EARTHJUSTICE

February 28, 2023

Via electronic mail only

Department of Land and Natural Resources
Division of Forestry and Wildlife
Endangered Species Recovery Committee
dofaw.hcp@hawaii.gov

Re: Kauai Island Utility Cooperative Draft Long-Term Habitat Conservation Plan, Kauai, HI

Dear Endangered Species Recovery Committee Members:

Earthjustice submits these comments on Kauai Island Utility Cooperative's ("KIUC's") draft long-term habitat conservation plan ("LTHCP").[1] As discussed below, the draft LTHCP fails to satisfy the minimum legal requirements of Hawai'i Revised Statutes ("HRS") chapter 195D and the federal Endangered Species Act ("ESA"). Accordingly, the Endangered Species Recovery Committee should not recommend approval of the LTHCP in its current form. Far from minimizing its take "to the maximum extent practicable" as both state and federal law mandate, KIUC instead proposes to conduct no further minimization projects over the LTHCP's entire 50-year term, and jettisons or disregards minimization strategies known to reduce take caused by both powerlines and streetlights. *See* HRS § 195D-4(g)(1); 16 U.S.C. § 1539(a)(2)B)(ii). Moreover, KIUC's distant and at best theoretical projections of "net environmental benefits" from its attempts to mitigate the substantial toll its operations will continue to inflict on imperiled seabirds do not provide the requisite "reasonable certainty" as to the likely effects of the LTHCP. *See* HRS § 195D-4(g)(8); *id.* § 195D-21(c). We strongly urge this Committee to recommend that the LTHCP be revised to comply with these legal mandates.

Background

Kaua'i's population of Newell's shearwater or 'a'o (*Puffinus auricularis newelli*) has been in precipitous decline for decades, due in significant part to collisions with powerlines and fallout caused by street lighting. LTHCP at 3A-6-10 (pdf 409-13).[2] Kaua'i is home to an

[1] Our review of the LTHCP is ongoing, and we intend to submit further comments to the Division of Forestry and Wildlife ("DOFAW") by the March 24, 2023 LTHCP comment deadline.

[2] For ease of reference, we cite to both the LTHCP page number designation and the portable document format ("pdf") page number, based on the draft LTHCP published in *The Environmental Notice* on January 23, 2023.

estimated 90% of all ʻaʻo in the world. *Id.* at ES-4 (pdf 19). From 1993-2013, the ʻaʻo population on Kauaʻi fell by an average of 13% annually, or a full **94%** over those 20 years. *Id.* at 3A-6-7 (pdf 409-10). The powerlines, streetlights, and associated structures for which KIUC now seeks 50 years of incidental take coverage are directly responsible for the lion's share of the tens of thousands of ʻaʻo documented as "taken" on Kauaʻi over the last three decades, to our knowledge the largest documented take of any ESA-listed bird species. *See id.* at 4-36 (pdf 129) ("the [Save Our Shearwaters] Program has recovered and released more than 30,500 seabirds since the 1970s"). Documented take, however, is only a small fraction of the take that actually occurs: most downed birds are never recovered, and the massive take levels associated with the Powerline Trail were unknown until only recently, when acoustic monitoring of powerline strikes was initiated. The Kauaʻi population of Hawaiian petrel or ʻuaʻu (*Pterodroma sandwichensis*) has similarly plummeted, decreasing by 78% from 1993-2013, again significantly due to powerline collisions and light-induced fallout. *Id.* at 3A-17-18 (pdf 420-21); *see also id.* at 3A-8-10 (pdf 411-13). The endangered Kauaʻi population of band-rumped storm-petrel or ʻakēʻakē (*Oceanodroma castro*) faces the same threats posed by KIUC's ongoing activities. *See id.* at 3A-22 (pdf 425).

Powerlines and light attraction have been known to cause disastrous seabird take on Kauaʻi since at least the 1990s, when an ESA citizen suit against Kauaʻi Electric, KIUC's predecessor, resulted in a 1995 study recommending various strategies to minimize take, including undergrounding, rerouting, and reconfiguring powerlines. After acquiring the utility in 2002, KIUC continued to operate its powerlines, streetlights, and other infrastructure in knowing violation of the ESA, prompting the U.S. Department of Justice in 2010 to indict KIUC on criminal charges for its unpermitted seabird take. A short-term HCP ("STHCP") went into effect in 2011, lasting five years, but take continued at a much higher rate than was authorized and seabird populations continued to nosedive. In the STHCP, KIUC claimed that all of KIUC's streetlights were shielded ("more than 3,000 KIUC streetlights"), but in the LTHCP KIUC now notes that only in 2017 were KIUC's streetlights retrofitted to minimize light attraction, LTHCP at 4-33 (pdf 126), and only since 2020 has KIUC made any concerted effort to continue minimizing its powerline take beyond the handful of segments partially addressed under the STHCP. *Id.* at 4-29 (pdf 122). KIUC's foot-dragging in implementing take minimization measures, together with its decades of past and ongoing seabird take, mean that there are now far fewer seabirds for KIUC to worry about killing.

