle alcyon*	Resident				
SFBBO	BEWR	Bewick's Wren	*Thryomanes bewickii*	Resident				
SFBBO	BGGN	Blue-gray Gnatcatcher	*Polioptila caerulea*	Migrant				
SFBBO	BHCO	Brown-headed Cowbird	*Molothrus ater*	Resident				
SFBBO	BHGR	Black-headed Grosbeak	*Pheucticus melanocephalus*	Migrant				
SFBBO	BLGR	Blue Grosbeak	*Passerina caerulea*	Migrant				
SFBBO	BLPH	Black Phoebe	*Sayornis nigricans*	Resident				
SFBBO	BLPW	Blackpoll Warbler	*Setophaga striata*	Migrant				
SFBBO	BNOW	Barn Owl	*Tyto alba*	Resident				
SFBBO	BNST	Black-necked Stilt	*Himantopus mexicanus*	Resident				
eBird	BOPU	Bonaparte's Gull	*Chroicocephalus philadelphia*	Winter				
SFBBO	BRBL	Brewer's Blackbird	*Euphagus cyanocephalus*	Resident				
SFBBO	BRCR	Brown Creeper	*Certhia americana*	Winter				
SFBBO	BRSP	Brewer's Sparrow	*Spizella breweri*	Migrant				
SFBBO	BRTH	Brown Thrasher	*Toxostoma rufum*	Migrant				

Source	**Species Code**	**Common Name**	***Scientific Name***	**Status at Coyote Creek Field Station**	**California Status**	**SOTB Watch List 2016**	**Audubon Watch List 2007**	**USFWS**
SFBBO	BTYW	Black-throated Gray Warbler	*Setophaga nigrescens*	Migrant				BCC
eBird	BUFF	Bufflehead	*Bucephala albeola*	Winter				
SFBBO	BUOR	Bullock's Oriole	*Icterus bullockii*	Migrant				
eBird	BUOW	Burrowing Owl	*Athene cunicularia*	Resident	SSC-2			BCC Focal Species
SFBBO	BUSH	Bushtit	*Psaltriparus minimus*	Resident				
SFBBO	BWWA	Black-and-white Warbler	*Mniotilta varia*	Migrant				
eBird	CAEG	Cattle Egret	*Bubulcus ibis*	Migrant				
eBird	CAGU	California Gull	*Larus californica*	Winter				
SFBBO	CAHU	Calliope Hummingbird	*Stellula calliope*	Migrant			yellow list	BCC
SFBBO	CALT	California Towhee	*Melozone crissalis*	Resident				
eBird	CANG	Canada Goose	*Branta canadensis*	Resident				
SFBBO	CAQU	California Quail	*Callipepla californica*	Resident				
eBird	CATE	Caspian Tern	*Hydroprogne caspia*	Winter				
SFBBO	CATH	California Thrasher	*Toxostoma redivivum*	Migrant		x	yellow list	
SFBBO	CAVI	Cassin's Vireo	*Vireo cassinii*	Migrant				
eBird	CAWA	Canada Warbler	*Cardellina canadensis*	Migrant				BCC
SFBBO	CBCH	Chestnut-backed Chickadee	*Poecile rufescens*	Resident				
SFBBO	CCSP	Clay-colored Sparrow	*Spizella pallida*	Migrant				
SFBBO	CEWA	Cedar Waxwing	*Bombycilla cedrorum*	Winter				
SFBBO	CHSP	Chipping Sparrow	*Spizella passerina*	Migrant				
SFBBO	CITE	Cinnamon Teal	*Anas cyanoptera*	Resident				
SFBBO	CLSW	Cliff Swallow	*Petrochelidon pyrrhonota*	Migrant				
eBird	COGO	Common Goldeneye	*Bucephala clangula*	Winter				
SFBBO	COHA	Cooper's Hawk	*Accipiter cooperii*	Resident				
SFBBO	COHU	Costa's Hummingbird	*Calypte costae*	Migrant		x	yellow list	BCC
eBird	COME	Common Merganser	*Mergus merganser*	Winter				
SFBBO	COMO	Common Gallinule	*Gallunula chloropus*	Resident				
SFBBO	COPO	Common Poorwill	*Phalaenoptilus nuttallii*	Migrant				
SFBBO	CORA	Common Raven	*Corvus corax*	Resident				
eBird	COTE	Common Tern	*Sterna hirundo*	Migrant				
SFBBO	COWA	Connecticut Warbler	*Oporornis agilis*	Migrant		x		
SFBBO	COYE	San Francisco Common Yellowthroat	*Geothlypis trichas sinuosa*	Resident	SSC-3			BCC
SFBBO	CSWA	Chestnut-sided Warbler	*Setophaga pensylvanica*	Migrant				
eBird	DCCO	Double-crested Cormorant	*Phalacrocorax auritus*	Resident				

Source	Species Code	Common Name	*Scientific Name*	Status at Coyote Creek Field Station	California Status	SOTB Watch List 2016	Audubon Watch List 2007	USFWS
SFBBO	DEJU	Dark-eyed Junco	*Junco hyemalis*	Winter				
SFBBO	DEJU/ ORJU	Oregon Junco	*Junco hyemalis oregonus*	Winter				
SFBBO	DEJU/ SCJU	Slate-colored Junco	*Junco hyemalis hyemalis*	Winter				
SFBBO	DOWO	Downy Woodpecker	*Picoides pubescens*	Resident				
SFBBO	DUFL	Dusky Flycatcher	*Empidonax oberholseri*	Migrant				
SFBBO	DUNL	Dunlin	*Calidris alpina*	Migrant				
SFBBO	EAKI	Eastern Kingbird	*Tyrannus tyrannus*	Migrant				
eBird	EUCD	Eurasian Collared-Dove	*Streptopelia decaocto*	Resident				
SFBBO	EUST	European Starling	*Sturnus vulgaris*	Resident				
SFBBO	EVGR	Evening Grosbeak	*Coccothraustes vespertinus*	Migrant				
SFBBO	FOSP	Fox Sparrow	*Passerella iliaca*	Winter				
eBird	FOTE	Forster's Tern	*Sterna forsteri*	Resident				
eBird	FRGU	Franklin's Gull	*Leucophaeus pipixcan*	Migrant				
SFBBO	GADW	Gadwall	*Anas strepera*	Resident				
SFBBO	GBHE	Great Blue Heron	*Ardea herodias*	Resident				
SFBBO	GCKI	Golden-crowned Kinglet	*Regulus satrapa*	Winter				
SFBBO	GCSP	Golden-crowned Sparrow	*Zonotrichia atricapilla*	Winter				
SFBBO	GHOW	Great Horned Owl	*Bubo virginianus*	Resident				
SFBBO	GOEA	Golden Eagle	*Aquila chrysaetos*	Winter				BCC Focal Species
SFBBO	GRCA	Gray Catbird	*Dumetella carolinensis*	Migrant				
SFBBO	GREG	Great Egret	*Ardea alba*	Resident				
SFBBO	GRFL	Gray Flycatcher	*Empidonax wrightii*	Migrant				
SFBBO	GRHE	Green Heron	*Butorides virescens*	Resident				
SFBBO	GRSP	Grasshopper Sparrow	*Ammodramus savannarum*	Migrant	SSC-2			
SFBBO	GRYE	Greater Yellowlegs	*Tringa melanoleuca*	Winter				
eBird	GTGR	Great-tailed Grackle	*Quiscalus mexicanus*	Migrant				
SFBBO	GTTO	Green-tailed Towhee	*Pipilo chlorurus*	Migrant				
eBird	GWGU	Glaucous-winged Gull	*Larus glaucescens*	Winter				
SFBBO	HAFL	Hammond's Flycatcher	*Empidonax hammondii*	Migrant				
SFBBO	HAWO	Hairy Woodpecker	*Picoides villosus*	Resident				
eBird	HERG	Herring Gull	*Larus argentatus*	Winter				
SFBBO	HETH	Hermit Thrush	*Catharus guttatus*	Winter				
SFBBO	HEWA	Hermit Warbler	*Setophaga occidentalis*	Migrant				
SFBBO	HOFI	House Finch	*Haemorhous mexicanus*	Resident				
eBird	HOME	Hooded Merganser	*Lophodytes cucullatus*	Winter				

Source	**Species Code**	**Common Name**	***Scientific Name***	**Status at Coyote Creek Field Station**	**California Status**	**SOTB Watch List 2016**	**Audubon Watch List 2007**	**USFWS**
SFBBO	HOOR	Hooded Oriole	*Icterus cucullatus*	Migrant				
SFBBO	HOSP	House Sparrow	*Passer domesticus*	Resident				
SFBBO	HOWA	Hooded Warbler	*Setophaga citrina*	Migrant				
SFBBO	HOWR	House Wren	*Troglodytes aedon*	Winter				
SFBBO	HUVI	Hutton's Vireo	*Vireo huttoni*	Migrant				
SFBBO	INBU	Indigo Bunting	*Passerina cyanea*	Migrant				
SFBBO	KEWA	Kentucky Warbler	*Geothlypis formosa*	Migrant		x	yellow list	BCC
SFBBO	KILL	Killdeer	*Charadrius vociferus*	Resident				
SFBBO	LAGO	Lawrence's Goldfinch	*Spinus lawrencei*	Migrant		x	yellow list	BCC
SFBBO	LAZB	Lazuli Bunting	*Passerina amoena*	Migrant				
eBird	LBCU	Long-billed Curlew	*Numenius americanus*	Winter		x		BCC Focal Species
SFBBO	LBDO	Long-billed Dowitcher	*Limnodromus scolopaceus*	Winter		x		
SFBBO	LEFL	Least Flycatcher	*Empidonax minimus*	Migrant				
SFBBO	LEGO	Lesser Goldfinch	*Carduelis psaltria*	Resident				
SFBBO	LEOW	Long-eared Owl	*Asio otus*	Migrant	SSC-3	x		
SFBBO	LESA	Least Sandpiper	*Calidris minutilla*	Migrant				
SFBBO	LEYE	Lesser Yellowlegs	*Tringa flavipes*	Migrant		x		BCC
SFBBO	LISP	Lincoln's Sparrow	*Melospiza lincolnii*	Winter				
SFBBO	LOSH	Loggerhead Shrike	*Lanius ludovicianus*	Resident	SSC-2			BCC
eBird	MAGO	Marbled Godwit	*Limosa fedoa*	Winter			yellow list	BCC Focal Species
SFBBO	MALL	Mallard	*Anas platyrhynchos*	Resident				
SFBBO	MAWA	Magnolia Warbler	*Setophaga magnolia*	Migrant				
SFBBO	MAWR	Marsh Wren	*Cistothorus palustris*	Resident				
eBird	MEGU	Mew Gull	*Larus canus*	Winter				
SFBBO	MERL	Merlin	*Falco columbarius*	Winter				
SFBBO	MGWA	MacGillivray's Warbler	*Oporornis tolmiei*	Migrant				
eBird	MOBL	Mountain Bluebird	*Sialia currucoides*	Migrant				
SFBBO	MODO	Mourning Dove	*Zenaida macroura*	Resident				
SFBBO	NAWA	Nashville Warbler	*Vermivora ruficapilla*	Migrant				
SFBBO	NOFL	Northern Flicker	*Colaptes auratus*	Winter				
SFBBO	NOFL/ FLIN	Flicker Intergrade	*Colaptes auratus auratus x cafer*	Winter				
SFBBO	NOFL/ RSFL	Red-shafted Flicker	*Colaptes auratus cafer*	Winter				
SFBBO	NOFL/ YSFL	Yellow-shafted Flicker	*Colaptes auratus auratus*	Winter				

Source	Species Code	Common Name	*Scientific Name*	Status at Coyote Creek Field Station	California Status	SOTB Watch List 2016	Audubon Watch List 2007	USFWS
SFBBO	NOHA	Northern Harrier	*Circus cyaneus*	Resident	SSC-3			
SFBBO	NOMO	Northern Mockingbird	*Mimus polyglottos*	Resident				
SFBBO	NOPA	Northern Parula	*Setophaga americana*	Migrant				
eBird	NOPI	Northern Pintail	*Anas acuta*	Winter				
eBird	NOSH	Northern Shoveler	*Anas clypeata*	Winter				
SFBBO	NOWA	Northern Waterthrush	*Parkesia noveboracensis*	Migrant				
SFBBO	NRWS	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	Migrant				
SFBBO	NSWO	Northern Saw-whet Owl	*Aegolius acadicus*	Winter				
SFBBO	NUWO	Nuttall's Woodpecker	*Picoides nuttallii*	Resident			yellow list	BCC
SFBBO	OATI	Oak Titmouse	*Baeolophus inornatus*	Resident		x	yellow list	BCC
SFBBO	OCWA	Orange-crowned Warbler	*Vermivora celata*	Migrant				
SFBBO	OSFL	Olive-sided Flycatcher	*Contopus cooperi*	Migrant	SSC-2	x	yellow list	BCC
eBird	OSPR	Osprey	*Pandion haliaetus*	Winter				
SFBBO	OVEN	Ovenbird	*Seiurus aurocapilla*	Migrant				
SFBBO	PABU	Painted Bunting	*Passerina ciris*	Migrant			yellow list	BCC Focal Species
SFBBO	PAWR	Pacific Wren	*Troglodytes pacificus*	Winter				
SFBBO	PBGR	Pied-billed Grebe	*Podilymbus podiceps*	Resident				
SFBBO	PEFA	Peregrine Falcon	*Falco peregrinus*	Winter				BCC
SFBBO	PESA	Pectoral Sandpiper	*Calidris melanotos*	Migrant		x		
SFBBO	PISI	Pine Siskin	*Carduelis pinus*	Winter				
eBird	PRFA	Prairie Falcon	*Falco mexicanus*	Winter				BCC
SFBBO	PUFI	Purple Finch	*Haemorhous purpureus*	Winter				
SFBBO	RBGR	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Migrant				
eBird	RBGU	Ring-billed Gull	*Larus delawarensis*	Winter				
SFBBO	RBSA	Red-breasted Sapsucker	*Sphyrapicus ruber*	Winter				
SFBBO	RCKI	Ruby-crowned Kinglet	*Regulus calendula*	Winter				
eBird	REDH	Redhead	*Aythya americana*	Winter				
SFBBO	REVI	Red-eyed Vireo	*Vireo olivaceus*	Migrant				
SFBBO	RITD	Ringed Turtle-Dove	*Streptopelia roseogrisea*	escaped?				
eBird	RNDU	Ring-necked Duck	*Aythya collaris*	Winter				
SFBBO	RNEP	Ring-necked Pheasant	*Phasianus colchicus*	Resident				
SFBBO	RNPH	Red-necked Phalarope	*Phalaropus lobatus*	Migrant				
SFBBO	ROPI	Rock Pigeon	*Columba livia*	Resident				
SFBBO	ROWR	Rock Wren	*Salpinctes obsoletus*	Migrant				
SFBBO	RSHA	Red-shouldered Hawk	*Buteo lineatus*	Resident				
SFBBO	RTHA	Red-tailed Hawk	*Buteo jamaicensis*	Resident				

Source	Species Code	Common Name	*Scientific Name*	Status at Coyote Creek Field Station	California Status	SOTB Watch List 2016	Audubon Watch List 2007	USFWS
eBird	RUDU	Ruddy Duck	*Oxyura jamaicensis*	Winter				
eBird	RUFF	Ruff	*Philomachus pugnax*	Migrant				
SFBBO	RUHU	Rufous Hummingbird	*Selasphorus rufus*	Migrant		x		BCC
SFBBO	RWBL	Red-winged Blackbird	*Agelaius phoeniceus*	Resident				
SFBBO	SAPH	Say's Phoebe	*Sayornis saya*	Winter				
eBird	SATH	Sage Thrasher	*Oreoscoptes montanus*	Migrant				BCC
SFBBO	SAVS	Savannah Sparrow (Bryant's)	*Passerculus sandwichensis alaudinus*	Resident	SSC-3			
SFBBO	SBDO	Short-billed Dowitcher	*Limnodromus griseus*	Migrant		x		BCC
eBird	SCTA	Scarlet Tanager	*Piranga olivacea*	Migrant				
SFBBO	SEPL	Semipalmated Plover	*Charadrius semipalmatus*	Migrant				
SFBBO	SESA	Semipalmated Sandpiper	*Calidris pusilla*	Migrant		x	yellow list	
SFBBO	SNEG	Snowy Egret	*Egretta thula*	Resident				
SFBBO	SORA	Sora	*Porzana carolina*	Winter				BCC
SFBBO	SOSP	Song Sparrow	*Melospiza melodia*	Resident				
SFBBO	SOSP	Marin Song Sparrow	*Melospiza melodia gouldii*	Resident				
SFBBO	SOSP	Alameda Song Sparrow	*Melospiza melodia pusillula*	Resident	SSC-2			BCC
SFBBO	SOVI	Solitary Vireo	*Vireo (sp)*	Migrant				
SFBBO	SPSA	Spotted Sandpiper	*Actitis macularius*	Migrant				
SFBBO	SPTO	Spotted Towhee	*Pipilo maculatus*	Winter				
SFBBO	SSHA	Sharp-shinned Hawk	*Accipter striatus*	Winter				
eBird	STJA	Steller's Jay	*Cyanocitta stelleri*	Resident				
eBird	STSA	Sharp-tailed Sandpiper	*Calidris acuminata*	Winter				
eBird	STSA	Stilt Sandpiper	*Calidris himantopus*	Winter			yellow list	
SFBBO	SUTA	Summer Tanager	*Piranga rubra*	Migrant	SSC-1			
eBird	SWHA	Swainson's Hawk	*Buteo swainsoni*	Winter	Threatened		yellow list	BCC
SFBBO	SWSP	Swamp Sparrow	*Melospiza georgiana*	Winter				
SFBBO	SWTH	Swainson's Thrush	*Catharus ustulatus*	Migrant				
SFBBO	TEWA	Tennessee Warbler	*Oreothlypis peregrina*	Migrant				
eBird	THGU	Thayer's Gull	*Larus thayeri*	Winter			yellow list	
SFBBO	THWH	Townsend's X Hermit Warbler Hybrid	*Setophaga townsendi x occidentalis*	Migrant				
SFBBO	TOWA	Townsend's Warbler	*Setophaga townsendi*	Migrant				
SFBBO	TRBL	Tricolored Blackbird	*Agelaius tricolor*	Resident	SSC-1	x	red list	BCC Focal Species
SFBBO	TRES	Tree Swallow	*Tachycineta bicolor*	Migrant				
SFBBO	TUVU	Turkey Vulture	*Cathartes aura*	Resident				

Source	**Species Code**	**Common Name**	***Scientific Name***	**Status at Coyote Creek Field Station**	**California Status**	**SOTB Watch List 2016**	**Audubon Watch List 2007**	**USFWS**
SFBBO	VASW	Vaux's Swift	*Chaetura vauxi*	Migrant	SSC-2			
SFBBO	VATH	Varied Thrush	*Ixoreus naevius*	Winter				
SFBBO	VESP	Vesper Sparrow	*Pooecetes gramineus*	Migrant				
SFBBO	VGSW	Violet-green Swallow	*Tachycineta thalassina*	Migrant				
eBird	VIRA	Virginia Rail	*Rallus limicola*	Winter				BCC
SFBBO	VIWA	Virginia's Warbler	*Oreothlypis virginiae*	Migrant		x	yellow list	BCC
SFBBO	WAVI	Warbling Vireo	*Vireo gilvus*	Migrant				
SFBBO	WBNU	White-breasted Nuthatch	*Sitta carolinensis*	Resident				
SFBBO	WCSP	White-crowned Sparrow	*Zonotrichia leucophrys*	Winter				
SFBBO	WCSP/ GWCS	Gambel's White-crowned Sparrow	*Zonotrichia leucophrys gambelii*	Winter				
SFBBO	WCSP/ PSWS	Puget Sound White-crowned Sparrow	*Zonotrichia leucophrys pugetensis*	Winter				
eBird	WEBL	Western Bluebird	*Sialia mexicana*	Resident				
SFBBO	WEFL	Western (Pacific Slope) Flycatcher	*Empidonax difficilis*	Migrant				
eBird	WEGU	Western Gull	*Larus occidentalis*	Winter				
SFBBO	WEKI	Western Kingbird	*Tyrannus verticalis*	Migrant				
SFBBO	WEME	Western Meadowlark	*Sturnella neglecta*	Winter				
SFBBO	WESA	Western Sandpiper	*Calidris mauri*	Migrant			yellow list	
SFBBO	WESJ	Western Scrub-Jay	*Aphelocoma californica*	Resident				
eBird	WESO	Western Screech-Owl	*Megascops kennicotti*	Resident				
SFBBO	WETA	Western Tanager	*Piranga ludoviciana*	Migrant				
SFBBO	WEWA	Worm-eating Warbler	*Helmitheros vermivora*	Migrant				BCC
SFBBO	WEWP	Western Wood-pewee	*Contopus sordidulus*	Migrant				
eBird	WGWH	Western x Glaucous-winged Gull (hybrid)	*Larus occidentalis x glaucescens*	Winter				
SFBBO	WIFL	Willow Flycatcher	*Empidonax traillii*	Migrant	Endangered		yellow list	Endangered (*E. t. extimus*)
SFBBO	WIFL/ TRFL	Traill's Flycatcher	*Empidonax alnorum/traillii*	Migrant				
eBird	WILL	Willet	*Tringa semipalmata*	Winter				
eBird	WIPH	Wilson's Phalarope	*Phalaropus tricolor*	Winter				
SFBBO	WISN	Wilson's Snipe	*Gallinago delicata*	Winter				BCC
SFBBO	WIWA	Wilson's Warbler	*Wilsonia pusilla*	Migrant				
eBird	WODU	Wood Duck	*Aix sponsa*	Winter				
SFBBO	WPWA	Western Palm Warbler	*Setophaga palmarum palmarum*	Migrant				

Source	**Species Code**	**Common Name**	***Scientific Name***	**Status at Coyote Creek Field Station**	**California Status**	**SOTB Watch List 2016**	**Audubon Watch List 2007**	**USFWS**
SFBBO	WREN	Wrentit	*Chamaea fasciata*	Migrant		x	yellow list	
eBird	WRSA	White-rumped Sandpiper	*Calidris fuscicollis*	Winter			yellow list	
SFBBO	WTKI	White-tailed Kite	*Elanus leucurus*	Resident				
SFBBO	WTSP	White-throated Sparrow	*Zonotrichia albicollis*	Winter				
SFBBO	WTSW	White-throated Swift	*Aeronautes saxatalis*	Resident				
SFBBO	YBCH	Yellow-breasted Chat	*Icteria virens*	Migrant	SSC-3			
eBird	YBCU	Yellow-billed Cuckoo	*Coccyzus americanus*	Migrant	Endangered			Threatened *(C. a. occidentalis)*
SFBBO	YEWA	Yellow Warbler	*Setophaga petechia*	Resident	SSC-2			BCC
SFBBO	YHBL	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	Migrant	SSC-3			
SFBBO	YRWA	Yellow-rumped Warbler	*Setophaga coronata*	Winter				
SFBBO	YRWA/ AUWA	Audubon's Warbler	*Setophaga coronata auduboni*	Winter				
SFBBO	YRWA/ MYWA	Myrtle Warbler	*Setophaga coronata coronata*	Winter				
SFBBO	ZSHY	Zonotrichia Sparrow Hybrid	*Zonotrichia leucophrys x atricapilla*	Winter				

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Wire Marking Results in a Small but Significant Reduction in Avian Mortality at Power Lines: A BACI Designed Study

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Abstract

Background: Collision with electric power lines is a conservation problem for many bird species. Although the implementation of flight diverters is rapidly increasing, few well-designed studies supporting the effectiveness of this costly conservation measure have been published.