KIUC's LTHCP nevertheless seeks permission to take, on average, over 1,200 seabirds each year, including 801 ʻaʻo, of which 375 are expected to die. LTHCP at 5-21-23 (pdf 184-86). Over the LTHCP's full 50-year term, KIUC requests permission to kill or injure over 61,000 additional imperiled seabirds. *See id*. But in so requesting, KIUC fails to propose any additional minimization measures with respect to either its powerlines or streetlights, other than now

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https://files.hawaii.gov/dbedt/erp/Other_TEN_Publications/2023-01-23-KA-Draft-HCP-Kauai-Island-Utility-Cooperative.pdf (last visited Feb. 28, 2023).

long-overdue work it expects to complete before the 50-year LTHCP term even begins. *Id.* at 4-29 (pdf 122), 4-34 (pdf 127). The only achievable outlook KIUC has suggested in the LTHCP is that, after many additional years (for ʻaʻo, decades) of take, its proposed mitigation strategies may—KIUC hopes—show a slight uptick in seabird numbers as compared to the hypothetical scenario in which KIUC immediately removes its infrastructure and ceases operations. *See, e.g.*, *id.* at 5E-40 (pdf 737) (showing long-term modeled projections for ʻaʻo). KIUC's approach fails to comply with either state or federal law.

The Draft LTHCP Fails To Minimize Take Of Endangered And Threatened Seabirds To The "Maximum Extent Practicable."

Under both HRS chapter 195D and the federal ESA, approval of KIUC's LTHCP depends on whether KIUC will minimize its take of listed seabirds "to the maximum extent practicable." HRS §§ 195D-4(g)(1), 195D-21(c)(4); 50 C.F.R. §§ 17.22(b)(2)(i)(B), 17.32(b)(2)(i)(B). Since KIUC cannot operate without both a state incidental take license ("ITL") and federal incidental take permit ("ITP"), the more demanding incidental take standard imposed under state law, which mandates that the "cumulative impact of the [authorized] activity … provides net environmental benefits," HRS § 195D-4(g)(8), informs the analysis of what alternatives are "practicable." *See also infra* at 6. KIUC moreover cannot secure an ITL under Hawaiʻi law unless the LTHCP identifies "steps that will be taken to minimize and mitigate all negative impacts, including *without limitation* the impact of any authorized incidental take." HRS § 195D-21(b)(2)(C) (emphasis added). The draft LTHCP falls far short of these mandates, with KIUC seeking credit for decades-overdue modifications to its infrastructure that precede the LTHCP's effective date, proposing no further powerline reconfigurations and no further modifications to streetlights whatsoever throughout the 50-year LTHCP term. *See* LTHCP at 4-29 (pdf 122), 4-34 (pdf 127). Far from minimizing take to the *maximum* extent practicable as chapter 195D and the ESA require, KIUC proposes to do *nothing* to minimize take for the next 50 years.

1. The LTHCP Must Include Powerline Reconfiguration Strategies To Minimize Take, Including Undergrounding Of New And Existing Powerlines.

Seabird take caused by collisions with powerlines is "one of the most significant threats to Newell's shearwater (ʻaʻo) and Hawaiian petrels (ʻuaʻu) on Kauaʻi." LTHCP at 5-3 (pdf 166). Powerline collisions break bones, tear off feathers and skin, injure heads, eyes, and wings, and are assumed in many cases to result in grounding and death. *Id*. at 5-4-5 (pdf 167-68). KIUC, however, refuses to take any further steps to minimize powerline take beyond the minimization measures that KIUC says it will complete before the LTHCP takes effect. In other words, KIUC seeks to *maintain*, not minimize, its disastrous rates of seabird take.

Despite asking to continue taking seabirds at devastating rates for another half-century, KIUC proposes ***no further powerline take minimization*** measures and instead seeks only credit for work done before implementation of the LTHCP. The draft LTHCP notes a handful of powerline minimization projects completed in 2015-2016 covering just over six miles of powerlines, *id.* at 4-24-25 (pdf 117-18), notes the stop-gap powerline minimization measures that were initiated only in 2020, *id.* at 4-26 (pdf 119), and lists just three discrete powerline reconfiguration projects which KIUC began implementing in 2020, covering only 8.1 of the 171 miles of transmission lines KIUC operates. *Id.* at 4-29 (pdf 122). KIUC refuses to implement any further powerline minimization, stating unequivocally that "[n]o additional powerline reconfiguration projects are planned as part of this HCP." *Id.*

To satisfy the federal and state mandates, KIUC must do more to ensure that seabird take is minimized "to the maximum extent practicable." HRS §§ 195D-4(g)(1), 195D-21(c)(1); 16 U.S.C. § 1539(a)(2)(B)(ii), (iv). Although KIUC claims that its current minimization strategy will reduce seabird take by an average of 65% (ranging as low as 42%), LTHCP at 4-25 (pdf 118), this is not the maximum practicable take reduction strategy available and does not justify KIUC's request to continue taking over 1,200 seabirds per year. Undergrounding powerlines, which has been recommended for reducing seabird take on Kauaʻi since at least 1995, "would *eliminate* the potential for covered seabird collisions." *Id.* at 8-2 (pdf 333) (emphasis added). Other benefits of undergrounding powerlines include increased resilience against extreme weather and improved sightlines, both of which would benefit Kauaʻi residents. While there has been historical pushback by KIUC to undergrounding current and future powerlines, KIUC has been aware of the need to bury powerlines since it acquired Kauaʻi Electric and should have prepared and funded an undergrounding program years ago. KIUC anticipates new powerline construction, but does not even consider the possibility of undergrounding the new lines (or any existing lines), instead assuming new, 45-foot tall powerlines for the next 50 years. *Id.* at 4-32-33 (pdf 125-26). KIUC's estimates of "reduction in powerline collisions for new powerlines" due to omission of static wires and installation of diverters moreover defy logic. *Id.* at 4-33 (pdf 126). Prior to the installation of new powerlines, there would be no collisions to reduce. Thus, any new powerlines would inflict new harm on imperiled seabirds, not minimize take. KIUC should not assume that it would be allowed to operate new powerlines in violation of chapter 195D and the ESA.

KIUC should be required to invest in take minimization efforts through the entire life of the 50-year LTHCP, including projects like undergrounding, which would eliminate powerline take altogether. DLNR must consider all relevant circumstances, such as the duration of the proposed ITP/ITL, in determining what minimization and mitigation measures are "practicable," *see* HRS § 195D-4(g)(1); 16 U.S.C. § 1539(a)(2)(B)(ii), and should not allow KIUC to skate by with credit for stop-gap minimization measures that pre-date the LTHCP. KIUC claims that undergrounding any powerlines is "infeasible and cost prohibitive," despite noting an operating budget surplus of $12 million for *one year alone*. LTHCP at 8-2-3 (pdf 333-34). Considering the 50-year scope of the LTHCP, it is not impracticable for KIUC to include, plan for, and fund undergrounding projects to eliminate take over time, particularly in high-volume seabird flyways.

2. The LTHCP Should Include Replacing KIUC's Streetlight Bulbs To Minimize Take.

Artificial lighting such as streetlights attract seabirds and cause them to become disoriented and tire, circling around lights and sometimes colliding with structures, ultimately becoming grounded, a phenomenon known as fallout. LTHCP at 5-7 (pdf 170). Take caused by fallout predominantly affects fledging seabirds attempting their first flights to sea, or birds at sea who are attracted back to land by lights onshore. *Id*. Bright lights confuse, disorient, or blind seabirds, causing them to land where they would not otherwise land, unable to take off again due to injury, exhaustion, or confusion, and subjecting them to predation, starvation, dehydration, and being crushed by automobiles. *Id*. Seabirds experiencing fallout are assumed to die. *Id.* at 5-15 (pdf 178).

As with powerline collisions, KIUC fails to minimize take caused by streetlight attraction "to the maximum extent practicable." The draft LTHCP notes that KIUC finished installing shielding on its existing streetlights only in 2017, but again proposes no additional take minimization strategies other than to mimic the 2017 retrofitting when installing new streetlights. *Id.* at 4-33-34 (pdf 126-27). KIUC ignores substantial scientific evidence that seabirds are affected differently by different wavelengths of light, with bright white streetlights like KIUC's that contain a high percentage of short-wavelength ("blue") light attracting wildlife to a greater degree than amber streetlights containing longer wavelength light, and therefore causing more take. *See*, *e.g.*, Att. A: Airam Rodriguez, et al., *Reducing light-induced mortality of seabirds: High pressure sodium lights decrease the fatal attraction of shearwaters*, Journal for Nature Conservation (2017).

Further minimizing the take caused by KIUC's high-blue-light-content streetlights is *not* impracticable. Indeed, both Maui County and Hawaiʻi County have enacted ordinances requiring the retrofit of county streetlights with fixtures that have less than 2% "blue light content" (defined as "the ratio of the amount of energy emitted by the outdoor light fixture between 400 and 500 nm divided by the amount of energy between 400 and 700 nm"). Hawaiʻi County Code § 14-51(a)(9); *see* Maui County Ord. 5434, § 2 (Oct. 24, 2022) (enacting Maui County Code § 20.35.060.D) (same); *see also* Hawaiʻi County Code § 14-55, Table 14-A (specifying that LED fixtures must have "less than 2% blue light content"). In supporting the Maui ordinance, DOFAW itself urged the county to use only LED streetlights "designed or filtered to have a correlated color temperature of 2200 Kelvin or less, or a *blue light content of less than 2%*" and noted that "LED lights with these specifications have been found to have *fewer impacts on protected wildlife, including seabirds* and turtles" (emphases added). A copy of DOFAW's letter is attached as Att. B.

To minimize take of listed seabirds, KIUC must replace its high-blue-light-content streetlight fixtures with fixtures with no more than 2% "blue light content." Particularly considering the 50-year term of the LTHCP and the astronomical level of take authorization

KIUC seeks, minimizing take from streetlights by requiring low-blue-light fixtures is certainly practicable.

<u>KIUC Fails To Provide "Reasonable Certainty" That The LTHCP Will Result In "Net Environmental Benefits."</u>

Under HRS chapter 195D, KIUC must show that the cumulative impacts of its activities will "provide[] net environmental benefits," HRS § 195D-4(g)(8), and must provide "sufficient information for the board to ascertain with reasonable certainty the likely effect" of the LTHCP. *Id.* § 195D-21(c). Instead of providing any certainty, however, KIUC relies on an admittedly *uncertain* model, *see*, *e.g.*, LTHCP at 5E-14-15 (pdf 711-12) ("there remains a high level of uncertainty for many of the biological assumptions that are input parameters for the . . . model"); *id.* at 5E-41 (pdf 738) ("many model uncertainties have not been quantified"), to speculate that, after continuing to drive seabird populations down for many more years to come, the balance of KIUC's planned activities may finally result in a slight uptick in seabird numbers, for ʻaʻo only perhaps in the late 2060s. *See id.* at 5E-40 (pdf 737). KIUC's long-range guesswork fails to establish the requisite "reasonable certainty" that the LTHCP will result in "net environmental benefits" for listed species. *See* HRS § 195D-21(c); *id.* § 195D-4(g)(1).

DLNR's consideration of "net environmental benefits" must moreover consider the effects of KIUC's seabird take and KIUC's proposed take minimization and mitigation as compared with no take at all. In other words, KIUC must provide "reasonable certainty" that its mitigation measures would save more listed seabirds than its permitted activities would kill. *See* HRS § 195D-21(c). Instead of carrying its burden to show "net environmental benefits" with "reasonable certainty," KIUC places the burden to survive on the seabirds themselves, with little more than a hope that reproduction rates, a handful of managed breeding sites, and the chance of rescue will combine to save these birds from the brink of extinction.