Methodology/Principal Findings: We provide information on the largest worldwide marking experiment to date, including carcass searches at 35 (15 experimental, 20 control) power lines totalling 72.5 km, at both transmission (220 kV) and distribution (15 kV–45 kV) lines. We found carcasses of 45 species, 19 of conservation concern. Numbers of carcasses found were corrected to account for carcass losses due to removal by scavengers or being overlooked by researchers, resulting in an estimated collision rate of 8.2 collisions per km per month. We observed a small (9.6%) but significant decrease in the number of casualties after line marking compared to before line marking in experimental lines. This was not observed in control lines. We found no influence of either marker size (large *vs.* small spirals, sample of distribution lines only) or power line type (transmission *vs.* distribution, sample of large spirals only) on the collision rate when we analyzed all species together. However, great bustard mortality was slightly lower when lines were marked with large spirals and in transmission lines after marking.

Conclusions: Our results confirm the overall effectiveness of wire marking as a way to reduce, but not eliminate, bird collisions with power lines. If raw field data are not corrected by carcass losses due to scavengers and missed observations, findings may be biased. The high cost of this conservation measure suggests a need for more studies to improve its application, including wire marking with non-visual devices. Our findings suggest that different species may respond differently to marking, implying that species-specific patterns should be explored, at least for species of conservation concern.

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Introduction

Bird collisions with electric power lines have raised conservation concerns since the early 1900s, but it was not until the 1970s that biologists and engineers began to realize the extent of this problem [1,2]. Today the number of power lines is increasing worldwide at an annual rate of approximately 5% [3]. Mortality from collisions with power lines and other electric utility structures has been documented for some 350 bird species [4]. However, until a cumulative impacts assessment of power line mortality is conducted, the real level of mortality will remain uncertain [5]. Only some crude estimates of the importance of the problem, all of them based on extrapolations, are available. For example, in the Netherlands it has been found that bird collisions with power lines may cause one million deaths per year [6]. In the United States [5], it is estimated that power lines may kill up to 175 million birds annually, and it is estimated that bird collisions with power structures, including transmission (≥70 kV, usually with groundwire and wires at more than one height) and distribution (<70 kV, commonly without ground-wire and all the wires at the same height) lines, could approach one billion avian fatalities per year worldwide [7]. Fortunately, these values are probably overestimated since most of the studies are usually carried out on power lines that cause an important number of fatalities. Nevertheless, these figures allow conservationists to speculate that mortality due to collisions with power lines represents a serious threat for population viability in many species, at least in those that undergo higher collision risks, and that this threat is not equal for all species. Indeed, birds with low manoeuvrability, i.e., those with high wing loading and low aspect, such as bustards, pelicans, waterfowl, cranes, storks, and grouse, are among the species most likely to collide with power lines [2,8]. Species with narrow visual fields are also at high collision risk as they do not see the wires [9,10]. Despite this potentially important conservation problem, few studies have analyzed in detail how these losses affect population trends. For instance, it has been estimated that collision-related losses might equal up to 90% of the annual number of grouse harvested by hunting in Norway [11]. Based on ring-recovery data [12], it has been assessed that 25% of juveniles and 6% of adult white storks (*Ciconia ciconia*) die annually in Switzerland due to power lines (although these data also include electrocutions). It has also been estimated that 30% of Denham's bustards (*Neotis denhami*) die annually by collisions with power lines in South Africa [13].

Researchers and managers have used several methods to reduce collisions, including the removal of the static wire [14,15]. However, the most popular measure has been the attachment of spirals, plates, swivels, or spheres (collectively known as *bird flight diverters*) to the static wire in order to increase visibility [3,16,17,18]. While a recent review concluded that marking static wires reduces the overall number of bird casualties at power lines, it also called attention to the fact that there are a surprisingly small number of well-designed, peer-reviewed studies to support this [19]. Furthermore, there remain many gaps in the research in this area, with several important details still unresolved; for example, the comparative effectiveness of various currently available marker types [19]. To confirm diverter effectiveness, and to study all details of this conservation measure in depth is especially important because despite the high costs of wire marking (e.g., 1,100–2,600 US$ per marked kilometre in South Africa, [20]; 6,000€ in Spain; [21]), the application of this conservation measure is rapidly increasing worldwide.

As stated above, it has been shown that the presence of flight diverters was associated with a decrease in bird collisions [19]. However, the large differences in wire-marking techniques constrained the ability to evaluate potential differences among methods (e.g., different performance based on diverter traits) in that review. To complement such an approach, in the present study we designed the largest field experiment to date, to investigate: (i) the effectiveness of wire marking in reducing collisions; and the roles of (ii) power line type (transmission *vs.* distribution), and (iii) spiral size on marking effectiveness. We expected that: (i) the attachment of spirals would reduce bird mortality [19]; (ii) the effectiveness of marking would be higher in transmission lines because power line type influences the frequency of reactions to marked spans [22]. Morkill & Anderson [22] found that whooping cranes (*Grus americana*) reacted more than expected to transmission lines (345 kV, 27 m high) whereas the opposite was true in distribution lines (69 kV, 12 m high). It is worth noting that transmission lines in our study accumulate a larger number of collisions of those groups of birds especially prone to collision, such as bustards, storks or waterfowl (see below) compared to distribution lines. Therefore, the improvement margin once spirals are attached is greater in transmission lines; and, (iii) larger spirals may be more effective in increasing the visibility of wires [23,24], reducing collisions to a larger extent.

Methods

Study Area

The study was conducted in five important bird areas (IBAs) in central Spain (see [25] for details), which are also the main dry cereal farmland areas in the Madrid region. The terrain is flat to slightly undulating, with a mean elevation of c. 750 m a.s.l. These areas are primarily dedicated to cereal cultivation (mainly wheat *Triticum aestivum* and barley *Hordeum* spp.), with minor fields of legumes *Vicia* spp., grapevines *Vitis vinifera* and olive *Olea europaea* groves. Most cereal is grown in a traditional 2-year rotation system that creates a dynamic mosaic of ploughed, cereal and stubble patches over the region. Small patches of natural vegetation (holm oaks *Quercus ilex*, and scrubland of *Retama* spp. and *Thymus* spp.) remain dispersed across the cereal matrix. Cereal fields are harvested in late June to early July. Stubbles and fallows are also used for sheep grazing [26].

Study species

We considered all birds that we found dead under the power lines in the study area. We discarded the dead birds found beside poles whose cause of death could be attributed to electrocution. However, since not all species have the same collision risk [2,8,9], it is worth noting that the study area holds significant populations of threatened species which are prone to high collision rates due to their low manoeuvrability, high speed flight and/or poor vision [2,8,9], such as the great bustard *Otis tarda* (c. 1500 individuals; [27]), little bustard *Tetrax tetrax* (c. 2600 individuals; [28]), pin-tailed sandgrouse *Pterocles alchata* and black-bellied sandgrouse *P. orientalis* (c. 150 and 200 individuals, respectively, [29]).

Study design and power line monitoring

The study was carried out using a before-after-control-impact (BACI) design, i.e. monitoring power lines before and after the placement of spirals, combined with the use of controls during similar time intervals. Between August 2001 and December 2010 we surveyed bird collisions monthly at 22 different power lines, 7 of them transmission (220 kV) and 15 distribution (15 kV–45 kV) lines, totalling 16.1 and 27.0 km, respectively (Table 1). Fifteen of these lines were our *experimental* lines, i.e. to which spirals were attached. These were monitored once per month for two complete years (one year *before* and one year *after* wire marking). Another 7 lines to which no spirals were attached were used as *control* lines and were monitored also once per month for two complete years. Because no more non-marked control lines were available, in addition to these 7 control lines we also used as controls the second of 10 two-year and the third of 3 three-year surveys carried out at experimental lines once spirals were attached to them (Table 1). These surveys can be considered as *controls* since once the line was marked no changes occurred in the factor presence/absence of spirals and thus no changes were expected between years in the variable under study, i.e. collision rate. The resulting number of power lines (35) and the total length surveyed monthly (72.5 km) for all study years make our study both the most detailed and that with the largest number of power lines monitored to date (for instance, the mean number of power lines per study was 1.9 in a recent review, see Appendix S2 in [19]).

One month before the beginning of each monitoring year we removed all carcasses under the power line. Each monthly search

Table 1. Power line name, type of line (transmission or distribution), design (experimental or control) and number of years monitored after spiral attachment.

Power line	Type	Length (km)	Design	Times after
Aranjuez E-O	Distribution	2.0	Control	One
Aranjuez N-S I	Transmission	2.0	Experimental	One
Aranjuez N-S II	Transmission	4.1	Experimental	One
Belvis-Cobeña	Transmission	3.0	Experimental	Three
Camarma-Fresno	Distribution	2.0	Experimental	Two
Camarma-Meco	Transmission	1.6	Experimental	Two
Camarma-Torote	Transmission	2.1	Experimental	Three
Campo Real-Valdilecha	Distribution	3.2	Experimental	Two
Daganzo-Alcalá	Distribution	0.9	Control	One
Daganzo-Fresno Rio	Distribution	1.1	Control	One
Daganzo-Torote	Transmission	1.8	Experimental	Three
El Colegio	Distribution	3.0	Experimental	Two
La Cueva-El Casar	Distribution	1.5	Control	One
Mesones	Distribution	2.0	Control	One
Pinto	Transmission	1.5	Experimental	Two
Pozuelo-Valdilecha	Distribution	2.6	Experimental	Two
Quer	Distribution	1.4	Experimental	One
San Martín de la Vega	Distribution	1.7	Experimental	Two
Valdepiélagos-Talamanca I	Distribution	2.2	Experimental	One
Valdepiélagos-Talamanca II	Distribution	0.5	Control	One
Valdetorres-La Jara	Distribution	1.4	Control	One
Villanueva-Quer	Distribution	1.5	Experimental	One

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for bird carcasses was carried out by one observer walking at a slow, regular pace parallel to the wires but making zigzags to reasonably visually cover a 25 m band at each side of the vertical of the central conductor wire. The observer surveyed first one side along the line (e.g. the 25 m band on the right side), and then he/she returned to the starting point surveying the other side (25 m band on the left side). All remains found were identified to the species level and removed to avoid double counts. When the species was unknown ($<2\%$ of the cases), the carcass was assigned to one of the four sizes considered (see below). We recorded a carcass when the remains found consisted of more than five feathers in a square meter, because a smaller number of feathers cannot safely be interpreted as a collision, since they could have been lost by a bird during preening, moulting or fighting [30]. Carcass searches were not performed in June because crop height may lead to unrealistically low carcass detection figures. July surveys were always carried out after cereal harvesting. However, it is worth noting that in our rather structurally-homogeneous study area, there was no relationship between vegetation height or cover and carcass detection rates [25].

Potential detection biases such as site- or year-dependent carcass removal by scavengers or variation in carcass detection due to habitat heterogeneity are minimized in our study, since we used a BACI design combined with the use of control power lines at the same time intervals. Furthermore, potential outbreaks in scavenger populations are unexpected because predator control is widespread in our study region [31]. However, since monthly search frequencies may be adequate to detect medium- to large-sized corpses, but are insufficient for smaller birds, we used equations from [25] to adjust our mortality estimates in relation to search periodicity and carcass size (Table 2), because both can influence mortality estimates. The correction of field data is important because larger carcasses are detected by researchers more easily than smaller ones, and because the longer time elapsed between consecutive searches and the smaller the size of the carcasses, the larger the effect of scavengers on corpse disappearance [25]. Ideally, surveys to evaluate carcass losses should be carried out in each study area before undertaking further mortality studies [25], because detection rates can differ among study areas (e.g., due to habitat biases, [30]). Therefore, we used our own correction equations instead of others recently published (e.g., [32]). Observers were previously trained in order to minimize potential biases due to their different levels of expertise in carcass searches [25].

In addition to testing the effectiveness of line marking as a means to reduce bird collision rate, we also evaluated two potential sources of variation in marking efficiency: power line type and spiral size. Whereas all transmission lines were equipped with large spirals (35 cm diameter and 1 m length, Figure 1a), either large or small spirals (10 cm of diameter and 24 cm m long, Figure 1b) were attached to distribution lines, with the same spiral size attached to all the spans of a given power line. We compared (i) the differences in marking efficiency in transmission *vs.* distribution lines when equipped with large spirals; and (ii) the efficiency of large *vs.* small spirals to reduce bird mortality in distribution lines.

Unfortunately, we have no data on flight frequencies to estimate collision rates associated with our different designs, but in the study of marking effectiveness alone we used the corresponding *controls* to

Table 2. Equations from [25] used in our study to correct numbers of dead birds found at the power line, in order to account for removal by scavengers or missed observations during carcass searches.

Equation	
A_n (Detectability)	A_1 : Large = (no. carcasses found+1)*100/71.7 A_2 : Medium = (no. carcasses found+1)*100/55.8 A_3 : Small = (no. carcasses found+1)*100/32.1 A_4 : Very small = (no. carcasses found+1)*100/33.3
B_n (Periodicity and scavenging)	B_1 : Large = 0.744+28.063*log10(days) B_2 : Medium = −1.751+41.880*log10(days) B_3 : Small = −6.623+58.111*log10(days) B_4 : Very small = 13.538+60.342*log10(days)
C_n (Correction)	$(A_n*B_n)/100$
Mortality estimate $_n$	A_n+C_n

Different equations are given for the four size categories specified in [25] (see Table 3 for their weights). We first corrected the number of carcasses found in the field by their size-dependent detectability (A). Second, we applied equation B for different carcass sizes where "days" is the number of days elapsed from the last visit. Third, we obtained a correction for every size category. Finally, we added C to A to obtain the mortality estimates for each category. The mortality estimate for a given power line was the sum of mortality estimates for the four carcass sizes.

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evaluate potential changes in bird mortality associated with changes in bird population densities. Furthermore, power lines of different categories were surveyed in the same study area, minimizing the effect of potential local differences in bird densities.

Statistical analyses

As a basic first analytical approach we tested whether there was a trend in the number of bird carcasses found after marking the line compared to before marking. This was done considering each power line as a sample unit, and comparing the number of decreases and increases in casualties recorded after marking (in the case of experimental lines), or in the second survey year compared to the first year (in the case of control lines). These comparisons were performed using the two-tailed sign test for small samples [33]. The same test was carried out using the total *estimated* number of dead birds, i.e. after correcting the number of casualties recorded during the field surveys [25]. To confirm the observed trends, we checked the differences in the accumulated numbers of *estimated* deaths before-after marking (first-second year in the case of controls) and experimental lines-control lines by means of a chi-squared test.

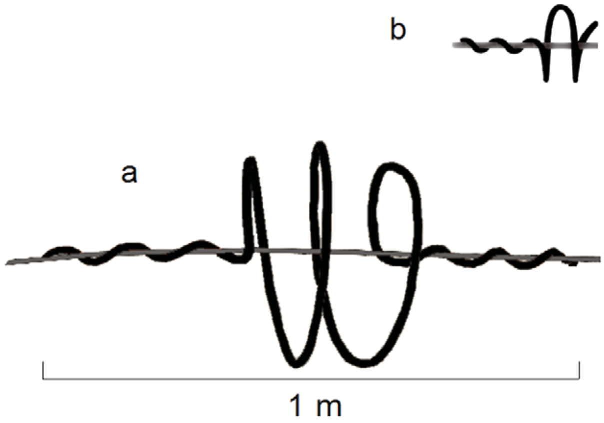

Figure 1. Spirals used in our experiments. Difference in size between large (a) and small (b) can be appreciated.

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As a second approach we used a Generalized Linear Mixed Model (GLMM) of various independent factors on the monthly estimated collision rate, after applying corrections proposed by [25] to the number of carcasses found to account for carcass losses due to removal by scavengers or to being overlooked by observers. For this analysis we considered one month as a time lapse long enough to allow the use of carcass search results in different months as statistically independent. We performed three GLMMs with Poisson error distributions and log link functions. The three analyses shared the same dependent variable, the *estimated* number of dead birds per month, and standardizing per kilometre of power line [30]. They also shared the random factor (power line). The models were fitted by maximizing the log-likelihood using the Laplacian approximation in R-Program 2.11.1 ([34]; *lmer* in *lme4* package). The three analyses were the following: (i) Marking effectiveness alone: We evaluated the effect of wire marking on bird mortality with two fixed factors, 'Marked *vs.* non-marked', with two levels, and 'First survey year *vs.* second survey year', also with two levels. This analysis includes both lines marked in the second year, but not in the first, and control lines. (ii) Power line type: We explored the effect of the power line type by including a factor with two levels (transmission and distribution) in the sample of power lines marked with large spirals. (iii) Spiral size: We studied the effect of spiral size through a factor with two levels (large and small) in the sample of distribution power lines.

In order to evaluate the importance of correcting for corpse losses, we performed a *sensitivity analysis* with a second group of GLMM tests where the dependent variable was the raw number of carcasses (i.e., those found in the field, without correction per losses) per km per month. All other parameters remained constant. This was only a methodological approach, as all the findings were based on the above-mentioned *estimated* mortality.

Finally, to study the specificity of the patterns found, we re-analyzed our data from a species-specific point of view. However, most of the species did not allow analyzing them with a GLMM procedure because they were not well represented in all the power lines along the study area. We thus proceeded with Wilcoxon paired-sample tests for the three most common species: (i) doves (rock and domestic doves and wood pigeons, all together), (ii) great bustards and (iii) little bustards. We took into account the changes in mortality (first year *vs.* second year) for the whole power line and separating experimental and control lines. We made these species-specific calculations after correcting the number of casualties recorded during the field surveys, i.e., with *estimated* mortality.

Results

We found 521 carcasses of 45 bird species, 19 of conservation concern (Table 3). Among experimental lines, most showed a decline in mortality after line marking compared to before line marking (11 lines with a decrease, 4 with an increase; $P = 0.10$, two-tailed sign test). The overall decrease in the number of carcasses recorded in the sample of 15 experimental lines was 88 birds (189 birds before marking, 101 birds after marking, 47% reduction in observed casualties). In control lines we did not observe a significant trend (10 lines with a decrease, 5 with an increase, 5 remained constant, $P = 0.30$, two-tailed sign test), with an overall reduction of 20%.

The 521 dead birds found represent 14,282 estimated bird collisions, an average 8.2 collisions per month and km, after

Table 3. Species found dead under power lines in the present study and their size following [25]: XS (<50 g), S (50–150 g), M (150–600 g) and L (>600 g).

Species	Size	Carcasses found	SPEC
Cattle Egret *Bubulcus ibis*	L	9	Non-SPEC
White Stork *Ciconia ciconia*	L	24	SPEC 2
Mallard *Anas platyrhynchos*	L	4	Non-SPEC
Shoveler Duck *A. clypeata*	L	1	Non-SPEC
Black Kite *Milvus migrans*	L	2	SPEC 3
Cinereous Vulture *Aegypius monachus*	L	2	SPEC 1
Marsh Harrier *Circus aeruginosus*	L	1	Non-SPEC
Sparrowhawk *Accipiter nisus*	M	1	Non-SPEC
Common Buzzard *Buteo buteo*	L	1	Non-SPEC
Common Kestrel *Falco tinnunculus*	M	6	SPEC 3
Red-legged Partridge *Alectoris rufa*	M	10	SPEC 2
Common Quail *Coturnix coturnix*	S	3	SPEC 3
Common Moorhen *Gallinula chloropus*	M	2	Non-SPEC
Little Bustard *Tetrax tetrax*	L	57	SPEC 1
Great Bustard *Otis tarda*	L	73	SPEC 1
Stone Curlew *Burhinus oedicnemus*	L	12	SPEC 3
Lapwing *Vanellus vanellus*	M	19	Non-SPEC
Black-headed Gull *Larus ridibundus*	L	2	Non-SPEC
Pin-tailed Sandgrouse *Pterocles alchata*	M	6	SPEC 3
Rock/Domestic Dove *Columba livia*	M	130	Non-SPEC
Wood Pigeon *C. palumbus*	M	49	Non-SPEC
Common Swift *Apus apus*	S	1	Non-SPEC
European Roller *Coracias garrulus*	S	4	SPEC 2
Crested Lark *Galerida cristata*	XS	1	SPEC 3
Skylark *Alauda arvensis*	S	14	SPEC 3
Barn Swallow *Hirundo rustica*	XS	1	SPEC 3
Meadow Pipit *Anthus pratensis*	XS	7	Non-SPEC
Robin *Erithacus rubecula*	XS	1	Non-SPEC
Northern Weather *Oenanthe oenanthe*	XS	1	SPEC 3
Blackbird *Turdus merula*	S	1	Non-SPEC
Reed Warbler *Acrocephalus scirpaceus*	XS	1	Non-SPEC
Melodious Warbler *Hippolais polyglotta*	XS	1	Non-SPEC
Subalpine Warbler *Sylvia cantillans*	XS	3	Non-SPEC
Orphean Warbler *S. hortensis*	XS	1	SPEC 3
Blackcap *S. atricapilla*	XS	2	Non-SPEC
Common Chiffchaff *Phylloscopus collybita*	XS	4	Non-SPEC
Willow Warbler *P. trochilus*	XS	3	Non-SPEC
Magpie *Pica pica*	M	28	Non-SPEC
Jackdaw *Corvus monedula*	M	1	Non-SPEC
European Starling *Sturnus vulgaris*	S	1	SPEC 3
Spotless Starling *S. unicolor*	S	8	Non-SPEC
House Sparrow *Passer domesticus*	XS	3	SPEC 3
European Serin *Serinus serinus*	XS	1	Non-SPEC
Linnet *Carduelis cannabina*	XS	3	SPEC 2
Corn Bunting *Emberiza calandra*	XS	7	Non-SPEC
Undetermined medium-sized bird	M	3	—
Undetermined passerine	XS	6	—

Table 3. Cont.

Figures are numbers of carcasses found during the whole study period (2001–2010). Note that statistical analyses were made both with raw data and after applying correction equations proposed by [25] to field data shown in this table. The conservation status is based on [43] criteria: 'SPEC 1': European species of global conservation concern; 'SPEC 2': Species having global populations concentrated in Europe and an unfavourable conservation status in Europe; 'SPEC 3': species having global populations not concentrated in Europe but an unfavourable conservation status in Europe; and, 'Non-SPEC': species having global populations not concentrated in Europe and a favourable conservation status in Europe.

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accounting for carcass removal by scavengers and missed observations during surveys. Significantly more experimental lines showed a decrease in the number of estimated casualties after line marking compared to before line marking (12 lines with a decrease, 3 with an increase; $P = 0.04$, two-tailed sign test). The overall difference in the sample of 15 lines was 316 birds (3,300 estimated birds before marking, 2,984 birds after marking, 9.6% reduction in estimated mortality). The control sample did not show significant before-after differences (10 lines with a decrease, 10 with an increase, $P = 1.0$, two-tailed sign test; total estimated casualties: 4,067 before and 3,931 after marking, 3.3% reduction). A chi-squared test with the former data (3,300, 2,984, 4,067 and 3,931) confirmed the difference between experimental and control samples in the reduction of estimated casualties ($\chi^2 = 3.90$, $P = 0.048$).

In the GLMM considering all monthly surveys, the number of estimated collisions per kilometre was significantly reduced in experimental power lines after marking, while it remained similar in controls (Table 4i.a; Figure 2). This model explained 96.4% of the deviance. The effectiveness of large spirals was similar in transmission and distribution power lines (Table 4ii.a; Figure 3). The model explained 99.6% of the deviance. Spirals of different sizes had similar marking effectiveness when attached to distribution lines (Table 4iii.a; Figure 4), with 98.8% of the deviance explained by the model. The comparisons with uncorrected raw data (Table 4i.b, ii.b and iii.b) showed different statistical differences (e.g., in 'marked *vs.* non-marked'), highlighting the importance of correcting field data.

Regarding species-specific patterns, doves did not show significant differences in the six treatments, regarding marking effectiveness alone (Wilcoxon paired-sample test, marked *vs.* non-marked, $Z = 0.87$, $P = 0.39$; first survey year *vs.* second survey year, $Z = 0.00$, $P = 1.00$), power line type (transmission lines, $Z = 0.41$, $P = 0.68$; distribution lines, $Z = 0.41$, $P = 0.68$) or spiral size (large spirals, $Z = -0.32$, $P = 0.75$; small spirals, $Z = -0.50$, $P = 0.62$).

In contrast, great bustard mortality was reduced only after marking of transmission lines (transmission lines, $Z = 2.04$, $P = 0.04$; distribution lines, $Z = 0.00$, $P = 1.00$) or only when marking with large spirals (large spirals, $Z = 2.00$, $P = 0.046$; small spirals, $Z = -0.71$, $P = 0.48$), being not significant regarding marking effectiveness alone (marked *vs.* non-marked, $Z = 1.81$, $P = 0.07$; first survey year *vs.* second survey year, $Z = 0.00$, $P = 1.00$).

In the little bustard, wire marking reduced mortality ($Z = 2.47$, $P = 0.01$), whereas statistical differences were not found for controls ($Z = 0.50$, $P = 0.62$) or for power line type (transmission lines, $Z = 1.79$, $P = 0.07$; distribution lines, $Z = 1.15$, $P = 0.25$) or spiral size (large spirals, $Z = 1.22$, $P = 0.22$; small spirals, $Z = 0.00$, $P = 1.00$).

Table 4. Parameter estimates from the Generalized Linear Mixed Model for marking effectiveness alone model (i), power line type model (ii) and spiral size model (iii).

(i.a) Marking effectiveness alone (n = 770) (with corrections)

	Estimate	SE	z	*P*
Intercept	2.34	0.09	27.31	<0.0001
Marked *vs.* non-marked	−0.08	0.04	−2.13	0.03
First survey year *vs.* second survey year	−0.04	0.03	1.57	0.12

(i.b) Marking effectiveness alone (n = 770) (without corrections)

	Estimate	SE	z	*P*
Intercept	−1.20	0.20	−6.35	<0.0001
Marked *vs.* non-marked	−0.30	0.16	−1.90	0.06
First survey year *vs.* second survey year	0.47	0.14	3.46	<0.0001

(ii.a) Power line type (n = 242) (with corrections)

	Estimate	SE	z	*P*
Intercept	2.10	0.11	18.49	<0.0001
Power line type	0.11	0.14	0.78	0.44

(ii.b) Power line type (n = 242) (without corrections)

	Estimate	SE	z	*P*
Intercept	−1.71	0.32	−5.42	<0.0001
Power line type	0.75	0.38	1.99	0.05

(iii.a) Spiral size (n = 176) (with corrections)

	Estimate	SE	z	*P*
Intercept	2.10	0.08	25.12	<0.0001
Spiral size	0.10	0.12	0.88	0.38

(iii.b) Spiral size (n = 176) (without corrections)

	Estimate	SE	z	*P*
Intercept	−1.75	0.36	−4.92	<0.0001
Spiral size	0.65	0.49	1.32	0.19

We show GLMM with (a) and without (b) corrections for carcass losses due to researcher overlooking and removing by scavengers. Estimate, standard error (SE), statistic value (z) and statistical significance (*P*) are provided.

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Discussion

Our results show a slight (overall, 9.6%, after correcting for carcass removal by scavengers and missed observations), but significant reduction in bird mortality after flight diverters were attached to power lines. Regardless of statistical significance, a slight mortality reduction may be very biologically relevant in areas, species or populations of high conservation concern. It is important to note that overall mortality reduction values were not the same if calculated using raw numbers of dead birds found, i.e. before correcting for carcass removal by scavengers and missed observations. This is because correction factors differ between species [25]. Thus, uncorrected mortality values would lead to incorrect conclusions, and special care should be taken when dealing with certain birds of conservation concern. Neither the type of line (transmission *vs.* distribution) marked with large spirals, nor the size of spirals in distribution lines influenced the magnitude of mortality reduction when we assessed overall mortality in all species together. However, great bustard mortality showed reductions when lines were marked with large spirals, and also considering only transmission lines.

The effectiveness of wire marking in reducing bird mortality through collision has been recently reviewed by Barrientos et al. [19]. However, in that study, different markers were combined since available sample sizes did not allow inclusion of marker type as a factor in the analysis. Thus, despite spirals of different sizes and colours being the most frequently employed bird flight diverters, half of the studies included in Barrientos et al. [19] referred to other device types (see Appendix in [19]). The present study suggests that the mortality reduction found in that review was not due to the inclusion of other markers, and that the most widely used spirals are effective. The present study also overcomes a common problem detected in Barrientos et al. [19], namely that sample sizes are generally small. Here we based our conclusions on a large sample including two-year monthly surveys at 15 experimental and 20 control power lines, covering 72.5 km. Moreover, these lines were distributed over a relatively large geographical area, encompassing most farmland areas used by steppe birds in our study region. This overall low (9.6%) reduction could be greater in some places (e.g., migration corridors, power lines close to resting sites, etc), or could represent a valuable reduction for endangered species with high collision risk. Thus, a

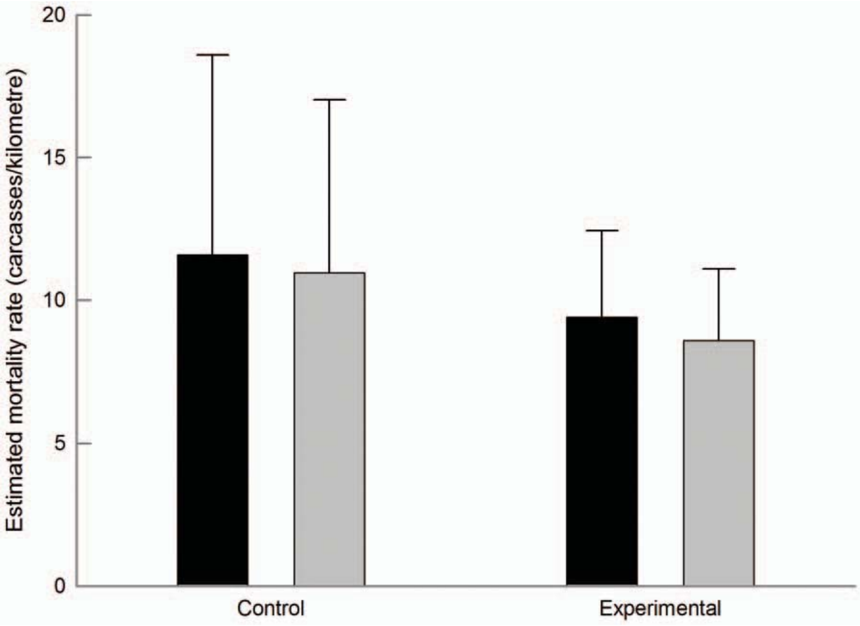

Figure 2. Number of estimated carcasses per kilometre (mean ± SE) before (black) and after (grey bars) marking in control (left) and experimentally marked (right) power lines. Sample sizes were 219 and 165 in each period for control and experimental power lines, respectively.
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detailed evaluation of mortality due to collision should be carried out before deciding where to attach spirals as a bird protection measure in relatively large conservation areas.

Some of the species found dead in our study are among those suggested in previous studies to be the most likely to collide with power lines [2,8], namely those with low maneuverability such as bustards, storks or waterfowl. These species usually fly higher than, for instance, many passerines, and thus most of their collisions are expected to be with transmission lines. Indeed, if we consider the data from the first year only, i.e. before attaching spirals, transmission lines in our study accumulated 71% ($n = 42$) of all great bustards found dead in all lines, 50% ($n = 50$) of all little bustards *Tetrax tetrax*, 83% ($n = 12$) of all white storks *Ciconia ciconia* and 100% ($n = 3$) of all ducks *Anas* spp., despite the fact that transmission lines represented only 36% of the total length of power lines surveyed. In their study with whooping cranes, Morkill

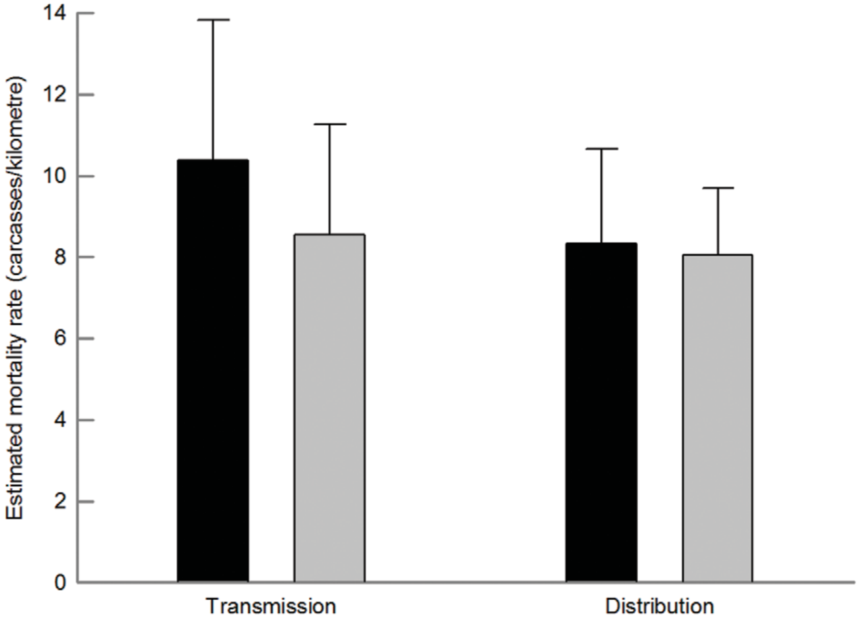

Figure 3. Number of estimated carcasses per kilometre (mean ± SE) before (black) and after (grey bars) marking in transmission (left) and distribution (right) power lines. Sample sizes were 77 and 44 in each period for transmission and distribution power lines, respectively.
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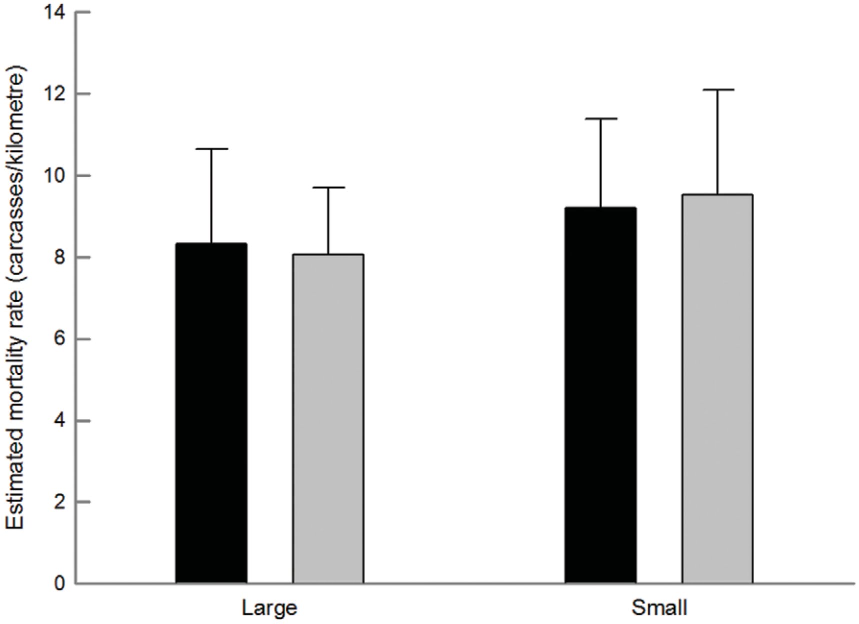

Figure 4. Number of estimated carcasses per kilometre (mean ± SE) before (black) and after (grey bars) marking in distribution power lines marked with large (left) and small (right) spirals. See Figure 1 for more details. Sample sizes were 44 in all cases.
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& Anderson [22] found that birds reacted more than expected to transmission lines and less to distribution lines. However, we did not find a significant difference in mortality reduction in marked transmission lines compared to marked distribution lines when we considered all species together. When looking at species-specific patterns, only the great bustard showed a slight mortality reduction in marked transmission lines. Although some studies found that species suffering high collision mortality may show a tendency to avoid areas with transmission lines (e.g. little bustard, [35]), collision with transmission lines is still one of the most important sources of mortality in these species [35,36]. Thus, as suggested in Barrientos et al. [19], it is possible that at least some of these particularly sensitive species do not properly respond to conventional marking methods (see below).

Although one would expect that large flight diverters are more effective than small diverters in increasing the visibility of marked wires, other authors that have used spirals of different sizes [23,24] did not statistically test for differences among them. Our study explores this possibility for the first time. Considering all species together, our results suggest that the decrease in collision rate is independent of spiral size, and thus it seems reasonable to conclude that the main advantage of marking is already achieved with small spirals, with larger spirals being unnecessary. This could imply interesting applied findings. For example, small diverters do not apply excessive weight to the wire. Large devices can constitute a problem for this reason especially in high winds, contributing to the downing of power lines, especially if devices are frozen [14,22]. However, a flagship species like the great bustard showed mortality reduction with larger spirals, suggesting that, at least for this species, large spirals work better.

Despite our study being, to our knowledge, the largest published field experiment, and ca. 310,000 € were spent to mark 33.7 kilometres of power lines in our study area, few conclusions can be drawn beyond the general effectiveness of bird flight diverters in reducing collision mortality. We found differences in effectiveness when we compared markers in transmission versus distribution lines, or when we compared spirals of different sizes in distribution lines only with one species (although we could carry out species-specific analyses only with three species). However, it is worth noting that even after marking, bird collisions in our study area were still high, especially for some endangered species usually showing high collision risks (e.g. great and little bustards). Several non-mutually exclusive explanations could account for this. First, it is possible that the generally low probability of collision (0.21-0.05 birds per 1,000 crossings; [19]) makes it very difficult to find differences even with well-designed experiments. If this is the case, huge experimental designs would be necessary to find larger differences and extract stronger conclusions. Second, it has been argued that bad weather or light conditions can increase bird collisions, especially if birds have problems with flight control [14,37]. For most birds, sustained slow flight is costly or aerodynamically impossible [38,39], and hence reducing speed is an unlikely mechanism to increase safety under bad weather or light conditions. Third, collisions frequently occur even under low wind and good visibility conditions [40]. Recent studies [9,10] suggest that some species, which undergo high collision rates (e.g. bustards and storks) have narrow fields of view in the frontal plane, hindering their ability to see the way ahead. Fourth, Martin [10] suggests that birds flying in open airspace above vegetation could relax –by means of either behavioural or evolutionary adaptations- the monitoring of this airspace since it is a highly predictable environment, usually clear of hazards. In other words, birds of some species could simply not look ahead during flight. Indeed, frontal vision in birds is not a high-resolution vision [10]. Instead, the best resolution occurs in the lateral vision, which most birds employ to detect conspecifics (very important in social species like bustards or storks) and predators, or in identify foraging opportunities. All of these may be more important for a bird than simply looking ahead during flight into open airspace [10]. Fifth, anecdotal events can have potentially important effects on collisions. For instance, Sastre et al. [41] suggest that human-related disturbances causing flight response can increase the probability of collision of great bustards with power lines. Sixth, regarding the effectiveness evaluation of different devices, it is also plausible that misguided approaches have been used to date. For instance, whereas bird flight diverters are usually coloured with a single colour bright to the human eye [19], a recent review [10] recommends the use of black-and-white diverters, which reflect highly or absorb strongly across the full spectrum of ambient light. Thus, it is possible that the few valuable studies carried out to date that compared the effectiveness of different colours for a certain bird flight diverter [42] actually compared colours too close in the spectrum to identify differences in their effectiveness. Since it is recognized that the colour vision of birds extends into the ultraviolet range, thus broadening, compared with humans, the range of stimuli to which the avian eye can respond [10], the use of ultraviolet-devices should be investigated.