<u>Conclusion</u>

KIUC's draft LTHCP fails to minimize seabird take to the maximum extent practicable and fails to provide reasonable certainty that KIUC's combined actions will have net environmental benefits. Accordingly, the LTHCP must be revised to address these deficiencies before it can be approved. We appreciate the opportunity to provide these comments. Please feel free to contact us if you have any questions or would like to discuss any of the issues raised above. I can be reached by telephone (808-599-2436) or email (mcleveland@earthjustice.org).

Sincerely,

Mahesh Cleveland
Senior Associate Attorney
Earthjustice

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Short communication

Reducing light-induced mortality of seabirds: High pressure sodium lights decrease the fatal attraction of shearwaters

Airam Rodríguez[a,b,*], Peter Dann[a], André Chiaradia[a]

[a] Research Department, Phillip Island Nature Parks, Victoria, Australia
[b] Department of Evolutionary Ecology, Estación Biológica de Doñana (CSIC), Seville, Spain

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ABSTRACT

The use of artificial light at night and its ecological consequences are increasing around the world. Light pollution can lead to massive mortality episodes for nocturnally active petrels, one of the most threatened avian groups. Some fledglings can be attracted or disoriented by artificial light on their first flights. Studies testing the effect of artificial light characteristics on attractiveness to seabirds have not provided conclusive results and there is some urgency as some endangered petrel species experience high light-induced mortality. We designed a field experiment to test the effect of three common outdoor lighting systems with different light spectra (high pressure sodium, metal halide and light emitting diode) on the number and the body condition of grounded fledglings of the short-tailed shearwater *Ardenna tenuirostris*. A total of 235 birds was grounded during 99 experimental hours (33 h for each treatment). 47% of birds was grounded when metal halide lights were on, while light emitting diode and high pressure sodium lights showed lower percentages of attraction (29% and 24%). Metal halide multiplied the mortality risk by a factor of 1.6 and 1.9 respectively in comparison with light emitting diode and high pressure sodium lights. No differences in body condition were detected among the birds grounded by the different lighting systems. We recommend the adoption of high pressure sodium lights (or with similar spectra) into petrel-friendly lighting designs together with other light mitigation measures such as light attenuation, lateral shielding to reduce spill and appropriate orientation.

1. Introduction

The increasing use of artificial light at night is causing a loss of the natural nightscapes worldwide (Falchi et al., 2016). Light pollution is an emerging threat to biodiversity conservation by disrupting circadian rhythms, affecting natural behaviours, reproduction, animal movement or endocrine systems, and finally, influencing the ecosystem functioning by cascading effects (Gaston, Duffy, Gaston, Bennie, & Davies, 2014; Hölker, Wolter, Perkin, & Tockner, 2010; Longcore & Rich, 2004). Although marine environments are mostly free of artificial light, most coastal areas are affected by light pollution at night (Davies, Duffy, Bennie, & Gaston, 2014). Artificial lights along the coast can cause direct and incidental mass mortality events in endangered marine taxa, e.g. turtles or seabirds (Rich & Longcore, 2006; Rodríguez, Holmes et al., 2017). Despite the multiple effects on human health and biodiversity, artificial light is steadily proliferating in the night environment led by improvements in luminous efficiency (Kyba, Hänel, & Hölker, 2014). Thus, the determination of the impact of the different artificial lighting systems on biodiversity should be a priority for developing appropriate lighting policies to enable better coastal planning and conservation practices.

Fledglings of nocturnal petrel species (including shearwaters and storm-petrels) are attracted to artificial lights during their first flights from nest-burrows to the ocean, often colliding with human structures or the ground. If they survive the collision, they are grounded in artificially lit areas and susceptible to being killed by incidental threats (vehicle collision, predation, starvation or dehydration) (Ainley, Podolsky, Deforest, & Spencer, 2001; Le Corre, Ollivier, Ribes, & Jouventin, 2002; Rodríguez, Rodríguez, Curbelo et al., 2012; Rodríguez et al., 2014). To mitigate light-induced mortality of petrels, rescue programs have been implemented in several locations around the world (Rodríguez, Holmes et al., 2017). However, pre-emptive measures, that reduce the attractiveness of artificial lighting to seabirds, would be much more effective at the population level. To our knowledge, there is no published information on whether seabird attraction to artificial lights is related to the type of lights or individual traits of the seabirds. Here, we test the effect of three commonly used lighting systems with different

* Corresponding author at: Department of Evolutionary Ecology, Estación Biológica de Doñana (CSIC), Avda. Américo Vespucio, 26, 41092, Seville, Spain.
E-mail address: airamrguez@ebd.csic.es (A. Rodríguez).