In summary of the above-mentioned explanations, and given that is seems clear that no single type of marker will be equally effective for all bird species, we acknowledge that the importance of type and size of bird flight diverters is not yet clear and should be confirmed in future studies. Our study does not pretend to be comprehensive in this respect, and regarding the different susceptibilities of different bird species or groups to collision [see 2,8], and particularly the mortality reductions obtained for specific models of flight diverters should be further investigated. In this sense, we encourage researchers to explore the effectiveness of non-visual diverters. Finally, we highly recommend the identification of mortality hot-spots based on the number of individuals killed and the vulnerability of the species involved [e.g. 44]. Taking into account the economic cost of marking, it is likely more useful to attach flight diverters to these hot-spots rather than to do it to whole sections of power line.

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Author Contributions

Conceived and designed the experiments: JCA C. Palacín CM. Performed the experiments: RB C. Ponce BM CM. Analyzed the data: C. Ponce RB JCA. Contributed reagents/materials/analysis tools: C. Ponce RB JCA. Wrote the paper: RB C. Ponce JCA.

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Attachment

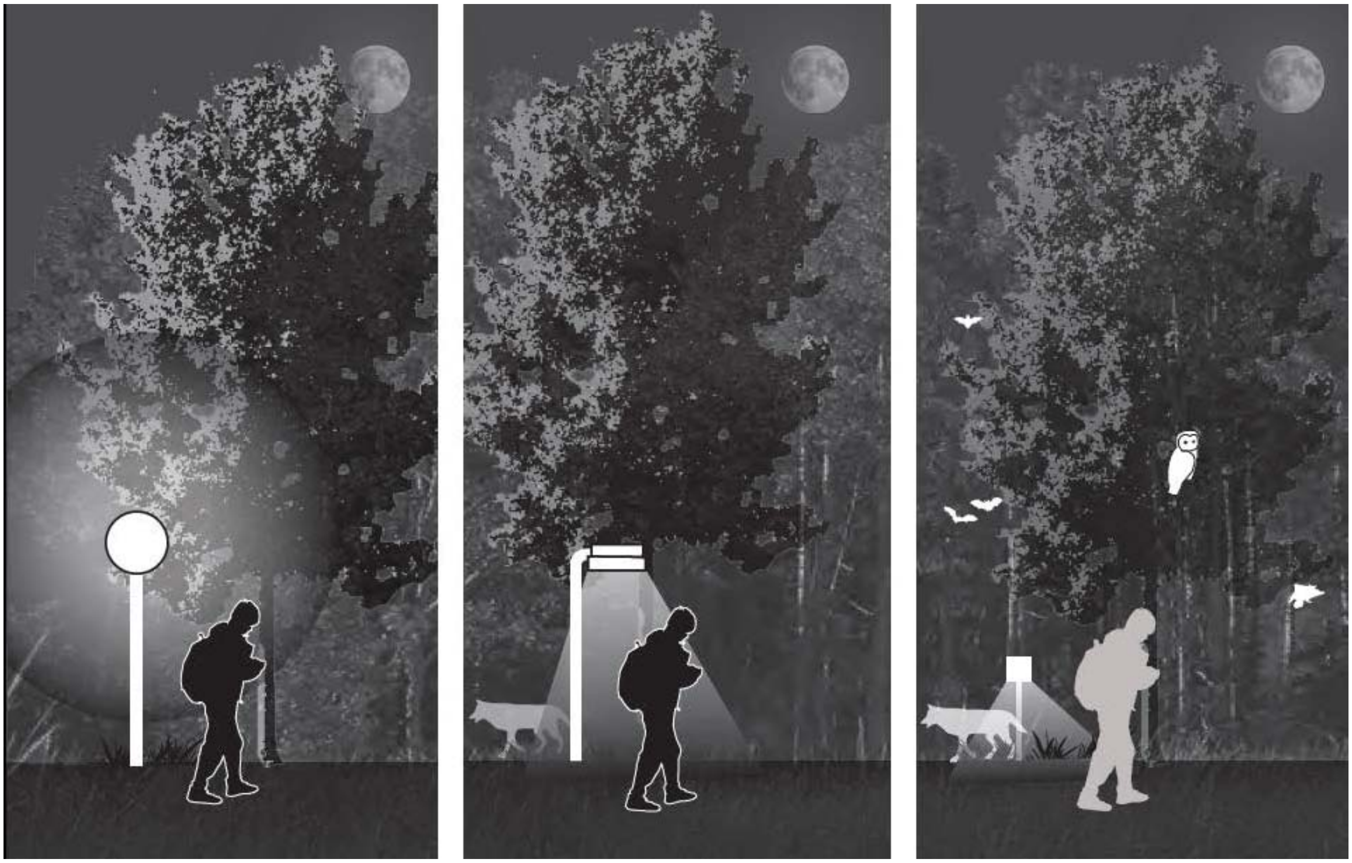
National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Artificial Night Lighting and Protected Lands

Ecological Effects and Management Approaches

Natural Resource Report NPS/NRSS/NSNS/NRR—2016/1213



The Urban Wildlands Group

USC School of Architecture

USC Dornsife
Dana and David Dornsife
College of Letters, Arts and Sciences

ON THE COVER

Example of controlling light direction to reduce environmental consequences

Illustration by Leigha DelBusso

Artificial Night Lighting and Protected Lands

Ecological Effects and Management Approaches

Natural Resource Report NPS/NRSS/NSNS/NRR—2016/1213

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National Park Service
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Figures

Figures (continued)

Two natural forms of light at night — from the moon and bioluminescent plankton — contrast with coastal urban lighting in New Jersey, United States. Artificial lighting dramatically changes the intensity and spectrum of light available at night and homogenizes the nocturnal visual environment over space and time. Photograph by Flickr user catalano82 is reproduced with permission.

Executive Summary

Artificial night lighting represents a growing challenge for managers of parks and protected lands. The disruption of natural patterns of light and dark, which have been more or less reliable for millions of years, has a range of adverse consequences for wildlife across taxonomic groups and landscape types. This document reviews effects of artificial night lighting by habitat type and discusses the approaches available to land managers to mitigate and avoid certain adverse effects of artificial night lighting.

Coastal dunes, beaches, and shorelines are a transition zone between terrestrial and aquatic habitats. They often contain gradients of lighting influence from developed shorelines to darker lakes and oceans. Sea turtles are prominent victims of these disrupted lighting regimes. The foraging decisions of many other species are influenced by lighting conditions, embodying tradeoffs between predation risk and dietary needs.

Deserts and scrublands are open habitats with few barriers to light transmission. They are also often hot in the day, with large proportions of nocturnal and crepuscular species avoiding thermal stress. Many nocturnal desert species prefer low illumination levels and have good visual performance under the faint light of the darkest nights.

Wetlands and rivers are often dark spots surrounded by lights, especially when close to human settlement. Movement of species into and out of wetlands and streams is influenced by lights, as is the movement of animals, such as fishes or aquatic invertebrates, up and down rivers and streams. Downwelling light mediates most predator–prey interactions in the water column. Changing light levels cause predators and prey to change depth. Small prey species are influenced by the phase of the moon, and lighting can degrade conditions favorable to successful foraging. Emerging research demonstrates that lighting influences the developmental rates of wetland organisms such as amphibians.

Islands, oceans, and reefs are increasingly influenced by lights from onshore sources, hydrocarbon extraction platforms, fishing vessels, and all manner of ships. Downwelling light is also a dominant factor in structuring ecosystem processes in marine water columns, and many organisms are sensitive to extremely small changes in light levels. Extensive vertical migrations are driven by changes in surface illumination. Changes in surface lighting can have effects hundreds of meters below the surface. Lighting will alter reproduction and predator–prey interactions, and can attract organisms across wide areas.

Grasslands are also open habitats with few barriers to block lights. Research shows influence of lighting on nesting behavior of birds, distribution of predators, and signaling by bioluminescent organisms such as fireflies.

Deciduous and evergreen forests can block light and reduce its influence, but also contain communities of forest floor species adapted to lighting levels much dimmer than in exposed habitats. Therefore even low levels of light can influence foraging times or timing of reproductive activity.

Alpine and tundra habitats are well represented in protected lands. Many species have annual rhythms designed to avoid the harsh winter that are potentially disrupted by lighting cues. In alpine habitats, the slope of the land potentially exposes habitats to direct glare from downslope sources in addition to light reflected in the atmosphere.

Finally, *urban environments* have many artificial light sources, but still can support significant biodiversity in the form of both resident and migratory species. Migratory birds are attracted to lighted structures at night and collide with windows during the day. Some bat species are attracted to insects found under city lights, while others avoid them.

Mitigation of adverse effects of anthropogenic light in these different habitats is guided in five ways:

1. Need. Creative solutions are often available to avoid use of lights where they are not absolutely necessary. Especially in natural areas, managers should exercise discretion in limiting the lighting infrastructure.
2. Spectrum. Although no color of light is benign in all situations, managers should avoid lights that have ultraviolet or blue light (shorter wavelengths) and in general use lights with red and yellow hues.
3. Intensity. Reducing the intensity of lights can often improve visibility for humans by reducing the contrast between light and shadow, allowing people to see a larger area than they might otherwise be able to discern. Guidelines for lighting intensity from the lighting industry should not be followed when trying to reduce impacts to wildlife, because they are usually higher than necessary for human vision and do not take into account impacts to wildlife.
4. Direction. Lights should be shielded such that they only cast light where it is needed, and never be directed upwards.
5. Duration. Timers and motion detectors can reduce the time a light is on and may therefore reduce impacts. Curfew hours for lights can also enhance visitor experience.

In this report, many lighting situations are considered, including communication towers, night hiking and mountain biking, campsite lighting, off-road vehicles, monuments, light-assisted fishing, security lighting, bridges, roadway lighting, energy production installations, indoor lighting, lighthouses, and billboards. With careful planning and collaboration, usually with nearby jurisdictions, managers of parks and other protected lands can be leaders in the control of light pollution and increase enjoyment of natural lands from inner city parks to wilderness areas.

Acknowledgments

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Introduction

Americans have long recognized that parks and protected lands can provide opportunities to see and enjoy the solitude of unspoiled nature, where the natural rhythms of life are allowed to flourish with minimal influence from humans. Managers of parks and protected lands balance the need to provide visitor facilities with the impacts of such infrastructure on the environment. Although night lighting may be a requirement for visitors in some circumstances, scientific research has documented a range of adverse consequences of night lighting on ecosystems and wildlife. The effects of lighting on species and ecosystems can be reduced, and in some instances avoided altogether. This report provides examples of assessing the impacts of night lighting on wildlife, and presents options to retrofit and design lighting that minimize impacts to wildlife and the nocturnal environment.

Extensive outdoor (and indoor) electric lighting is a recent phenomenon. Thomas Edison commercialized the electric light bulb in the late 1880s, and outdoor use was largely limited to cities until well into the 1900s. Electric lights were introduced in city centers as replacements for gas lamps in the late 1880s, with lethal effects on wildlife. Nearly 1,000 migratory birds were killed in collisions after being attracted to an electric light tower in Decatur, Illinois in 1886 (Gastman 1886). Significant outdoor lighting spread with the rural electrification programs of the 1930s and 1940s. More recently, other significant sources of outdoor lighting have spread across large swaths of the globe, primarily through illumination of human settlements and associated transportation infrastructure. Other sources of artificial night lighting have proliferated as well. Lighting associated with oil and gas development illuminates large terrestrial and offshore regions. Similarly, light-assisted fishing operations illuminate oceans in many regions and oceangoing freighters and passenger ships introduce mobile light sources along oceanic routes. Together, these and other light sources introduce novel lighting conditions that have no historical precedent in natural ecosystems. Natural patterns of darkness are lost or endangered globally (Bennie et al. 2015, Duffy et al. 2015, Marcantonio et al. 2015).

This document is divided into two sections. The first section reviews the effects of artificial night lighting on major habitat types. No single solution can mitigate all adverse effects of artificial night lighting. We therefore attempt to generalize the concerns that typify each biome. The second section provides recommendations for management approaches to minimize impacts from lighting. We address the characteristics of lights in terms of need, spectrum, intensity, direction, and duration, with reference to biomes in which each method of control would be applicable. This discussion addresses common lighting applications — roadways, parking, and walkways — as well as specialized situations like night hiking and mountain biking, vanity lighting, communication towers, and light-assisted fishing.

Effects of Artificial Night Lighting on Natural Ecosystems

Natural patterns of light and dark

In the natural world, sources of light are either very predictable or notably ephemeral. The dominant and structuring source of light is the sun, through daylight and the reflected light of moonlight.

Patterns and intensity of sunlight and moonlight vary with geographic location, weather, and time, but they have certain predictable characteristics. For example, the daily, monthly, and seasonal patterns of moonlight and sunlight incident upon the Earth's atmosphere are only rarely interrupted (e.g., by a solar eclipse). Once the sun has set, the brightest possible constant light source is a full moon until the sun rises again (**Figure 1**). The length of the night varies by season and latitude and these patterns are, in the timescale of biological activity, fixed. Weather influences illumination during the day, and does not, with the exception of lightning, increase nocturnal illumination. Fires, lightning, bioluminescence, starlight, airglow, and zodiacal light contribute to nighttime illumination under natural conditions, and these transient sources are brief, rare, or dim in comparison with sunlight and moonlight.

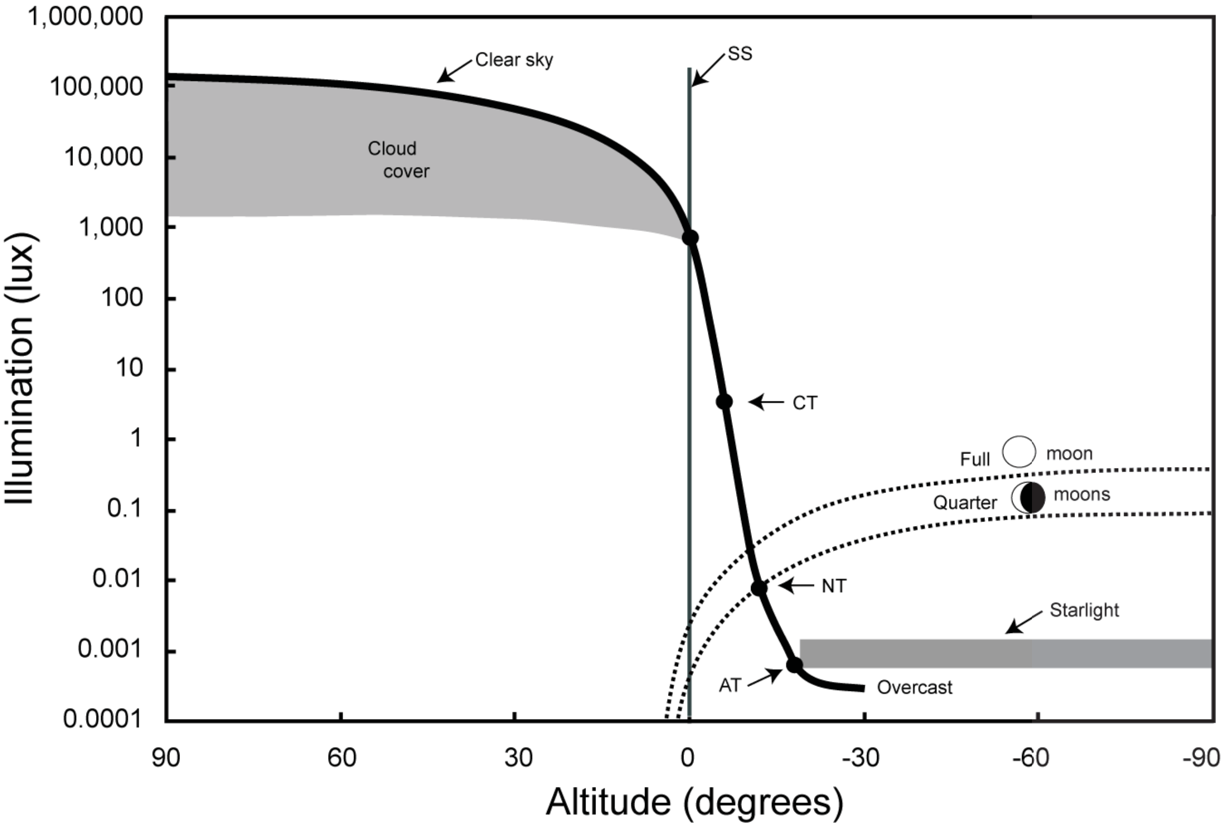

Figure 1. Natural horizontal illumination during the day, sunset, and at night (Beier 2006). Horizontal illumination on the y-axis; x-axis shows altitude above the horizon for the sun and moon. SS = sunset, CT = civil twilight, NT = nautical twilight, AT = astronomical twilight. Modified with permission from Beier (2006).

Light falling on a surface is often measured in lux, a unit of illuminance that sums electromagnetic energy after filtering in accordance with the daytime (photopic) sensitivity of the human eye. Light emitted from a source is often measured in lumens, a unit of luminance that also accounts for the photopic spectral sensitivity of the human eye. Measurements of lux and lumens place more weight on wavelengths to which the human eye responds most strongly, and less on those wavelengths to which the human eye is less sensitive. Similar measurements can be customized for the optic spectral sensitivities of different species by re-weighting the calculations to emphasize different wavelengths of light (Gal et al. 1999 and **Figure 2**).

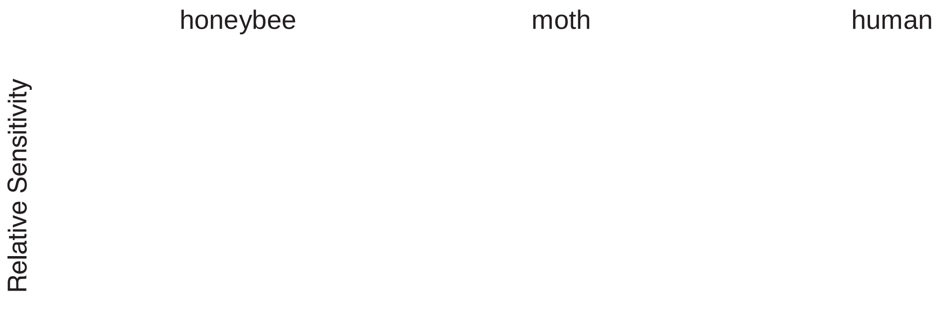

Figure 2. Relative sensitivity to light across the visual spectrum for honeybees (Menzel and Greggers 1985), moths (Cleve 1964), and human photopic vision (CIE 1932).

Outdoor illumination during the day ranges from 100,000 lux in full sunlight to 1,000 lux on a cloudy day (**Figure 1**). Dusk and dawn are transitions into and out of much darker conditions. These transitions are also characterized by predictable changes in the relative intensities of the wavelengths of light. As dusk falls, blue light increases, especially when the moon is new or not present. With moonlight, this blue pulse is diminished or absent and moonlight itself is red-shifted relative to sunlight (Sweeney et al. 2011). Both airglow and zodiacal light also contain more red light than daylight. Variations in illuminance and color trigger many behavioral and physiological processes (Sweeney et al. 2011, Walmsley et al. 2015). Circadian, circannual, and circalunar rhythms are linked to the predictable changes in the light environment. Light triggers can be at different illuminations depending on the environment. What is extraordinarily dim in one environment may be bright in another. For example, the illumination at which activity takes place on a forest floor is on average dimmer than illumination levels triggering the same activity for similar organisms in open grassland. Illumination that is within the natural range of variation on a beach may be far brighter than anything experienced at night at ground level in a dense forest.

Life evolved with predictable daily, monthly, and seasonal patterns of light and dark, and these patterns underlie the natural rhythms of nearly all living organisms. Artificial night lighting has long been known to affect these patterns. Nocturnal species, which represent the majority of some major taxonomic groups (**Figure 3**), are obviously vulnerable, as are diurnal or crepuscular species whose behavioral niches can be distorted by lighting. Concern about adverse effects of lighting dates to descriptions of the “destruction” of birds at lighthouses in the late 1800s (Allen 1880) and even the first electric urban lighting (Kumlien 1888). Mortality of hatchling sea turtles at lights was identified as a conservation issue in the 1960s (McFarlane 1963). Verheijen coined the term *photopollution* in 1985 (Verheijen 1985), which was followed by Ken Frank’s classic review of the effects of lighting on moths (Frank 1988), and a series of unpublished reports (Outen 1998), conference proceedings (Schmiedel 2001), and research reports from Europe (De Molenaar et al. 2000, Kolligs 2000). In 2004, we described *ecological light pollution* as “artificial light that alters the natural patterns of light and dark in ecosystems” (Longcore and Rich 2004).