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light spectra (metal halide – MH, high pressure sodium – HPS – and light emitting diode – LED) on the attraction of short-tailed shearwater (*Ardenna tenuirostris*) fledglings, a species severely affected by light pollution (Rodríguez et al., 2014). We also test if body condition of grounded fledglings differs among lighting systems. Why petrels are attracted to lights is not entirely understood, but it may be related to food as petrels could confuse lights with natural bioluminescent prey or associate light with food during the nestling period at their nest-burrows (see Rodríguez, Holmes et al., 2017). Although short-tailed shearwater fledglings attracted by artificial lights do not seem handicapped, as their body condition is similar to those of adults (Rodríguez, Moffett et al., 2017), degree of attraction to lighting systems could be mediated by body condition. Body condition at fledging is a proxy to greater likelihood of survival and recruitment in long-lived seabirds (Becker & Bradley, 2007; Maness & Anderson, 2013). Thus, attraction of birds in good condition, i.e. those with higher survival and recruitment probabilities, to a particular lighting system would worsen the impact of such light for petrel populations. Apart from lighting systems, other factors appear to play a role in the number of seabirds attracted to lights. First, birds tend to fledge early in the night (Reed, Sincock, & Hailman, 1985; Rodríguez, Rodríguez, & Negro, 2015), and therefore, it was expected that the number of grounded birds would increase during the first nocturnal hours. Second, fledging is a synchronous process leading to high number of birds fledging around a peak date (27–28 April for the short-tailed shearwater; Rodríguez et al., 2014). Third, fledging date is favoured by strong winds which give a lift to flight-inexperienced fledglings (Rodríguez et al., 2014; Skira, 1991). Fourth, the number of grounded birds is reduced during full moon nights (Le Corre et al., 2002; Rodríguez & Rodríguez, 2009; Telfer, Sincock, Byrd, & Reed, 1987). Fifth, the number of attracted birds in a year is related to the number of fledglings produced by the population in that particular year, i.e. the higher breeding success the higher the numbers of grounded birds (Day, Cooper, & Telfer, 2003; Rodríguez, Rodríguez, & Lucas, 2012).

2. Material and methods

Our study was conducted on Phillip Island, south-eastern Australia, where natural night skyscapes unpolluted by artificial lights are available adjacent to short-tailed shearwater breeding colonies (Fig. 1*a*). Phillip Island is relatively low with a maximum altitude about 112 m above sea level. It holds around 543,000 breeding pairs of short-tailed shearwaters (Harris, Brown, & Deerson, 1980), which is more than 1% of its global breeding population (BirdLife International, 2017), mainly distributed along the south coast (Fig. 1*a*). The short-tailed shearwater nests in dense colonies generally in sandy soils. Adults start migration before their chicks fledge and consequently fledglings depart the colony in the absence of their parents. Fledglings try to reach the ocean on their first flights.

Our experiment was conducted in the overflow car park at Phillip Island Nature Parks on the Summerland Peninsula (−38.505942°S, 145.149486°E), which is a 13,000 m^2 grassed area surrounded by some unlit buildings and short-tailed shearwater colonies (Fig. 1*b*). At the experiment site, masts held the three types of lamps (MH, HPS and LED) at the same height and orientation at each mast. Five masts of 3–5 m high supported the lamps used during the experiment (Fig. 1*b*, *c*). The three light types employed in our study are commonly used in outdoor facilities (e.g. car parks, sport stadiums and industrial areas) and they emit different spectra (Fig. 2*a*; Table 1). MH and HPS bulbs emit light in 360° in every direction, and for this reason they were housed in similar luminaries. In contrast, LED emits light in one direction.

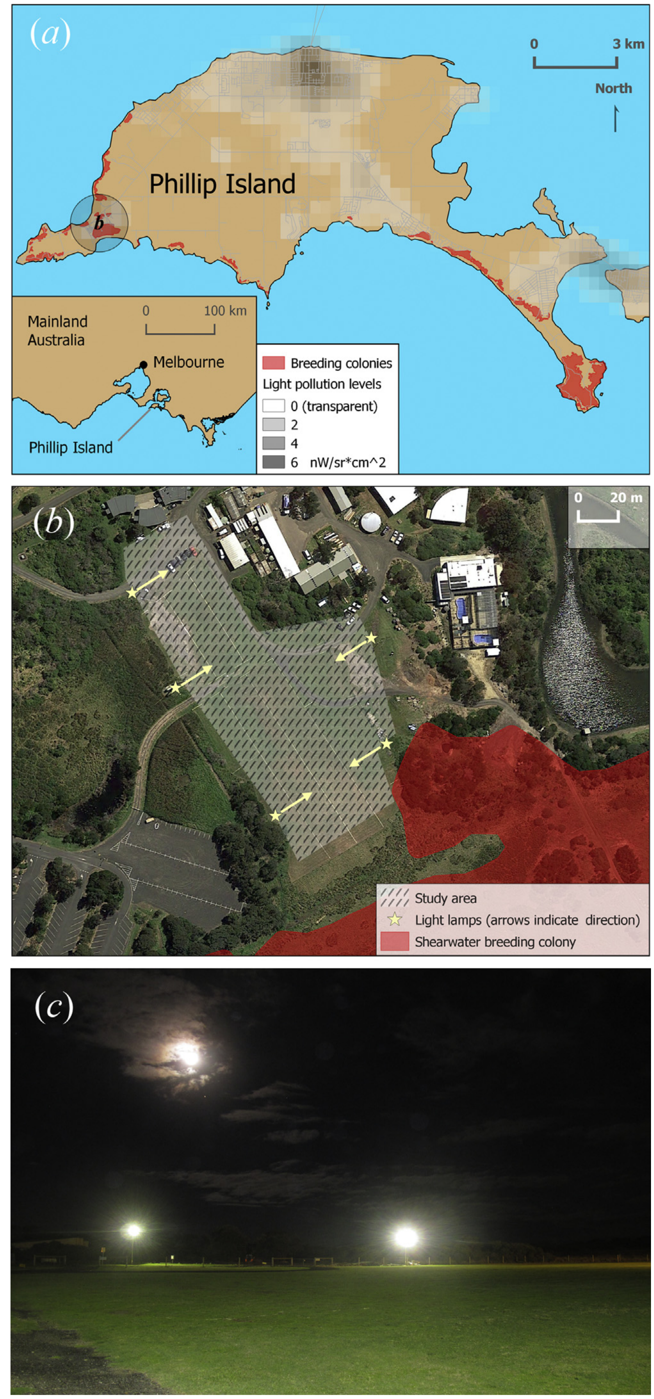

Fig. 1. (*a*) Phillip Island map showing distribution of breeding colonies, study site (grey circle) and light pollution levels taken from a nocturnal satellite imagery; NOAA National Geophysical Data Center; available at http://ngdc.noaa.gov/eog/viirs/download_monthly.html. (*b*) Map of the study area showing the light posts and the lit area. (*c*) Nocturnal picture showing two light-posts and the moon.

To assess the potential attraction of shearwater fledglings to the three lighting types, we designed an experiment in which every treatment (light type) was replicated every night. We lit the area at night during the fledging period and counted the number of grounded birds on the lit field. The experiment was repeated over three fledging seasons (2014: 22 April-4 May; 2015: 19 April-5 May; 2016: 26–29 April). To account for the high variability in number of groundings from night to night, we turned on each lighting type for one hour in a random order each night. The same type

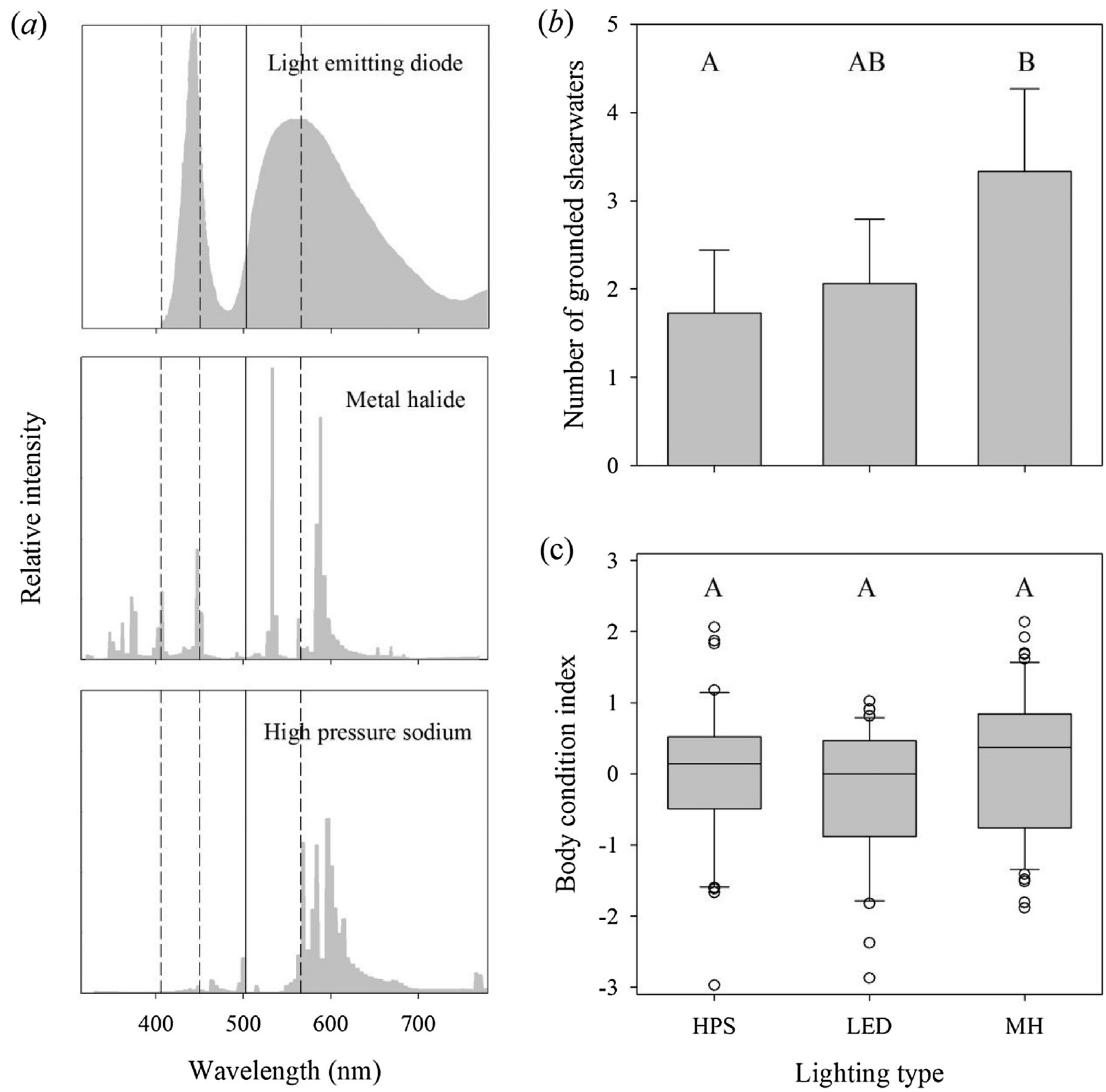

Fig. 2. Spectral composition (*a*) of the lighting types used (data provided by manufacturer). Vertical dashed and solid lines indicate the wavelength of maximum absorbance of visual pigment of cones and rods for *Ardenna pacifica* (Hart, 2004). Mean number per hour (*b*) and body condition (*c*) of short-tailed shearwater fledglings grounded by lighting types. In (*b*) bars show mean ± s.e. Different capital letters indicate significant differences between levels.

Table 1
Characteristics of light systems used in the experiment.