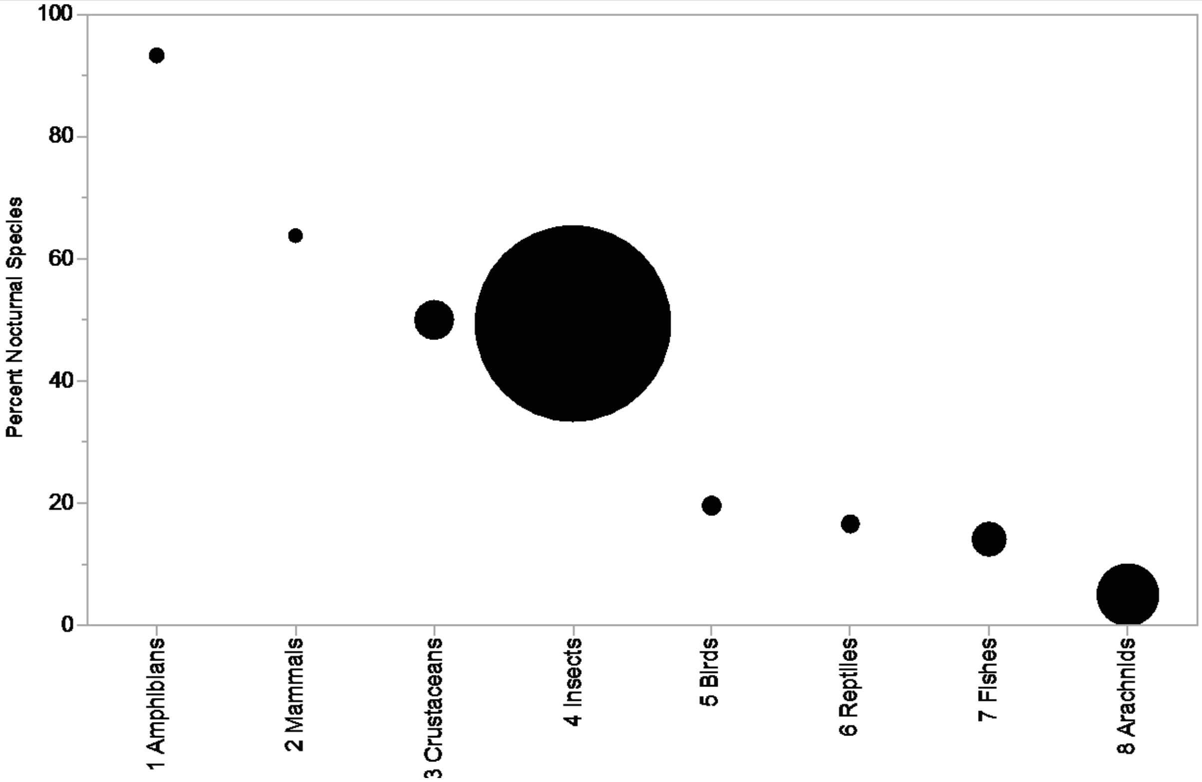

Figure 3. Proportion of major animal groups that are nocturnal. Area of markers is proportional to the number of species known in the group. Data from Hölker et al*.* (2010).

The disruptions caused by artificial night lighting occur whenever the natural patterns of light and dark are changed. This means that very low lighting levels (far below that of the full moon) can have important effects.

Reviews of the effects of artificial night lighting on different taxonomic groups can be found in Rich and Longcore (2006). Resource managers dealing with questions about specific groups of organisms should consult this source, which contains chapters on mammals, birds, reptiles and amphibians, fishes, invertebrates, and plants. Taxonomically specific information is essential to devise lighting systems that minimize impacts on sensitive species when lighting is necessary. Sensitive species should be identified relative to a specific area and might include both those species that have a formal designation as being threatened or endangered or any species of concern that would be sensitive to changes in nocturnal illumination. Nocturnal, crepuscular, and diurnal species can be affected by nighttime lighting conditions.

In the sections that follow, we present short reviews of the effects of artificial night lighting in different habitat types.

Coastal dunes, beaches, and shorelines

Coastal dunes and beaches are generally open environments with low vegetation adapted to moving sand (**Figure 4**). Dunes present unique environmental conditions that are often quite distinct from their surroundings, and they are often populated by endemic species that thrive in these unique conditions. Coastal endemic species are often a focus of management concern because of the development pressure on coastal ecosystems in the United States (Schlacher et al. 2007a). Dunes are also ecological transition zones between land and water; light from development in coastal dunes illuminates adjacent water bodies, and animals such as turtles move from water to land to nest. Shorelines are essential for organisms such as amphibians and aquatic insects that have biphasic life cycles.

Figure 4. Beach environments are vulnerable to the effects of anthropogenic light because of their open nature. Hatchling sea turtles are easily disoriented by onshore lights or sky glow and patterns of nocturnal foraging by shorebirds are also affected.

On a beach or coast under natural conditions, the view toward the land is almost always darker than the view toward the water. This is a function of landward vegetation and topography blocking light from the sky (Salmon 2006), in addition to moonlight and starlight reflected off the water. Organisms can use this pattern for orientation. Artificial lighting on the shore or from cities and other coastal development can reverse the natural conditions; the landward horizon becomes brighter, while the water is darker (Salmon 2006).

Stray light and sky glow from coastal development spread across and into many dune and shoreline environments. As in many environments, nocturnal activity near shorelines is significant (Salmon 2006). Beaches and coasts also regularly experience foggy and high-aerosol conditions, which scatter light and thereby amplify the local effects of lights (Kyba et al. 2011).

Artificial lighting has adverse consequences for sea turtles because the darkest horizon is no longer the landward horizon. Indeed, the lethal effects of lights on sea turtles have led to increased awareness of the adverse effects of artificial night lighting in general. Female sea turtles avoid illuminated beaches as nest sites, and hatchings are fatally affected by lights visible from beaches (Salmon 2003, 2006). This phenomenon was first recorded by MacFarlane (1963), and aversion of females to lights was confirmed experimentally by Witherington (1992). Habitat degradation by lights is caused both by lights adjacent to dunes and beaches and by regional sky glow (Salmon 2006).

As a general rule, additional light — whether moonlight or anthropogenic light — increases foraging efficiency of predators and reduces activity of prey (Longcore and Rich 2004, Rich and Longcore 2006, Seligmann et al. 2007). This phenomenon has been shown many times in different habitats. On dunes, Bird et al. (2004) investigated the effects of lighting on foraging behavior of beach mice. Bird et al. (2004) used low-pressure sodium lights and yellow incandescent “bug” lights, which are commonly employed on beaches in Florida because they have limited effects on sea turtle hatchlings. They found that foraging by beach mice was significantly decreased in proximity to both types of turtle-friendly lights. Similar behavior by prey species has been shown for both natural and anthropogenic light. For example, ghost crabs are active only at night, and avoid activity under both the full moon (Schlacher et al. 2007b) and artificial light (Christoffers 1986). The exception to this pattern is that prey species that flock or school together can be aided by additional light that facilitates communal vigilance (Nightingale et al. 2006).

Effects from lights on beaches and shorelines may also affect aquatic ecosystems. For example, lights affect the predator–prey dynamics of fishes and marine mammals (Hobson 1965, Hobson et al. 1981, Yurk and Trites 2000, Nightingale et al. 2006).

Shorebirds sometimes forage at night (Dugan 1981, Burger and Gochfeld 1991, Rohweder and Baverstock 1996). Various explanations have been proposed: as a defense against predation (Robert et al. 1989, McNeil et al. 1992, Thibault and McNeil 1994), as a result of slightly higher invertebrate activity on beaches at night (Dugan 1981, Evans 1987), and as a response to visual cues that are available due to higher levels of natural or anthropogenic light (Dwyer et al. 2012). Predator defenses of shorebirds are different during the night compared with the day; in an observational study, some proportion of Dunlins freeze and limit vocalizations as a defense at night while all individuals in a flock fly away in response to predators during the day (Mouritsen 1992). Owls are the major nocturnal predator of shorebirds and are aided by additional light when foraging (Clarke 1983). Timing of foraging by shorebirds, therefore, probably depends on tradeoffs between risks of becoming prey with ability to detect their own prey. Whether birds are flocking and have sufficient light for the associated communal predator vigilance probably also interacts with these factors.

Artificial night lighting on dunes and beaches can therefore have a variety of effects on species. Predator–prey relations are disrupted and key reproductive behaviors can be inhibited. Beaches and dunes also provide a gateway to adjacent water bodies, which have no barriers to block the propagation of light. Because there is usually less anthropogenic light at beaches and on shorelines than in surrounding urban or suburban areas, park visitors often use beaches and dunes to gaze at the night sky. Beaches and dunes should be kept as free from the influence of artificial lights as possible, with special attention paid to ensuring that any lights installed are absolutely necessary and that no lights are directly visible from the beach and points offshore.

Deserts and scrublands

Deserts and scrublands are open habitats with few barriers to the spread of light (**Figure 5**). Many animal species in hot deserts and scrublands adopt nocturnal behaviors to conserve water and avoid daytime temperature maxima. This shift to nocturnal activity may increase seasonally with higher temperature (Kronfeld-Schor and Dayan 2008). Consequently, artificial night lighting has the potential to change the ecology of these environments by disrupting the natural patterns of light and dark relied upon by a large proportion of fauna.

Desert animals can have narrow preferences for illumination levels. These preferences may be related to foraging opportunities, predation risk, or physiological requirements. For example, *Leucorchestris arenicola*, a trapdoor spider endemic to the Namib Desert, exhibits exclusively nocturnal activity patterns (Nørgaard et al. 2006). Males are active only during dark moonless nights, when they are able to navigate hundreds of meters across dune environments using only faint ambient light from stars, airglow, and zodiacal light (Nørgaard et al. 2006). For a species such as this, addition of illumination from any source in its habitat would eliminate its preferred habitat conditions.

Desert rodents also exhibit specific illumination preferences to manage their risk of becoming prey (Grigione and Mrykalo 2004, Beier 2006). Some species are active at twilight, others after twilight, and some during the darkest periods of moonless nights (Grigione and Mrykalo 2004, Upham and Hafner 2013). Anthropogenic light can disrupt these patterns; even the light from a camp lantern equivalent to a quarter moon (~10^{-2} lux) was sufficient to substantially inhibit foraging by a suite of rodent species (Kotler 1984). Those species vulnerable to this disruption lack other predator avoidance abilities such as exceptional hearing (Kotler 1984, Kotler 1985). Because many desert animals exhibit circalunar patterns in their activities, especially predaceous arthropods such as scorpions (Skutelsky 1996, Tigar and Osborne 1999) and granivorous small mammals (Price et al. 1984, Daly et al. 1992, Upham and Hafner 2013), it follows that any artificial light that produces light equivalent to even a quarter moon can alter these patterns.

Figure 5. Lights in desert scrublands are visible for long distances and night lighting affects a disproportionate fraction of the wildlife because high daytime temperatures induce nocturnal activity patterns.

Scrubland environments share many characteristics with deserts, especially in Mediterranean climates. A disproportionate number of species is nocturnal at high temperatures, and the open vegetation structure of drier scrublands allows for light to propagate for unusually long distances.

Perry and Fisher (2006) describe the decline of nocturnal snake species in the scrublands of southern California. Long-nosed snake (*Rhinocheilus lecontei*), a nocturnal species, showed a pattern of decline consistent with the gradient of light pollution as estimated by satellite imagery (Fisher and Case, unpub. data). Otherwise suitable scrub habitats, which supported other diurnal species of snakes, lacked long-nosed snakes. The authors hypothesized that decreases in numbers of the snake's small-mammal prey, also associated with light pollution, were responsible for the decline (Perry and Fisher 2006).

Wetlands and rivers

In some places, wetlands and lakes are the last refuges of a natural night on the landscape (**Figure 6**). The difficulty of developing wetlands often leaves them as the only remaining unlighted sites in urban and suburban regions. Many aquatic organisms depend on daily cycles of light and dark and artificial lights disrupt critical behaviors in many species (Moore et al. 2006, Perkin et al. 2011, Henn et al. 2014).

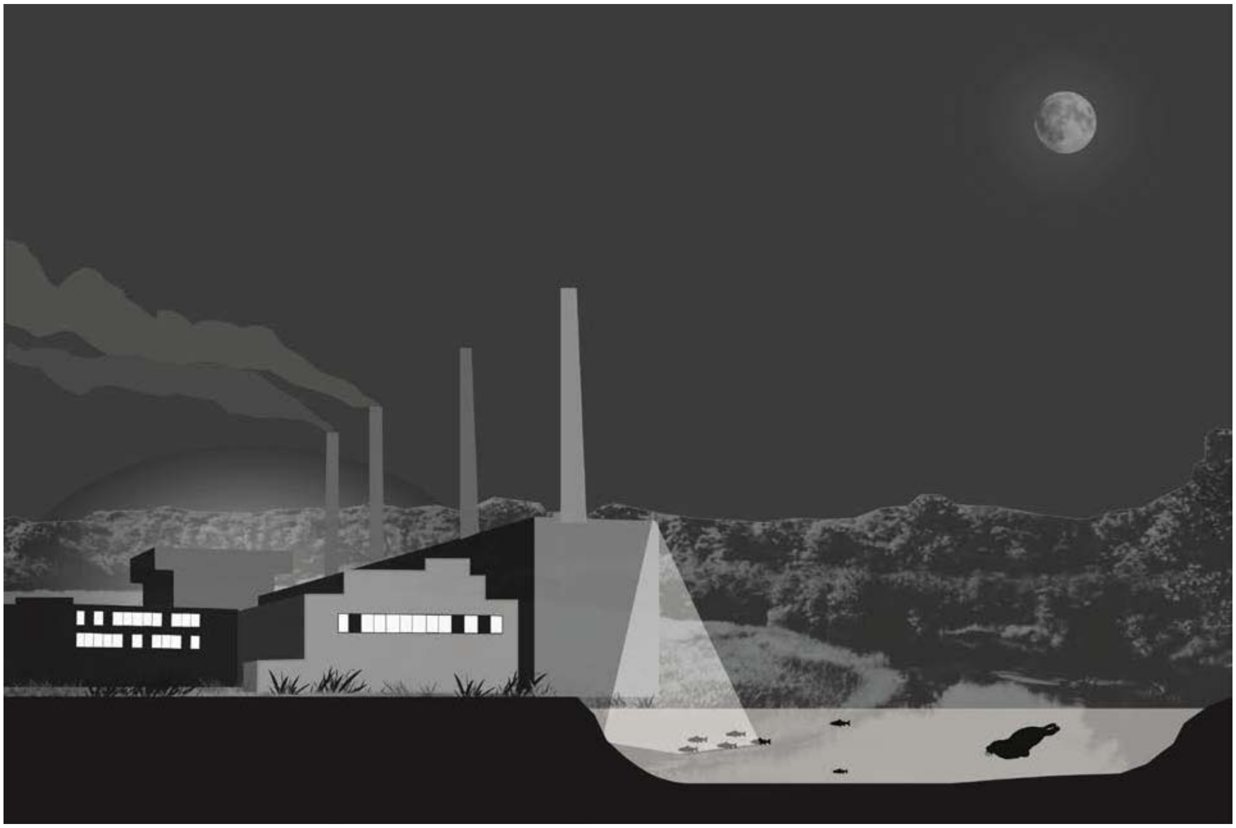

Figure 6. Lights along rivers and streams can disrupt predator–prey interactions, such as seals hunting salmon under lights.

Wetlands are often geographically fragmented, occurring as isolated patches or as linear features stretching across the landscape. Linear features are susceptible to disturbances such as artificial night lighting because they have a high edge-to-area ratio. They also tend to induce development along their edges, which leads to lighting from urban development on either side. Similarly, small wetlands are especially vulnerable to disturbances from their surroundings.

Aquatic invertebrates are important components of wetland ecosystems and provide an example of the sensitivity of wetlands to lighting levels (**Figure 7**). Many aquatic invertebrates migrate up and down in wetlands during the course of a night and day. This "diel vertical migration" presumably results from a need to avoid predation during lighted conditions so many zooplankton forage near water surfaces only during dark conditions. Light dimmer than that of a half moon ($<10^{-1}$ lux) is sufficient to influence the vertical distribution of aquatic invertebrates, and indeed diel vertical migration follows a lunar cycle. When constant light from human development is added to the natural nocturnal illumination of the moon and stars, the darkest conditions are never experienced, and the magnitude of diel migrations (both range of vertical movement and number of individuals migrating) is decreased, which has been shown experimentally for *Daphnia* (Moore et al. 2000). Disruption of diel vertical migration by artificial lighting may have significant detrimental effects on ecosystem health. Moore et al. (2000) conclude that "[decreases in] vertical migration of lake grazers may contribute to enhanced concentrations of algae in both urban lakes and coastal waters. This condition, in turn, often results in deterioration of water quality (i.e. low dissolved oxygen, toxicity, and odor problems).”

Figure 7. Light in wetlands can suppress diel vertical migration of zooplankton and influence foraging behavior of amphibians.

Amphibians found in nearshore and wetland habitats also are particularly vulnerable to artificial lighting. Amphibians are highly sensitive to light and can perceive increases in illumination that are impossible for humans to detect (Hailman and Jaeger 1976). A rapid increase in illumination causes a temporary reduction in visual acuity, from which the recovery time may be minutes to hours (Buchanan 1993, Buchanan 2006). In this manner, a simple flash of headlights can arrest activity of a frog for hours (Perry et al. 2008). Amphibians are also sensitive to changes in ambient illumination from sky glow. Frogs in an experimental enclosure ceased mating activity during night football games when lights from a nearby stadium increased sky glow (Buchanan 2006). In an experiment to investigate the effects of intermittent artificial light, male green frogs called less and moved more when exposed to the light of a handheld flashlight (Baker and Richardson 2006).

In naturally lit environments, some amphibians will forage only at extremely low light levels, and foraging times are partitioned among species with different lighting level preferences (Jaeger and Hailman 1976). The squirrel tree frog (*Hyla squirrela*) orients and forages at lighting levels as low as 10^{-6} lux and stops foraging at illumination above 10^{-3} lux (Buchanan 1998). The western toad (*Bufo* *boreas*) forages only at illuminations between 10^{-1} and 10^{-5} lux, while the tailed frog (*Ascaphus truei*) forages only during the darkest part of the night below 10^{-5} lux (Hailman 1984).

Laboratory experiments indicate that the development of amphibians is influenced by artificial light (Wise and Buchanan 2006, Wise 2007). Light interferes with the production of the hormone melatonin, which is involved in regulating many important functions, including sexual development, thermoregulation, adaptation of eyes to the dark, and skin coloration (Wise and Buchanan 2006, Wise 2007). Current research shows that artificial lighting slows larval amphibian development in the laboratory (**Figure 8**). The influence of artificial lighting on such physiological processes in the field is currently not well known, but the potential for lighting to harm amphibians and other wetland species is evident.

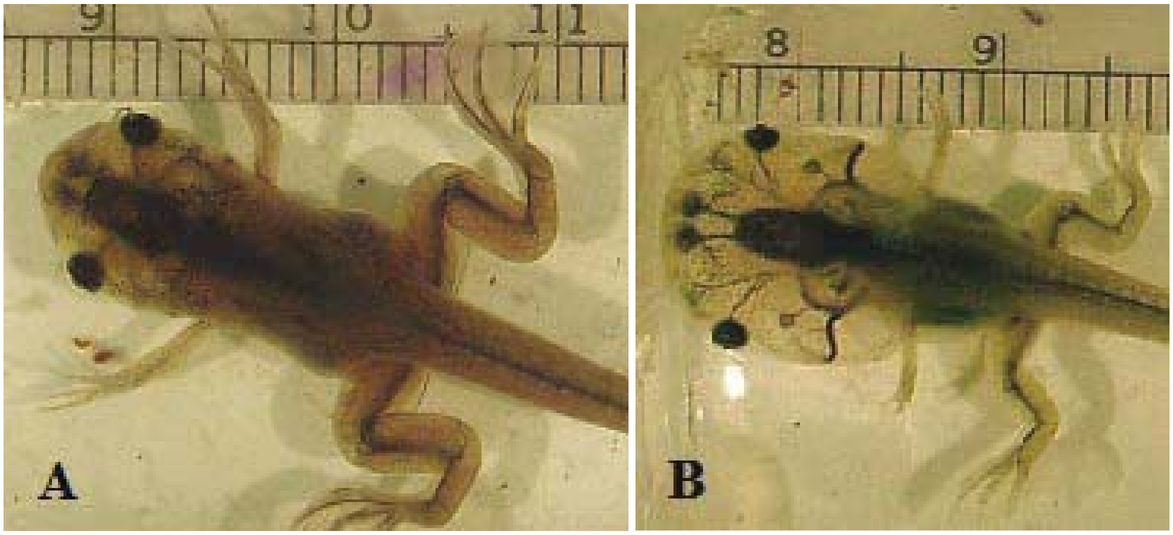

Figure 8. Two tadpoles of the same age and kept in 12:12 L:D lighting. (A) was kept in the equivalent of very dark night (10^{-4} lux) in the dark phase, while (B) was exposed to artificially bright illumination in the dark phase and is not yet metamorphosing (reprinted from Wise 2007).

Fishes are also highly attuned to natural ambient light conditions, with lighting levels influencing the distribution of predaceous species and the foraging behavior of their prey (Nightingale et al. 2006, Becker et al. 2013). Laboratory experiments have shown that the timing of downstream migration of salmon (*Salmo salar*) fry is significantly delayed and disrupted by lights of a similar illumination and spectrum as streetlights (Riley et al. 2013). Nocturnal downstream drift of insects is also delayed by artificial lighting (Henn et al. 2014).

Islands, oceans, and reefs

Light propagates unimpeded across open water, and its reach is extended beyond the curvature of the Earth by reflection off high clouds. Fog can increase local impacts of bright lights. Although light shining directly down on water tends to penetrate rather than reflect, light coming in at an angle is reflected. This physical property of water exacerbates the effects of coastal lighting as it is reflected and propagates out from the shoreline. Island, ocean, and reef environments are affected by artificial light sources that range from light-assisted fishing to urban sky glow to offshore hydrocarbon facilities (Davies et al. 2014) (**Figure 9**).