Light	Comercial reference	Lamp Wattage (W)	Color Temperature (K)	Luminous Flux (Lm)
High pressure sodium (HPS)	SON-T 400W/220 E40 1SL	400	2000 (warm)	48000
Metal halide (MH)	MASTER HPI-T Plus 400W/645 E40 1SL	400	4500 (cool)	32000
Light emitting diode (LED)	VBLFL-855-4-40	200	4536 (cool)	18111

of light (MH, HPS and LED) was on in the five masts during each experimental hour. We also had a period of 15-min in darkness between treatments to avoid potential attractive effects of the previous treatment on the birds. First light-treatment was turned on 45–60 min after sunset. We ran the experiments in the first hours of darkness (three experimental hours in total plus two 15-min gaps) as they coincide with the peak of fledging time (Reed et al., 1985; Rodríguez et al., 2015). By randomly sequencing the three treatments, we controlled for any changes in hourly fledgling rate through the night.

Grounded birds were collected and kept in boxes. Each individual was marked with a permanent marker pen on the toe webbing for identification and released in the closest colony at the end of each experimental night. Recaptured birds (five birds) were not included in the analyses. In 2015, body mass (g) and four biometric variables (wing, tarsus, bill length and bill length) were measured from grounded birds in the treatments of the experiment. The biometric variables were taken using an electronic balance (nearest 5 g), a ruler (nearest 1 mm) and an electronic calliper (nearest 0.01 mm). To obtain a size indicator of the grounded birds, we ran a principal component analysis (PCA) on centered and scaled morphometric variables (wing, tarsus and bill length, and bill depth) and the first principal component was used as a body size index (BSI). The first principal component retained 54% of variation. The four morphometric variables showed positive factor loadings (factor loadings: 0.47, 0.51, 0.49 and 0.52 for wing, tarsus, and bill length, and bill depth) and highly significant correlations to the first principal component (Fig. S1). Then, we run a linear model of body mass on BSI (the first principal component). This regression showed a $R^2 = 0.33$ and it was statistically significant ($F_{1,133} = 65.2$, $P < 0.001$). Diagnostic plots indicated that model assumptions were not violated (see Fig. S2). Finally, we extracted the standardized residuals of this model and used them as a body condition index (BCI), where positive and negative values indicate that birds are heavier and lighter than the average in the population, respectively (Green, 2001; Rodríguez, Rodríguez, Curbelo et al., 2012; Rodríguez, Moffett et al., 2017).

To control for the confounding variables noted in the introduction, i.e. fledging time/order and wind strength, moon light and inter-annual breeding success, we added five predictors: 1) Order of light treatment (three-level factor: first, second and third). 2) Quadratic term of fledging date (continuous variable ranging from 19 April to 5 May). 3) Wind speed (km/h) taken from an automated meteorological station located at Rhyll, Phillip Island, and distant 15 km from the study area (Bureau of Meteorology reference: 086373). The station provides wind data every 30 min and we calculated the average for the two readings of each experimental hour (treatment). 4) Moon light or luminance (continuous variable) measured as the percentage of luminance at full moon at zenith at distance equal mean equatorial parallax (Austin, Phillips, & Webb, 1976). We calculated moon luminance for each 10-min periods by using the moonlight Fortran software (Austin et al., 1976) and we assigned the maximum moon luminance to each experimental hour. 5) Year as a three-level factor to account for annual variation in breeding success.

We used generalised linear mixed models (GLMMs) with log link and Poisson error distributions to assess whether the number of grounded birds differs between light treatments (three-level factor). To control for the dependence in the number of grounded birds per light treatment in a single night, night was included as a random factor. To control for confounding variables, i.e. variables affecting the number of attracted birds (see above), we conducted GLMMs adding these predictors plus light treatment factor. To avoid over parameterization, only two predictors were included in each model (light treatment plus predictor). To assess whether body condition of grounded birds differs between lighting types, a linear model was conducted including body condition index as response variable and light treatment as a factor. Models were compared to null models, i.e. including only the intercept, using the 'anova' function (stats package) and assumptions were checked using diagnostic plots (Supplementary material). Statistical analyses were conducted in R version 3.3.2 (R Core Team, 2016). The function 'prcomp' (stats package) was employed to conduct the principal component analysis (PCA). Linear models and generalised linear mixed models were conducted using the functions 'lm' (stats package) and 'glmer' (lme4 package) (Bates, Mächler, Bolker, & Walker, 2015). Model assumptions of generalised linear mixed models were checked through a simulation-based approach using the 'DHARMa' package (Hartig, 2016).

3. Results

A total of 235 short-tailed shearwater fledglings were grounded during the 33 experimental nights (99 h; 33 h for each treatment) in the three annual fledging periods. Pooling all nights, the highest number of grounded fledglings was reached when MH lights were on ($\chi^2_2 = 19.974$; $P < 0.001$; 110, 68 and 57 birds for MH, LED and HPS lights, respectively). Eight out of the 235 birds were killed or subsequently euthanized after fatal collision with the ground or light-posts (4, 3 and 1 birds for MH, LED and HPS lights). The GLMM including just the light treatment was significant with regard to the null model, i.e. including only the intercept term ($\chi^2_2 = 19.209$; $P < 0.001$; Fig. 2*b*). Light treatment was also significant in all the GLMMs including additional variables (all P-values < 0.003; Supplementary material). In 2015, 135 grounded shearwaters were captured and measured. Body condition was similar between the shearwaters grounded by the different lighting types (Fig. 2*c*), as the model was not better than the null model ($F_{2,132} = 1.908$; $P = 0.153$).

4. Discussion

The number of grounded birds differed among light types, with MH being the light type attracting the highest number of the short-tailed shearwater fledglings. LEDs were second highest light type in causing grounded birds, although no statistical differences were apparent in comparison with HPS. Body condition of birds grounded by each lighting type was similar, indicating that attraction power of each lighting type did not depend on body condition, and more interestingly that no lighting system selectively attracted birds with higher survival and recruitment probabilities, i.e. birds in good body condition.