Figure 9. Cruise ships and squid boats are just two of the sources of artificial lighting on the oceans that attract seabirds and migrating songbirds.

In 1999, Xantus's murrelets (*Synthliboramphus hypoleucus*) nesting on Santa Barbara Island, part of Channel Islands National Park off the coast of southern California, were dying at twice the average annual rate. Park managers suspected this increase in mortality was directly related to a recent increase in fishing boats equipped with dusk-to-dawn floodlights to attract squid. Squid boats typically have 30,000 watts of light per boat. The number of squid boats increased dramatically in the 1990s, and in 1999 intense squid fishing occurred during murrelet nesting season (spring, while historically fishing was during fall and winter), and near important murrelet breeding islands. Managers believed that the nesting seabirds, without the safety of darkness, were subject to increased predation, especially from barn owls (*Tyto alba*). During the 1999 season, an unprecedented 165 dead Xantus's murrelets were found on Santa Barbara Island. Most of the dead were killed by barn owls, while five were victims of western gulls (*Larus occidentalis*). Researchers also recorded high nest abandonment closest to the most intensive squid boat activity. Faced with these observations, managers closed the areas around the islands to squid fishing, and death rates for the birds returned to normal. The excluded areas were subsequently incorporated into a permanent marine preserve with no fishing allowed to allow for replenishment of fish stocks. Also, the California Fish and Game

Commission listed Xantus's murrelet under the California Endangered Species Act, citing artificial night lighting as one of the major threats to the species.

Nearly all seabirds are nocturnal, and an adverse response to decidedly unnatural conditions such as those suffered by Xantus's murrelets should not be surprising (Montevecchi 2006). Years of studies have shown that nocturnal seabirds are less active during moonlit nights, and those that are active suffer more predation during those times. Seabird chicks are directly affected by lighting levels; they are far less likely to be fed by adults during bright nights (Riou and Hamer 2008). Seabirds are attracted to lights perhaps because they naturally cue in on bioluminescent plankton to find prey (Montevecchi 2006). They have, therefore, long suffered from collisions with light sources on and adjacent to the ocean, including lighthouses, cruise ships, fishing vessels, lighted buoys, oil derricks, and streetlights on and near islands where they nest (Rodríguez and Rodríguez 2009, Rodrigues et al. 2012, Wilhelm et al. 2013); many of these collisions are fatal. Where lights correspond with critical habitat or high-use zones such as feeding or breeding areas, or migratory routes, the effects could be significant.

Other sources of artificial night lighting threaten the nighttime environment of the oceans. Cruise ships are pervasive, large, and are often brightly illuminated. Ships in the path of bird migrations, or near undersea food sources, may attract both migratory birds and foraging seabirds, which collide with the ships and can be stunned or killed. Anecdotal accounts have emerged where cruise ship staff frantically work to clear the decks of dead birds before passengers awake in the morning. Offshore hydrocarbon extraction platforms are also significant sources of light, and attract and kill birds through collision, exhaustion, and even by incineration in flares burning off natural gas. Many of these birds are long-distance migrants, and the losses at oil platforms may affect regional and global breeding populations.

Coral reefs are also threatened by artificial night lighting. Lighting has been used as a proxy for other impacts (urban development, intense fishing, hydrocarbon extraction) to assess risk to coral reefs on a global scale (Aubrecht et al. 2008). Aubrecht et al. (2008) also illustrated how artificial lighting would adversely impact reefs directly. Corals themselves are highly sensitive to light and synchronize spawning according to lunar cycles (Jokiel et al. 1985, Gorbunov and Falkowski 2002). Many coral reef species exhibit marked light-driven diel cycles or synchronize reproduction by monthly cycles (Sebens and DeRiemer 1977, Bentley et al. 2001, Levy et al. 2001). Predator–prey interactions are influenced by light levels, with diel vertical migration of both zooplankton (Yahel et al. 2005) and planktivorous fishes observed (Leis 1986). Natural light signals, such as bioluminescence, are important to marine organisms (Johnsen 2012), and can both attract and repel fishes (Holzman and Genin 2003, 2005). Artificial lighting at similar and greater intensity must affect a range of marine organisms. Experimental investigation has now confirmed that lighting affects the colonization of marine invertebrates on surfaces (Davies et al. 2015).

Grasslands

Like other open habitats, light has few barriers in grasslands (**Figure 10**). Lights can thereby influence both illumination and direct glare over hundreds of meters or more, depending on topography. Artificial night lighting can be expected to influence habitat use and behavior of grassland species.

The lights of a road bisecting wet grassland in the Netherlands were shown to influence the spatial distribution of black-tailed godwit (*Limosa limosa*), a rare ground-nesting bird (De Molenaar et al. 2000, De Molenaar et al. 2006). When road lights were turned on during a breeding season, the birds nested slightly farther away from the road, with the effect extending 300 m (984 ft) from the lights. Birds that arrived first to the breeding area nested farther from the lights while those arriving later nested closer (De Molenaar et al. 2000, De Molenaar et al. 2006). The same research group investigated the behavior of mammals in wet grasslands and showed that some species (polecat, *Mustela putorius*, stout, *Mustela erminea*, weasel, *Mustela nivalis*, and fox, *Vulpes vulpes*) were more likely to take paths near lights, while other species were not influenced or preferred darker areas (De Molenaar et al. 2003). Such differences in habitat use have the potential to change predation rates and distribution of prey species as well (Lima 1998).

Figure 10. Grasslands are vulnerable to disruption from even distant lights because of their open character. Fireflies, often found in wet grasslands, can have their signals disrupted or be excluded by high illumination, while some grassland bird species, such as black-tailed godwit (*Limosa limosa*), have been shown to avoid streetlights in selecting nest sites (De Molenaar et al. 2006).

Fireflies are another group of grassland species that can be adversely affected by artificial night lighting (Lloyd 2006). Because light is used for firefly communication, both for sexual behavior and in some interspecific interactions (where females attract males of other species to capture and eat them), any disruption of the ability to see light will have adverse effects. Artificial light washes out the signals used for communication and is potentially contributing to the decline of fireflies and other organisms that rely on bioluminescent communication (Lloyd 2006, Hagen and Viviani 2009, Bird and Parker 2014).

Deciduous and evergreen forests

Although the structural complexity of forests blocks light and reduces its propagation, species that inhabit the forest floor are sensitive to illumination at levels appropriate to the darker nighttime environment there (**Figure 11**). A review of the research on forest species shows some general patterns that illustrate the potential for lights to affect wildlife behavior.

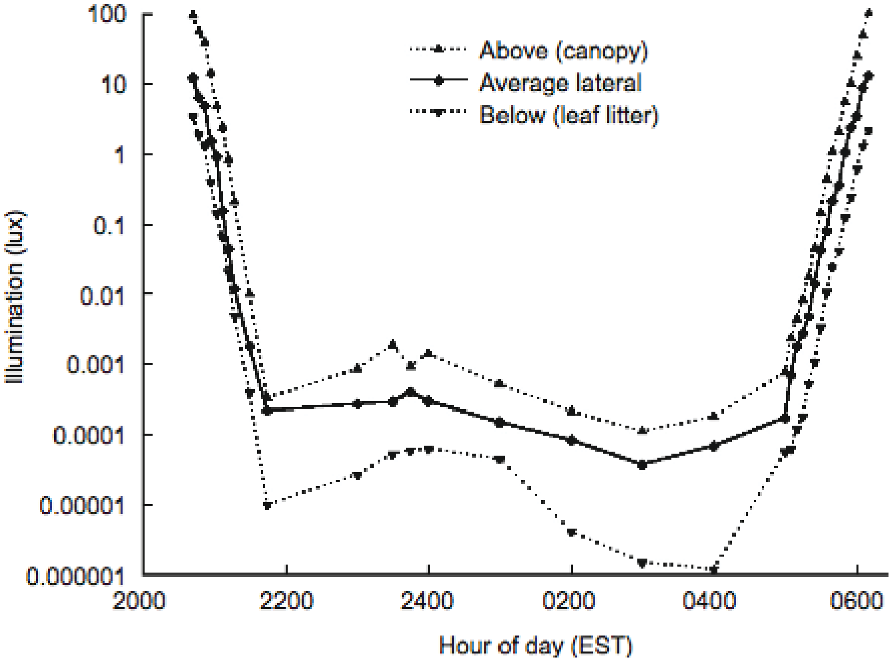

Figure 11. Illumination in deciduous forest (Buchanan 2006). Reprinted with permission.

As in many other ecosystems, salamanders in forests exhibit reactions to light equivalent to moonlight, under which foraging is reduced or delayed (Wise 2007) (**Figure 12**). This has been shown experimentally with dim artificial lights installed in a forest environment (Wise 2007). In two different experiments, lighting delayed the emergence time of nocturnal mammals (DeCoursey 1986, Barber-Meyer 2007) and reduced foraging activity (Barber-Meyer 2007). For sugar gliders, a nocturnal forest mammal native to Australia, light equivalent to that produced by streetlights (7–12 lux) reduced the time individuals were active at night (Barber-Meyer 2007).

In other instances, reproductive behavior can be affected by artificial lighting. The leafcutter ant *Atta texana* usually undertakes nuptial flights approximately 15 minutes before dawn, but in instances where security lights from homes and businesses were visible, the colonies flew 15 minutes after dawn (Moser et al. 2004). This change in timing interferes with behaviors that are carefully synchronized across colonies. Furthermore, artificial lights are also attractive to the flying ants and, as a result, may both decrease mating success and increase predation at the lights (Moser et al. 2004).

Figure 12. Species of the deciduous forest are adapted to the lower light levels found under the canopy. Flying squirrels and salamanders will delay their foraging under artificial lights.

Alpine and tundra habitats

Alpine and tundra habitats are disproportionately represented in parks and other protected lands. They are on average less developed than other habitat types but can be, and are, developed for recreational and industrial infrastructure. Control of artificial lighting in alpine and tundra habitats is important to avoid disruptions of predator–prey interactions and to avoid disrupting annual rhythms that are entrained by day length.

The topography of mountainous habitats also makes them vulnerable to sky glow from distant sources (**Figure 13**). Because sky glow brightens horizons, areas of steep slopes are positioned to be exposed to that light. In these locations, the aspect of the slope becomes important. Those facing bright horizons will be substantially brighter than nearby locations facing a different direction and therefore will be exposed to far less artificial lighting.

As in other habitats, predator–prey interactions in alpine environments are mediated by illumination (**Figure 14**). For example, small mammals of rocky outcrops typical of alpine regions are often nocturnal, foraging in open areas at night and retreating to the safety of outcrops for shelter (Kramer and Birney 2001). In experimental conditions one such species, long-eared mouse (*Phyllotis xanthopygus*), foraged less under 1.5 and 3.0 lux treatments (up to very bright moonlight) when compared with a 0.0 lux control (Kramer and Birney 2001). Similar results have been found for snowshoe hares (Gilbert and Boutin 1991), which are subject to more predation under brighter nocturnal conditions, especially during the winter (Griffin et al. 2005). Such small mammals depend on natural darkness for foraging to keep up body weight (Vasquez 1994).

Figure 13. Alpine habitats can be affected by distant lights and those from recreational and industrial facilities.

Circannual rhythms are found in most animals, but the environmental conditions that influence them are less well understood because of the long period necessary to conduct experimental research (Beier 2006). Light appears to have a large influence in setting these cycles, although temperature is also important (Beier 2006). Light can be important in determining when species react to the seasons (e.g., hibernation, Hock 1955), and consequently disrupting these signals has the potential to put species out of phase with climate. In alpine and tundra environments, where conditions change so dramatically between the seasons, appropriate synchronization of activities is important. For example, reindeer (*Rangifer tarandus*) eyes change seasonally to reflect different wavelengths of light; color of the tapetum lucidum shifts from yellow in the summer to blue in the winter, which is associated with increased retinal sensitivity during the dark winter nights (Stokkan et al. 2013). Captive reindeer exposed to sodium vapor streetlights, not directly visible but just over the horizon, are reported to have green eyes in the winter, not completing the normal transition from yellow to blue, and with reduced visual sensitivity (Yong 2013).

Figure 14. Predator–prey interactions are affected by artificial lights during long nights on the tundra.

Urban environments

Even though urban environments have many sources of artificial lighting at night, variations within already light-polluted environments still make a difference to wildlife (**Figure 15**). For example, American crows (*Corvus brachyrhynchos*) choose roost sites in urban areas that are on average more brightly illuminated than non-roost sites (Gorenzel and Salmon 1995). Presumably, this allows the communal predator response behaviors of the flock to operate more efficiently, reducing predation from owls. Elevated populations of this native species have adverse consequences for other native species for which the crows are predators. In another example, urban-tolerant bat species are influenced by the degree of illumination on the exit hole of their roosts. Nightly emergence is delayed by illumination of the exit hole, which reduces fitness of individuals in the colony and can eliminate the colony altogether (Boldogh et al. 2007). Because of the importance of bats as consumers of insects, and their conservation status, the adverse impacts of lighting are concerning (Stone et al. 2015).

Cities are also sites of mortality for nocturnally migrating birds, which are attracted to lights. Birds die either in collisions with buildings at night, or during the day when they attempt to regain their orientation and continue migration. This phenomenon is well documented in Chicago, Toronto, New York, and Washington, D.C. A notable example in a national park is the ongoing mortality of nocturnal migrant birds at the Washington Monument, which started when it was illuminated (Overing 1938).

The profusion of light in urban areas also has spillover effects on surrounding natural areas and open spaces within cities. For example, extremely high levels of ambient light are measured in the Santa Monica Mountains National Recreation Area near Los Angeles, with all-sky brightness exceeding natural levels by 18.4 times and maximum nocturnal vertical illuminance 32.4 times brighter than natural levels (J. White and C. Moore, pers. comm.). Although it is difficult to address the multitude of sources of light, it is worthwhile for parks to incorporate lighting and the night sky as part of their education, outreach, and engagement in communities adjacent to and near parks (Aubé and Roby 2014).

Figure 15. Cities are affected by altered light environments, which are exploited by synanthropic species such as crows and some bat species.

The evidence from across habitat types indicates that artificial lighting at night is either proven to, or has the potential to, disrupt the natural behavior of wildlife species, sometimes with lethal consequences. From this context we can identify practices that can reduce and minimize the effects of lighting in parks and other lands managed for natural resource values.

Mitigating the Effects of Lighting on Protected Lands

Knowledge about the effects of lighting on wildlife continues to grow. All indications are that lighting can have cumulative and additive consequences that are especially important for vulnerable species. Many general approaches to minimizing the effects of artificial lighting on wildlife are known. To reduce effects on certain target species, these mitigations may need to be adapted to craft desirable solutions for specific locations. In the following two sections, considerations for developing such mitigation measures are discussed. First we introduce the attributes of nighttime lighting that might be manipulated — spectrum, intensity, direction, and duration — and how different groups of species might be affected by them. Then we review the many contexts in which light is used (e.g., security lighting, vanity lighting, communication towers) and identify preferred mitigation strategies for them.

Approaches to minimize lighting impacts

The impacts of artificial lighting to wildlife can be reduced in five ways: 1) avoiding use of lighting that is not needed, 2) controlling color spectrum, 3) limiting light intensity, 4) managing the direction of light emissions, and 5) limiting the duration of light output. For some of these characteristics, a single approach applies in all instances. For others, the recommendation depends upon the context of use or the species that might be affected. A combination of mitigation approaches is likely to be more effective (e.g., reducing intensity and adjusting color spectrum) than would be any approach taken individually.

Need

The first question that should be asked about artificial lighting, especially in natural areas, is whether it is in fact needed. In some situations, a creative solution, such as the choice of a pale color for a pathway, curb, or steps, is all that is needed to guide visitors (**Figure 16**). In others, lighting can be left to the visitor to provide in the form of headlights or a flashlight. Only when the need is demonstrated and necessary for visitor experience, safety, or security, should lights be installed.

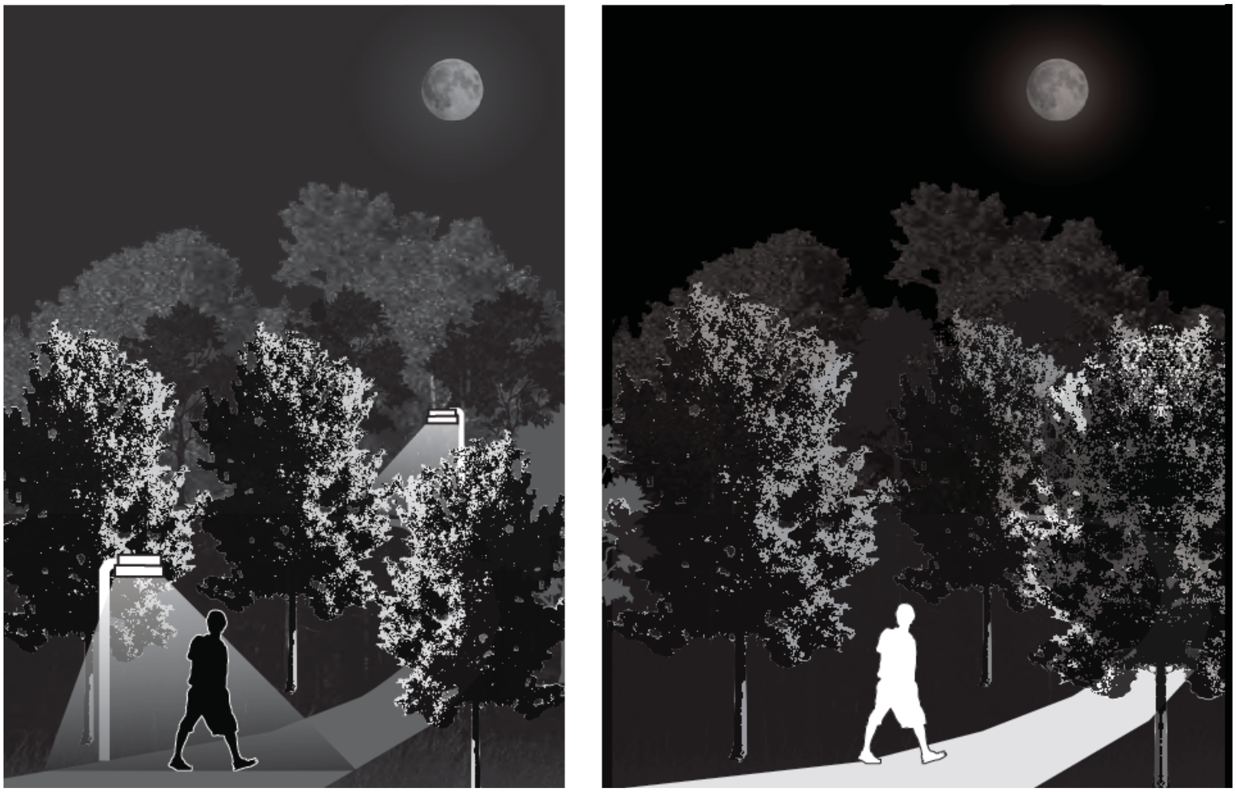

Figure 16. A pale-colored path can be just as effective as electric lights in some park situations.

Spectrum

It is tempting to believe that a certain spectrum of light will minimize the effects of lighting in all situations. Unfortunately, no universal solution exists. Rather, it is possible to identify spectra of light that have shown to affect wildlife less in certain contexts. The only 100% wildlife-friendly light is one that is switched off or never installed.

The higher efficiency of high-pressure and low-pressure sodium lamps resulted in their widespread adoption in street lighting applications and security lighting, replacing the older mercury vapor lamp technology. Recently, however, full-spectrum light sources such as metal halide lamps, compact fluorescent lamps, and LEDs are becoming more common (Gaston 2013). Full-spectrum lights appear white, in contrast with other lights such as sodium vapor lamps that appear yellow or orange. Earlier technologies, such as mercury vapor lamps, were also full-spectrum, but have largely been replaced by sodium vapor lamps. LEDs are more efficient than older lamps used for outdoor lighting, and have greater color rendition than sodium vapor light sources. This return to white light sources brings certain advantages for human use, but includes a wider range of wavelengths, potentially impacting more species (Stone et al. 2012) and exacerbating sky glow (Aubé et al. 2013).

The combination of colors that make up a full-spectrum light is described by the correlated color temperature (CCT) of the light. CCT is measured in degrees Kelvin and corresponds to the appearance of light that would be emitted from an idealized “black body” if it were heated to that temperature. Lower CCTs are dominated by yellow and other longer wavelengths, while higher

CCTs are dominated by blue and other shorter wavelengths. For example, an incandescent bulb has a CCT of around 2400–2800 K, while a metal halide lamp has a CCT of 4000 K and direct sunlight 4800 K. LEDs are offered in many color temperatures, from 6500 K to 2700 K, and can also contain mixes of colors that do not have color temperatures associated with them (i.e., “off the black body curve”) and are measured in other ways. High-pressure sodium lamps have a CCT of around 1800 K and low-pressure sodium lamps, which are all yellow, do not have an associated color temperature.