Differences in the number of grounded birds per light type may be explained by the visual systems of shearwaters. The retina of the congeneric wedge-tailed shearwater (*Ardenna pacifica*) have five visual pigments with maximum absorbance at 406–566 nm (Hart, 2004). Assuming a similar visual system, short-tailed shearwater fledglings could be more sensitive to MH and LED lighting, which produce a very cool light (blue) and a wider emission spectrum, than HPS which produces warmer light (red/orange) and low emissions under 550 nm (Table 1; Fig. 2*a*). Thus, shearwaters are likely to perceive lights differently. Given they display an attraction response, heightened perception may lead to heightened attraction. Our results on the higher number of grounded birds by MH and LED than HPS lights, agree with the possibility that MH and LED lights are appreciably brighter for shearwaters than HPS lights, thus increasing the attraction response.

Our results agree with other studies on other taxa in which HPS lights affect behaviour less than MH or LED lights, e.g. bats (Stone, Wakefield, Harris, & Jones, 2015) or invertebrates (Pawson & Bader, 2014), but contrast with those found for songbirds at off-shore platforms. Nocturnal migrating songbirds are more attracted by light with visible long-wavelength radiation (red and white) than by light with less or no visible long-wavelength radiation (blue and green) (Poot et al., 2008). Thus, adopting taxa-specific recommendations for the effect of artificial lights is crucial.

Designing experiments to study the potential attraction of different light types to seabirds is a challenging task, due to the intrinsic seabird natural traits, the low number of colonies and the vast extensions of cities and their associated light pollution (Reed, 1987, 1986; Reed et al., 1985). Reed et al. conducted two field experiments changing light characteristics (polarization and spectra), but failed to reduce light attraction in Newell's shearwaters *Puffinus newellii* (Reed, 1987, 1986). Despite these inconclusive results, light signatures (wavelength and intensity) have been changed around nesting colonies around the world to mitigate light-induced mortality. However, these actions have been conducted without any scientific evidence and their effectiveness has not been appropriately assessed (Rodríguez, Holmes et al., 2017). Our experimental study sheds some light on the potential effect of commercially available lighting systems, providing first-hand information for the lighting management around seabird breeding grounds. If artificial lights cannot be completely avoided, we strongly recommend that HPS lights, or filtered LED and MH lights with purpose-designed filters for lower emission spectra, should be the only external lights used in proximity to shearwater colonies. The type of light must be adopted together with other light reduction actions (KSHCP, 2017). Light should be as dim as possible to be fit the purpose, and should be correctly oriented towards the target area or object to avoid skyward light spill. Shielding and cut-off designs for luminaries can also help to avoid unnecessary light spread and reduce shearwater attraction (Reed et al., 1985). Finally, turning off the lights when not required or using motion sensors to turn on/off the lights would contribute to reducing light pollution (for a complete list of light mitigation actions see KSHCP, 2017). More research is needed to further understand the role of emission spectra on the potential attraction of seabirds and the impact of seabird-friendly lighting on sympatric organisms.

Competing interests

The authors declare no competing interests.

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Ethics

Procedures were approved by the Animal Ethics Committee, Phillip Island Nature Parks (Project 1.2014), and the Department of Environment and Primary Industries, Victorian State Government (Permit 10007170).

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jnc.2017.07.001.

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DAVID Y. IGE
GOVERNOR OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

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AQUATIC RESOURCES
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KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF FORESTRY AND WILDLIFE
1151 PUNCHBOWL STREET, ROOM 325
HONOLULU, HAWAII 96813

February 24, 2022

Rowena M. Dagdag-Andaya, Director
County of Maui Department of Public Works
Engineering Division
200 South High Street
Room No. 410
Wailuku, Maui, HI 96793

Dear Ms. Dagdag-Andaya,

Subject: Request for consultation for proposed streetlight replacement at various locations; DPW Project No. 22-44

The Department of Land and Natural Resources, Division of Forestry and Wildlife (DOFAW) has received the subject request for consultation. As General Electric has ceased the production of high-pressure sodium (HPS) light fixtures, the Department of Public Works (DPW) proposes to replace those lights when they are broken or burnt-out with new light-emitting diode (LED) fixtures. DPW seeks concurrence that the replacement of the HPS lights with LED lights is exempt from the preparation of an environmental assessment (EA), pursuant to Chapter 343, Hawaiʻi Revised Statutes (HRS). Pursuant to §11-200.1-15, Hawaiʻi Administrative Rules, exemptions from the preparation of an EA are provided for certain categories of projects that will individually and cumulatively probably have minimal or no significant effects.

DOFAW appreciates the intent to replace broken streetlights in compliance with lighting standards identified in §201-8.5, HRS. However, we have documented incidences of protected seabirds being downed at LED streetlights reported to have been rated at 4,000 Kelvin or less. The Division of Aquatic Resources is additionally concerned with the impacts of lighting on the nesting success of both ESA endangered hawksbill and threatened green sea turtles on Maui. We therefore recommend that those replacement LED lights being installed under an exemption from preparation of EA be designed or filtered so as to have a correlated color temperature of 2200 Kelvin or less, or a blue light content of less than 2%. Blue light content refers the ratio of the amount of energy emitted by the outdoor light fixture between 400 and 500 nm, divided by the amount of energy between 400 and 700 nm. LED lights with these specifications have been found to have fewer impacts on protected wildlife, including seabirds and turtles, and are consistent, for example, with lighting ordinances on the island of Hawaiʻi.

If you have any questions, please contact Paul Radley, Protected Species Habitat Conservation Planning Coordinator at (808) 295-1123 or paul.m.radley@hawaii.gov.

Sincerely,

DAVID G. SMITH
Administrator