One general rule is to avoid any light that has emissions in the ultraviolet spectrum and adjacent short wavelengths. Ultraviolet light is not visible to humans, yet is visible to other species. Insects are highly attracted to ultraviolet light and their attraction and mass death at lights would be dramatically reduced by eliminating ultraviolet light from general use (Frank 1988, Eisenbeis and Hassel 2000, Eisenbeis 2006, Frank 2006). Mercury vapor lamps are high in ultraviolet radiation, while other commonly used outdoor lamps (e.g., metal halide, fluorescent) have some ultraviolet as well. LEDs have no ultraviolet emissions and therefore attract fewer insects than lamps of comparable intensity and color temperature that do have some ultraviolet emissions (Poiani et al. 2015, Longcore et al. 2015).

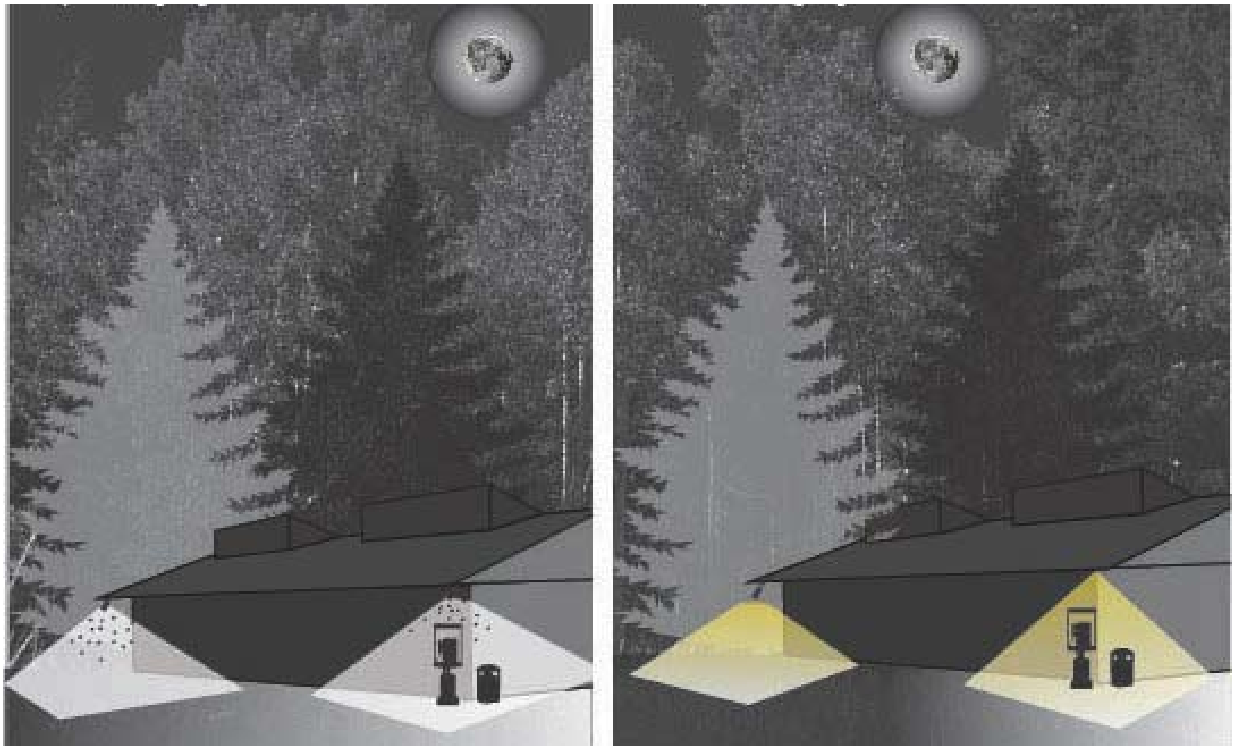

Figure 17. Yellow light that does not contain blue or ultraviolet wavelengths attracts far fewer insects.

Insects are also attracted to light in the short visible wavelengths (e.g., violet and blue) (**Figure 17**). Full-spectrum lighting that allows good color rendering for human vision is not advisable from the standpoint of ecological effects because it contains light in the blue spectrum (Eisenbeis and Eick 2011). All lights heavy in the blue portion of the spectrum, such as fluorescent lights, metal halide lights, and full-spectrum LED lights, will have greater impacts on insects than lights with longer wavelengths (e.g., low-pressure sodium vapor lamps or yellow/amber LEDs) (Eisenbeis and Eick 2011, Pawson and Bader 2014, Poiani et al. 2015, Longcore et al. 2015). If full-spectrum lighting is required, then the lowest possible color temperature is recommended (Longcore et al. 2015).

Blue light contains the most biologically active wavelengths for physiological processes such as the production of hormones and the timing of daily activities (Beier 2006, Brainard et al. 2015). This concern has been best expressed relative to human health (Pauley 2004, Brainard et al. 2015), but blue light also disrupts circadian rhythms in wildlife. To minimize disruption to circadian rhythms, shorter wavelengths such as blue and violet should be avoided. They might also be avoided to minimize influence on species that are phototactic to blue light, such as many frog species that have a blue light preference whereby they move toward blue light, presumably as an escape mechanism that leads them away from vegetation (and into water) in times of danger (Hailman and Jaeger 1974, Buchanan 2006); these preferences can vary depending on the intensity of illumination, however (Buchanan 2006).

Figure 18. Green lighting designed to minimize attraction of birds developed by Philips. Shell is using these lights on an oil platform in Alaska and Philips is adding the lights to its regular catalog. Photograph courtesy of Joop Marquenie.

Birds are able to orient to the Earth’s magnetic field under monochromatic blue or green light, but such navigational ability apparently does not function under lights that are only red or yellow. The molecular mechanism that allows detection of the Earth’s magnetic field requires light of a certain wavelength to be activated (Ritz et al. 2009), which presumably explains the inability of migratory birds to orient under light that lacks those wavelengths (Wiltschko et al. 1993, Wiltschko and Wiltschko 1995). Dutch researchers have experimented with the use of specially designed lamps that contain blue and green light at coastal locations and on offshore platforms to see if the number of attracted and disoriented birds is decreased (van de Laar 2007, Poot et al. 2008). Results show blue and green lights influence birds less than red and full-spectrum (white) light, although the effects on other species have not been documented in the scientific literature (**Figure 18**; **Figure 19**).

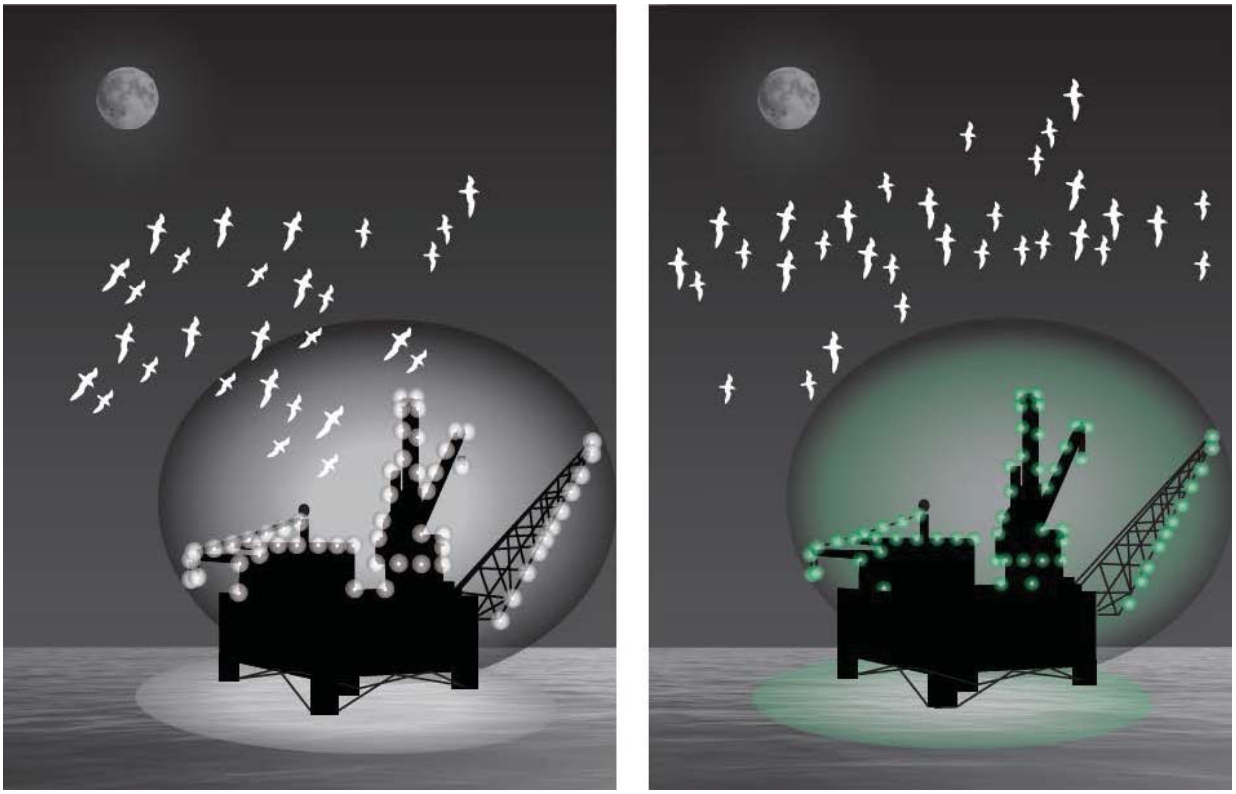

Figure 19. Green lights have been investigated for use on offshore structures and shown to be less attractive to birds.

In other situations, light that includes longer wavelengths appears to attract few insects and does not disrupt orientation of sea turtle hatchlings. For this reason, yellow lights are commonly identified as being wildlife-friendly (**Figure 17**). These same lights, however, reduce the foraging activity of native beach mice (some species of which are endangered) along the Florida coastlines where turtle-friendly lighting is recommended (Bird et al. 2004). Fireflies are vulnerable to impacts from yellow light because it is this part of the spectrum that is used by those species flying after dusk (Lloyd 2006).

Red light appears to disrupt the orientation capabilities of birds, but it seems to have the least effect on other species (**Figure 20**). Few insects are attracted to red light and dark-adapted eyes are not bleached by red light, making it the spectrum of choice for stargazers. In low-light environments in parks, red light might be preferable where lights are needed for safety reasons (**Figure 21**).

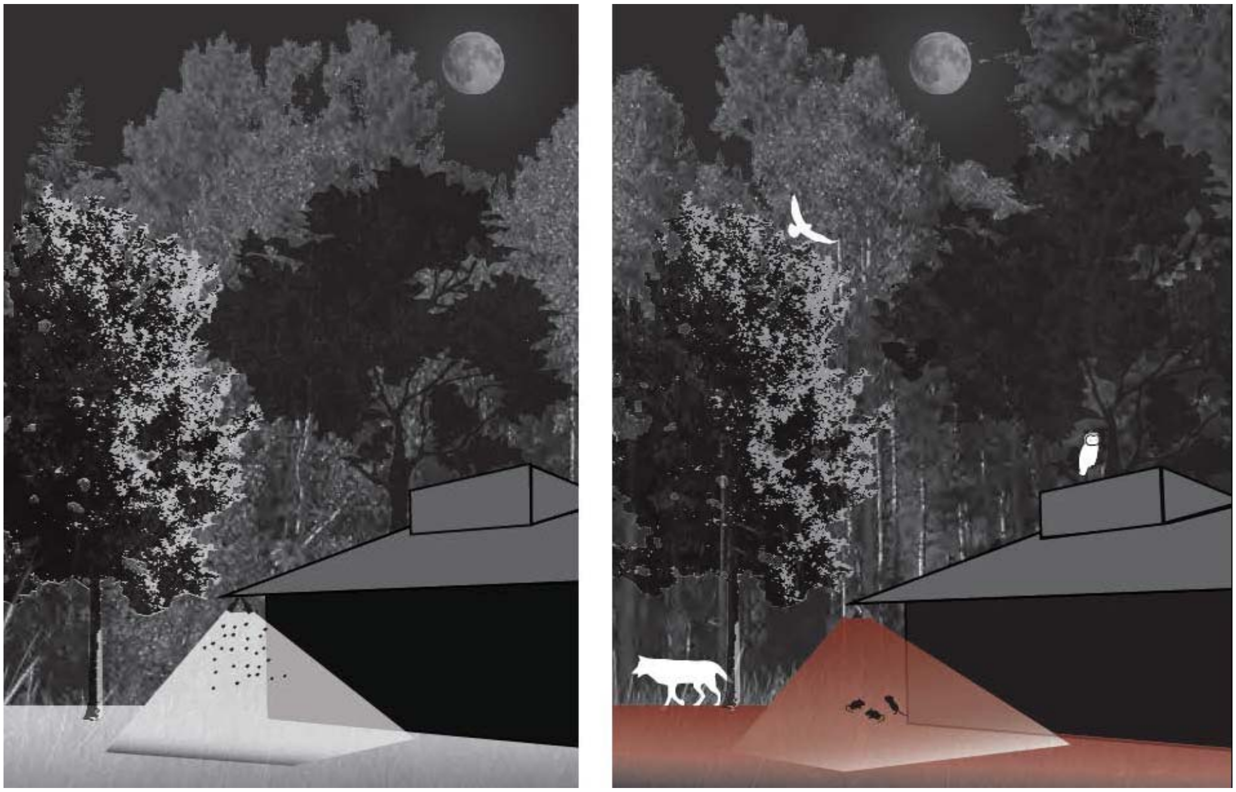

Figure 20. Red light does not disrupt dark-adapted vision and is therefore appropriate for campsites and locations used for astronomical observation.

Figure 21. Illumination of a stairway at a campground by two low-intensity red bulbs instead of by a bright white spotlight (Wagner et al. undated).

Through all the considerations for different taxa, a few general lessons emerge to guide use of spectrum: 1) the choice of color significantly affects the degree of biological disruption; 2) narrow-spectrum lights are preferable to broad-spectrum sources (i.e., white light); 3) ultraviolet light should be avoided; 4) blue and shorter wavelengths increase biological responses and generally should be avoided; and 5) concerns about individual species in an area may influence the choice of least disruptive color for lights.

Intensity

Land and facility managers have great latitude in selecting the intensity and quantity of lighting used. From a wildlife perspective, discretion should be exercised to use the minimum amount of light required. This can be accomplished by significantly decreasing the luminous output commonly specified by lighting designers. Land managers should not rely on standards promulgated by professional societies to guide lighting levels for natural areas because these are generally developed for urban/suburban areas with little to no regard for wildlife. Rather, every effort should be made to reduce the intensity of lights and still achieve the desired function.

Reduction in lighting intensity benefits species in the vicinity of lighting and also reduces the reflection of light in the atmosphere. The glow of lighted areas can thereby be reduced, decreasing impacts to natural systems and park visitor experience in wildlands. Often, illumination levels can be reduced without adverse consequence for human activity. In fact, reducing the contrast between light and dark areas increases the ability of humans to see. The human eye adapts to the brightest light in view. As the eye adapts to bright lights, acuity in darker areas is lost. Bright lights plunge the surrounding areas into dark shadows, while with dimmer lights the eye is able to retain some of its ability to see in darker areas.

Direction

Shielding lights is a common mitigation measure to reduce impacts to natural lands and species (**Figure 22**). Usually this involves shielding a fixture so that little or no light is emitted above the horizontal plane, and less than 10% of the light is emitted within ten degrees below the horizontal plane. This is the definition of a full cutoff lighting fixture. Shielding in this manner greatly reduces (but does not eliminate) sky glow. Light still reflects off the ground and scatters, so reduction in intensity should be combined with shielding. Downward-directed lights may still have adverse ecological consequences such as attracting insects and species that feed on the insects (e.g., bats, frogs, birds), or directing light into sensitive habitats such as wetlands and rivers.

Land managers should endeavor to shield lights beyond full cutoff to ensure that light falls only on the intended surfaces. Such mitigation will minimize direct glare, which can affect the orientation of organisms across distances (Reed et al. 1985, Telfer et al. 1987, Beier 1995, Longcore and Rich 2004); this will also minimize the area that is artificially illuminated. Design solutions to achieve these goals include the use of embedded lights to illuminate important surfaces (**Figure 23**) and simple retrofits to shield existing lights (**Figure 24**).

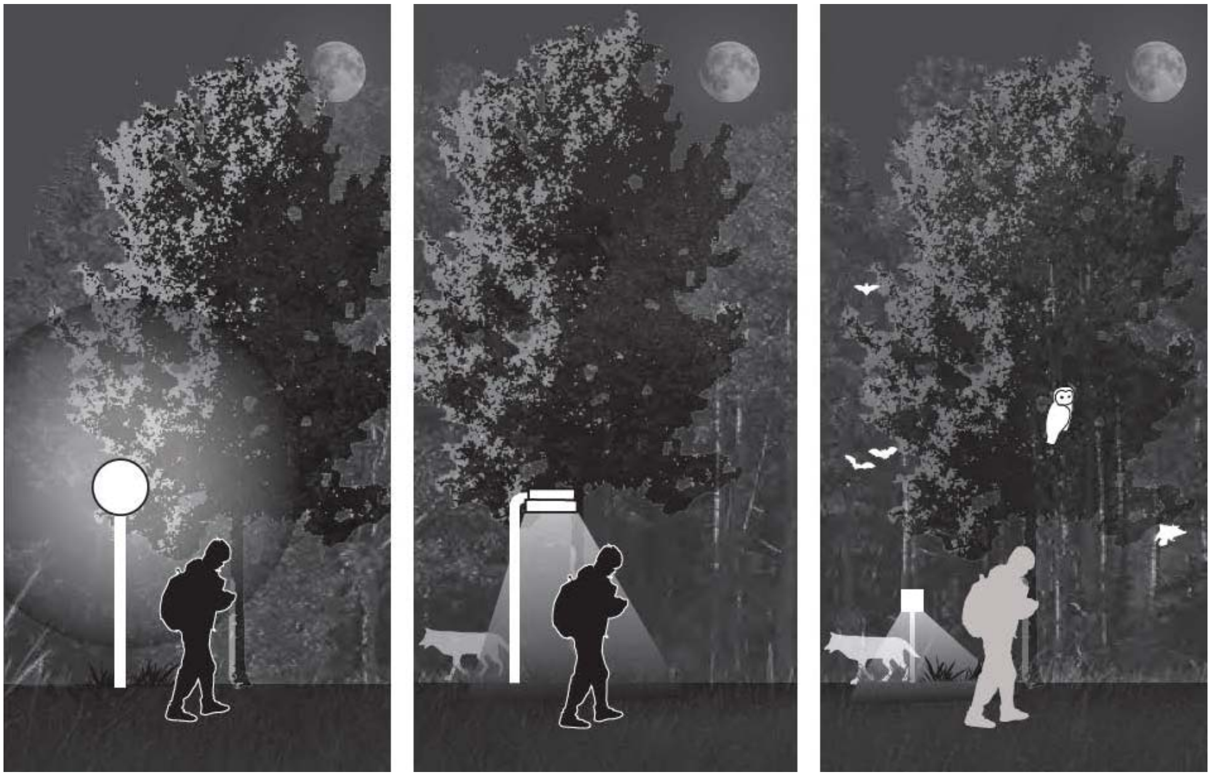

Figure 22. The more focused light can be on its target, the less it will affect other species.

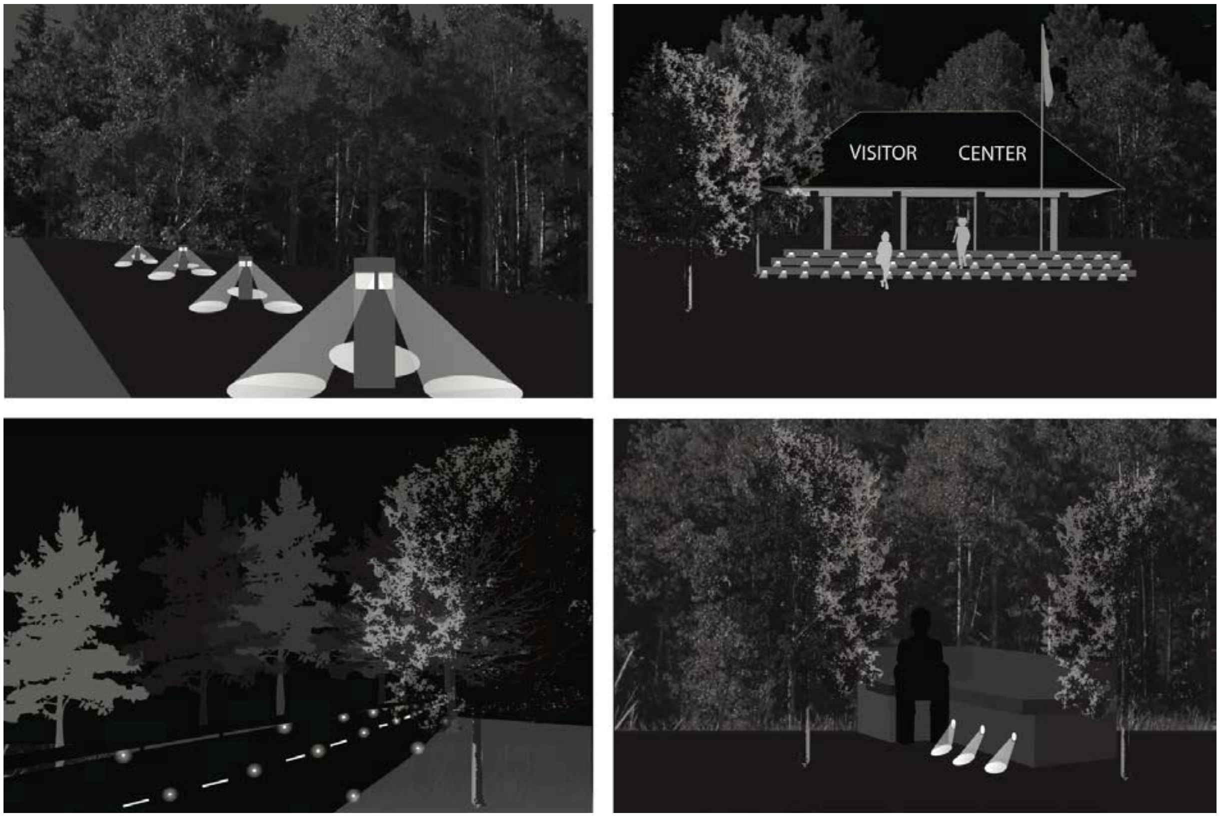

Figure 23. Embedded lights allow wayfinding with minimal intensity and good directional control.

Figure 24. A full cutoff shield being installed on an existing light on the lodge at Yellowstone National Park. This previously unshielded light was visible across the lake and from the backcountry. Photograph by Travis Longcore.

Duration

Impacts from lighting can be reduced by changing the duration of illumination. This approach reduces some impacts, but it may have some adverse consequences for those species sensitive to a changing light environment and so should be implemented with these limitations in mind. One common way to reduce the duration of illumination is to install a motion detector so that a light is only on when there is activity in a particular area (**Figure 25**). Although this limits the amount of time lights are on, lights that go on and off at irregular intervals may disrupt the nocturnal behavior of some species. For example, green frogs (*Rana clamitans*) reduce calling behavior and move away when a light is shined on them (Baker and Richardson 2006); return to a dark-adapted state can take hours (Buchanan 2006).

Figure 25. Motion- and heat-detecting lights provide illumination only when it is needed.

Another restriction on duration is setting a time for lights to be extinguished each night (**Figure 26**). For example, the lights that illuminate Mount Rushmore are only on for a few hours each night. This approach, known as part-night lighting, reduces impacts by allowing darkness during the late night and early morning hours. Depending on the timing of the lighting, darkness can be maintained for the majority of the activity period for a target species (Day et al. 2015). This approach, however, may still disrupt activities during the specific light conditions at dusk that are required by other species (Longcore et al. 2003, Day et al. 2015). Rather than a smooth range of illumination conditions occurring as the sun goes down and darkness falls, sites will experience a single illumination level until the lights are turned off. Many groups of species share resources across lighting levels; that is, one species may forage at dusk, another right after dusk, and another in the dark of night (Hailman 1984). Increased illumination, even on a temporary basis at dusk or dawn, reduces the time available for critical behaviors and could eliminate them altogether if a species prefers the transitional lighting levels of dusk when lights are illuminated. If artificial lighting eliminates a significant period of potential activity time for a species, the long-term consequences will be negative. In studies of bats, part-night lighting has been found to be ineffective in avoiding the activity periods of most species in the locations studied (Azam et al. 2015, Day et al. 2015).

Figure 26. Timed lights may affect species negatively during the transitional period of dusk, but may reduce impacts later at night.

There may be instances where avoiding lighting during a particular time when animals are active is an appropriate way to mitigate impacts. Many species are active during the crepuscular periods of dusk and dawn. If lighting can be avoided until after dark, or closer to dark, certain impacts on those species might be avoided. Setting photodetectors to activate lights only at very low levels of illumination will avoid the biologically active crepuscular period, reduce insect attraction, and limit light to after civil twilight when it is really needed.

Whenever lights are required, reducing their intensity or turning them off during periods they are not needed should always reduce impacts. For example, the Dutch government has mitigated lighting impacts on sensitive wet grassland habitats by turning off roadway lighting at 11 P.M. and replacing it with 7-watt incandescent bulbs halfway up the light standards (De Molenaar et al. 2006). These lights allow for wayfinding and have not changed the number of accidents occurring on the road.

Lighting situations

In addition to controlling for spectrum, intensity, direction, and duration, mitigation measures can be devised for many other situations in which lighting might be installed in parks. In the sections that follow, we discuss the issues involved with mitigating impacts from a series of different situations that might be faced by a park manager.

Communication towers

Each tower in the United States that is taller than 200 ft (61 m) must have obstruction lighting in accordance with Federal Aviation Administration (FAA) guidelines. Lighting is a primary factor resulting in the attraction to and mortality of birds at towers. An estimated 6.8 million birds per year are killed at tall towers (Longcore et al. 2012), including many species of conservation concern (Longcore et al. 2013). Reviews of previous work, and subsequent studies, have shown that mortality can be reduced by using a lighting system that has flashing lights only, whether these are strobe lights or red flashing lights (Gehring and Kerlinger 2007). White strobe lights have long been approved as lighting on towers and the FAA has updated its regulations to allow red flashing lights only (see FAA Advisory Circular 70/7460-1K). It is also important that towers do not have ground-level lighting around them because these lights can attract birds that then collide with tower guy wires (Longcore et al. 2008). Another option for tower lighting is an audio-visual warning system like OCAS (http://www.ocasinc.com). This approach uses radar to detect nearby aircraft, activating marker lights and emitting a verbal warning on aviation band radio. It is essentially a motion detector for tower lighting.

Night hiking and mountain biking

Night hiking and mountain biking have become popular activities in natural areas. The lights used in these activities, especially those used in mountain biking, have become brighter in recent years. For example, full-spectrum LED lights that emit 3,600 lumens (approximately the same as a 200-watt incandescent bulb) are advertised for use by bikers. Activities such as these expose wildlife to unnatural disturbance at night; this affects behaviors both because of the disturbance itself and because of the potential bleaching of eye pigments ("blinding") from which recovery time can take minutes to hours.

Managers can mitigate the impacts of night hiking and biking by employing various strategies. These include:

1. Restrict the time of month when illuminated nocturnal recreation is allowed to the days before and after the full moon. In this manner animals are allowed the darkest part of the month as a refuge from disturbance.
2. Restrict the total luminous intensity of lights used in these activities.
3. Set curfews for illuminated nocturnal recreation.
4. Restrict nocturnal recreation activities to areas that are already disturbed by night lighting, leaving more remote wildland areas protected from nocturnal disturbance.

Campsite lighting

Although "traditional" camping with firelight and flashlights is certainly still a popular activity, more and brighter portable lights are being brought to campsites. Large arrays of lights are readily available and increasingly used by campers. Such lights can degrade the nighttime camping experience for other campers and will have greater impacts on wildlife than a campfire or small personal flashlight. Park managers might consider establishing guidelines for nighttime lighting at campsites, including limits on overall illumination, lighting curfews, and recommendations to use flashlights instead of area lighting. Lighting restrictions could be established in conjunction with quiet hours, and address portable lanterns and recreational vehicle lights. In especially dark areas, managers could recommend the use of red filters on flashlights. Such actions should be paired with minimizing lighting from the existing infrastructure (e.g., converting lights on bathrooms to low-intensity red lamps).

Off-road vehicles

Deserts and beaches often accommodate vehicular recreation. Vehicles commonly have 1,000–1,500 lumens of forward-facing light, and because this is concentrated in a fairly narrow cone, the light intensity can be very high, with low-beam headlights exceeding 4,000 candela on axis (candela is a unit measuring the brightness of a light emitted in a particular direction). For wildlife along the axis of the headlight, the intensity of a directional headlight is equivalent to an unrestricted 100,000-lumen light source (Schoettle et al. 2004). This disruption can be an intermittent impact or, in some situations, a chronic one. For example, vehicles on a beach will often park with the headlights kept on, in which case multiple headlights will be directed into the shoreline environment and have the effect of a much larger number of streetlights due to their concentrated and directed nature. The most effective mitigation would be to prohibit vehicles from these environments during sensitive times for wildlife. Additional mitigations may include restricting headlights to when the vehicle is moving or requiring low beams only.

Monuments

Parks must consider the need to preserve natural and cultural resources when making decisions related to lighting cultural monuments. For example, the Washington Monument is bathed in white light and is known to attract and kill migratory birds (Overing 1938). Because the Washington Monument has been illuminated at night since the 1930s and is so powerfully symbolic of Washington, D.C., it is not feasible to propose elimination of lighting altogether. Limitation on the hours of illumination is probably the best management action in such situations. Lighting for monuments should be designed to illuminate the monument only, and with the lowest intensity possible. Bright lighting that might have been required to accommodate photography in the past is no longer needed with current digital imaging technology.

Lighting schemes at monuments could also play a role in pest management. At the Lincoln Memorial, the lights are turned on at twilight when midges and gnats fly over from the Potomac River and onto the Memorial. This in turn attracts many spiders that weave webs on the monument and require extensive and frequent cleaning (C. Moore, pers. comm.). It might be possible to turn the lights on slightly later, after the crepuscular period, or to change the spectrum of light used to eliminate short blue and ultraviolet wavelengths. In such a manner the lighting scheme then becomes part of an Integrated Pest Management program.

Light-assisted fishing

Offshore lighting poses threats both to aquatic and terrestrial ecosystems. Light has a long history of use as a method to attract fishes for capture. In artisanal fisheries, dim lamps may be used on small human-powered boats. Current industrial-scale fisheries, however, use extremely bright lights (equivalent to 30,000 watts incandescent) to attract squid and other fishes. Even boats that do not use lights to attract their catch operate during the night and are highly illuminated. Illumination in this manner affects behavior of fishes (Nightingale et al. 2006) and other aquatic organisms (Forsythe et al. 2004). Lighting is also implicated in the mortality of seabirds in fisheries (Dick and Donaldson 1978, Carter et al. 2000). Spillover light on seabird nesting colonies has the potential to increase predation on vulnerable species (Keitt et al. 2004). Park managers should take action to reduce fishing activity with disruptive lighting near sensitive island habitats and in marine protected areas. A range of options is available to do so, including outright bans, limiting light-assisted fishing by phase of the moon (to dates around the full moon), and limiting total luminance allowed in protected waters.

Security lighting

Managers are often faced with pressure to install security lighting in hopes of decreasing illegal activity. The evidence that increased illumination reduces crime is unclear at best (Tien et al. 1977, Sherman et al. 1997), and dimming or shutting off lights may in fact reduce crime (Steinbach et al. 2015). Some schools use a “dark campus” approach, wherein all lights are extinguished at a certain hour. Lights seen after this time are then quickly recognized as indicative of unauthorized activity (Mizon 2012). Park managers should think very carefully about installation of any dusk-to-dawn security lighting. It has very little chance of being effective if staff members are not on site to observe activity. Complete darkness at night for areas in parks and protected areas that are off-limits and unoccupied should be considered in consultation with law enforcement.

Bridges

Bridges can introduce artificial lighting into natural areas through roadway lighting for safety or through architectural lighting. Both of these have the potential to disrupt natural habitats. For example, harbor seals used the lights on the Puntledge Bridge in British Columbia to form a “feeding line” and intercept outmigrating juvenile salmonid smolts (Yurk and Trites 2000). Extinguishing these lights led to a decrease in salmon mortality. Other studies document increased predation on fishes under illuminated bridges and docks (Nightingale et al. 2006). For bridges with tall structures, illumination of these towers may result in attraction of migratory birds. Such lighting should be avoided to the extent possible, such that obstruction lighting is limited to red flashing lights (if lighting is required by the FAA) and any roadway lighting is carefully directed onto the roadway with little or no spillover into the river. Furthermore, use of yellow light is preferable under most circumstances to minimize the attraction of insects, although selection of yellow lights alone will not eliminate the effects of lighting on foraging behavior of mammals (Bird et al. 2004). Other considerations with bridges include the synergistic effects of lighting and polarization that misleads insects and may even result in bridges being dispersal barriers along rivers (Horváth et al. 2009, Málnás et al. 2011).

Roadway lighting

Roadway lighting is a major source of outdoor illumination and contributes significantly to sky glow. In a study of lighting in Tucson, Arizona, roadway lighting accounted for 12% of upward directed lighting, following only commercial lights (36%) and sports fields (32%) as a proportion of total uplight (Luginbuhl et al. 2009). To maintain natural illumination conditions inside parks, managers must work with communities outside park boundaries to address these sources. Inside park boundaries, managers must make the decision whether roadway lighting is necessary in the first place, and if so, what characteristics it should have. To minimize impacts on wildlife, roadway lighting should be avoided to the extent possible, and where used should only be designed for the required intensity. The recommended lighting for a local road with low pedestrian conflict in the United States is 3–4 lux (ANSI/IES RP-8-14), which is more than 30 times brighter than the full moon's maximum intensity, so no roadway lighting is ecologically trivial. Recommended illumination for most roadways ranges from 6–15 lux (ANSI/IES RP-8-14).

One issue with reducing illumination for roadways is a concern that any reduction will increase traffic collisions. Studies of changes to roadway lighting in England and Wales, however, found no significant effect on number of traffic collisions from part-night lighting, switching off roadway lighting entirely, or changing the spectrum of roadway lighting (Steinbach et al. 2015).

Where light is essential, fixtures should be full cutoff and shielded to minimize glare from any non-road site, especially in areas with known sensitive species. The best overall choice for spectrum is probably yellow (e.g., low-pressure sodium or yellow/amber LED), but technical considerations may lead to use of a broader spectrum (e.g., high-pressure sodium). Yellow/amber LED streetlight fixtures are commercially available in response to demand for lighting with minimal impacts on bats (e.g., Innolumis bat lamp from the Netherlands) and other wildlife (e.g., Star Friendly® lights, C&W Energy Solutions).

Other alternatives are available to further reduce the impacts of street lighting. Embedded roadway lighting (**Figure 27**) has been investigated in Florida as a way to minimize impacts on nesting sea turtles (Bertolotti and Salmon 2005). Such lights may be useful in locations where snow plowing is not necessary. Another alternative is the use of dynamic lighting systems that decrease illumination based on the time of day or traffic volume so that lights are extinguished by a certain time at night or at a percentage of peak traffic (Collins et al. 2002).

Interested park managers can consult reviews on the impacts of light from street lighting systems, which recommend against full-spectrum lamps because of ecological, physiological, and dark-sky impacts (Falchi et al. 2011, Bierman 2012).

Vehicles along roads can cause the type of periodic changes in lighting levels that can affect animal behavior (Baker and Richardson 2006) and influence views of the night sky (Luginbuhl et al. 2009). Birds, especially migratory species and seabirds, can be attracted to vehicle headlights (Gauthreaux and Belser 2006). Although additional research on this topic would be welcome, managers can mitigate impacts from headlights by providing shielding of sensitive receptors using a range of physical barriers, including berms, dense shrubs, or even walls in particularly sensitive areas.

Figure 27. Embedded roadway lighting. These LED lights installed in the pavement are not visible to sea turtles nesting on the adjacent beach and are well received by motorists and pedestrians (Bertolotti and Salmon 2005). Photograph courtesy of Michael Salmon.

Energy production installations

Efforts to increase domestic energy production have resulted in pressure to explore and extract fossil fuels and develop industrial-scale facilities for wind and solar energy both on land and water. Energy production facilities have the potential to affect natural resources on park properties that may be found intermixed with other public and private lands approved for such activities. The direct impacts of such activities are of great conservation concern, but are not discussed here. In the event that such facilities are evaluated in the environmental review process, the following recommendations could be made to minimize the impacts of artificial night lighting.

Wind energy installations are generally illuminated with red flashing lights at the corners of arrays of turbines. Not all turbines have obstruction lighting. Researchers documenting mortality of animals (both bats and birds) at wind turbines have concluded that these flashing lights do not attract birds, but that constant illumination of ancillary structures on the ground is associated with increased bird mortality at nearby turbines (Kerlinger 2004, Kerlinger et al. 2010). Wind turbines currently are estimated to kill on the order of 100,000 (Kerlinger et al. 2011) and 573,000 (Smallwood 2013) birds per year, with this number likely to grow 30-fold in the next 20 years to meet federal goals for renewable energy. Ensuring that lighting is only red flashing with no steady-burning lights on any accessory structures would reduce mortality of nocturnal migrant birds, but would not mitigate the significant bat mortality that is associated with wind turbines (Kunz et al. 2007, Smallwood 2013).

Solar power plants are proposed and being built in open desert areas near parks and protected natural lands. Such facilities should not require dusk-to-dawn night lighting. If security lighting is desired, the recommendation should be made that it be fully shielded, low intensity, and on a motion detector.

Oil and natural gas facilities are often brightly illuminated at night. This light can have adverse consequences for any habitat in which it is found. For example, offshore oil platforms attract seabirds, usually to their detriment (Wiese et al. 2001, Montevecchi 2006). Terrestrial oil and gas facilities are often the only sources of light in remote open spaces. Parks can work with existing facilities to retrofit lights. For marine facilities, some initially positive data have been collected suggesting that using a green light on an offshore platform reduces the number of birds that are attracted to it (van de Laar 2007, Poot et al. 2008). By retrofitting the platform from white lights to green lights, Dutch researchers documented a reduction in the number of birds observed circling a platform (van de Laar 2007). The cause of this reduction could have been the wavelength of light used, or an overall decrease in lighting intensity that was a byproduct of the lighting change. The research shows that decreasing illumination and restricting the spectrum of light is a promising approach to reducing impacts to biological resources while still maintaining safe operations.

Indoor lighting

Although outdoor lighting is usually the focus of efforts to reduce impacts of night lighting on wildlife, indoor lighting should be considered as well. Indoor lighting may contribute substantially to ecological light pollution. In the extreme example of all-glass structures, greenhouses in Germany attract insects and migratory birds (Abt and Schultz 1995, Kolligs 2000). Furthermore, office buildings in urban cores can contribute as much to sky glow as billboards or roadway lighting (Oba et al. 2005). In darker environments, even the lights from a residence may have some effect on local wildlife behavior and degrade the experience of visitors in adjacent natural areas. Managers can be aware of these issues and seek to shield interior lights through use of curtains. This also gives an additional reason to cluster developments within parks. For urban areas and office buildings, guidelines are available to minimize the effects on birds, including through steps to reduce interior illumination (New York City Audubon Society 2007).

Lighthouses

The fatal attraction of birds to lighthouses has been observed for well over a century (Dutcher 1884, Miller 1897, Hansen 1954). In the United States, mortality of birds is more commonly reported on the East Coast than on the West Coast (Allen 1880, Merriam 1885), although mortality has been recorded on the West Coast as well (Squires and Hanson 1918). There has been some conflicting research on lighting color and flashing since the early 1900s (see review in Gauthreaux and Belser 2006), but the view has solidified that mortality can be decreased through the use of a flashing rather than constant light (Baldwin 1965, Jones and Francis 2003, Gauthreaux and Belser 2006). It is important that the light itself flashes, extinguishing completely between flashes, rather than the flashing effect being created by a rotating beam that remains illuminated. Reduction in lighting intensity also reduces bird mortality (Jones and Francis 2003).

Billboards

Billboards and other signage can affect wildlife behavior when illuminated. For example, light from a single billboard was sufficient to change the concealment behavior of juvenile salmon in a stream (Contor and Griffith 1995). While the significance of such behavioral changes is unknown, illumination of billboards and other signs should be controlled to minimize cumulative effects of lighting on wildlife, especially as digital billboards proliferate. Illumination from a typical digital billboard proposed for installation in endangered species habitat in southern California would have caused lighting levels to exceed 10^{-1} lux (equivalent to that of a full moon) up to 1,000 ft (305 m) from the sign, according to the lighting engineers for the applicant (Longcore 2015; the proposal was not approved). Such intense lighting has the potential to influence nearby sensitive resources and contribute to sky glow.

Conclusion

Light pollution within parks and protected lands can have a measurable impact upon the habitat quality of the park, even if the light itself originates outside of the park's administrative boundary. Minimizing ecological impacts requires that land managers adopt an ethic of using only the minimum light necessary for human needs and being cautious when introducing light into or near a natural landscape. This report provides examples of the range of negative consequences that may arise from artificial night lighting. Though not a compendium of information for every species and every environment, it should provide adequate evidence for reasonable management of lighting in natural areas.

Park managers should first inventory their resources and determine if and where sensitive species or habitats exist. This information can then guide the development of the prescription of lighting zones within a park where different levels of lighting are allowed, depending on the uses and experiences desired for those zones. Lighting zones may be designed to minimize wildlife impacts only or also to integrate other aspects of a park experience. The most sensitive zone would have a prohibition on outdoor lighting or impose restrictions that define a narrow range of allowable artificial lighting. Looser restrictions that still provide adequate mitigation would be delineated for developed areas in parks and those with substantial human nighttime activity. In all instances, mitigation should address spectrum, intensity, direction, and duration. When all four aspects are addressed, mitigations can be effective at reducing ecological disruption from artificial night lighting.

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