MAUI NUI SEABIRD RECOVERY PROJECT

Best Management Practices to Protect Endangered and Native Birds at Solar Installations in Hawaiʻi

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2021

TABLE OF CONTENTS

Abstract

Solar Energy facilities in Hawaiʻi are a growing major source of low carbon emission energy generation as the state strives to reduce emissions of greenhouse gasses to prevent the worst predictions of global climate change. It is incumbent upon developers of these facilities to consider wildlife impacts and take measures to mitigate for them. While the technology is relatively new there are evolving best management practices that should be undertaken. We identify five endangered waterbird species, three listed seabird species, and one raptor of conservation concern, that have been or may be at risk from solar energy generation facilities in Hawaiʻi. In addition, there are migratory species: fifteen waterbirds and seventeen shorebirds that may be vulnerable. We review relevant literature for impacts and consequences of wildlife interactions with solar energy facilities and recommend best management practices to minimize wildlife impacts. Design considerations for minimizing wildlife impacts are identified, and must be implemented and followed by monitoring to identify and quantify downed wildlife incidents and further development of effective mitigation strategies.

1. Purpose

This document aims to outline the potential impacts to Threatened and Endangered avifauna in the Hawaiian Islands from the ongoing expansion of solar energy projects; to outline the need for robust, high quality pre-and-post construction monitoring to be included universally as a condition of planning permits; to suggest possible minimization and mitigation efforts that can be put in place now, or that require additional research to assess need and efficacy; and to advocate for that research to occur. The document is intended for decision makers at county and state level, as well as for landowners and developers of solar arrays.

We fully support the development of the solar industry in the islands. Our work is intended to ensure that potential bird impacts are considered early so that the industry is not adversely affected if bird collisions are identified as a critical problem at a later date.

2. Introduction

The use of solar facilities – an important source of renewable energy - is rapidly expanding across the State of Hawaiʻi. The investment in renewable energy by electricity providers is a key element in the overall strategy aimed at reducing Hawaiʻi's carbon emissions to curb climate change and meeting state climate goals.

Solar energy is a new and developing technology. As a result, understanding whether there are any potential impacts of solar facilities on native wildlife is in its infancy both nationally and internationally. To date, the main impacts that have been identified so far relate to two types of light pollution which can be produced by solar energy facilities: ecological light pollution (ELP; Longcore and Rich 2004) from lighting around the facility; and polarized light pollution (PLP; Horváth et al. 2009) which is produced at high levels by facilities using photovoltaic solar panels (Lovich and Ennen, 2011). ELP can result in grounding of birds attracted to light (such as seabirds). PLP can result in what is known as the 'lake effect' where birds mistakenly land on solar fields assuming that they are water bodies, leading to injury or death. There is broad agreement that further research is needed to assess impacts of both types of light pollution on birds (Birdlife International, 2020) but waterbird and seabird mortality has already been found to be a significant factor at some solar fields on the mainland (see section 2.1).

Hawaiʻi is home to critically important populations of threatened and endangered species. There is thus a clear concern that solar facilities within the Hawaiian Islands may cause injury or death to some of the rarest birds in the world. Interactions between solar power facilities and birds are likely to differ between habitats (Smith and Dwyer 2016) and Hawaiʻi's isolation and unique ecosystems may amplify these differences and their consequences.

As the construction of solar facilities expands, it is important that the State, developers and land owners ensure that any possible impacts to endangered and threatened birds in Hawaiʻi are investigated at an early stage through robust pre- and post-construction monitoring, as well as independent research, and that possible minimization and mitigation efforts are trialed for local

conditions. This will improve our understanding of potential risks and ensure that future sites can implement improved mitigation/minimization options in the design phase, rather than through expensive retrofits. It will also help companies to avoid future lawsuits involving endangered species. Leroy et al (2015) note that for the solar industry, '*participating in research to address wildlife impact challenges in the early stages of the growth of this energy sector may help avoid situations that the wind industry experienced, in which informative research was delayed or conducted under study designs that did not adequately address the issues.*'

2.1. Species Likely to Interact with Solar Facilities

- Endangered and Threatened Waterbirds

Hawaiʻi supports populations of endangered waterbird species. These are the:

- ʻalae ula - Hawaiian common gallinule (global popn: approx. 1000 individuals).
- ʻalea keʻokeʻo - Hawaiian coot (*Fulica alai)* (approx. 2,000 individuals) **An ʻalae keʻokeʻo has already been found dead at the Lawai solar field in Kauaʻi**
- koloa maoli - Hawaiian duck (*Anas wyvilliana)* (global popn: approx. 1000 individuals; Kauaʻi holds highest populations and those the least at threat from hybridization with Mallard);
- aeʻo - Hawaiian stilt (*Himantopus mexicanus knudseni)* (global population approx. 1000 individuals)
- nēnē – Hawaiian goose (*Branta sandvicensis)* (approx. 3159 global popn).

The island of Kauaʻi is particularly important for waterbirds and holds the largest population of nēnē, ʻalae ʻula, and pure bred koloa maoli. Oʻahu is also important for ʻalae ʻula, as the only other island which has this species.

- Endangered and Threatened Seabirds

Hawaiʻi also supports populations of endangered seabird species

- ʻaʻo - Newell's shearwater (*Puffinus newelli)*
- ʻuaʻu - Hawaiian petrel (*Pterodroma sandwichensis)*
- *ʻakēʻakē – Band-rumped storm-petrel (Hydrobates castro)* – genetic studies have shown that the Hawaiian population of this species may actually be a distinct sub-species or species.

Again, Kauaʻi is particularly important for all of these species, with 90% of the world population of ʻaʻo and a third of the ʻuaʻu. Maui Nui (Maui & Lānaʻi) hold important populations of ʻuaʻu.

- Other birds of conservation importance
  - Pueo – Hawaiian short-eared owl (*Asio flammeus sandwichensis*); Oahu-listed as endangered,
  - a wide variety of migratory shorebirds and waterfowl (see Appendix 1)

3. Understanding Potential Impacts to Native Avifauna

Understanding whether there could be a potential impact from solar fields is a conservation priority as well as a legal obligation due to the importance of the endangered bird populations outlined in above. There is a clear body of evidence from the mainland USA and internationally, that birds can confuse solar arrays with water sources due to the "lake effect" and attempt to land on them, dying in the process or being injured and/or subsequently depredated. Birds may collide with panels that reflect the sky, mistaking them for 'safe passage' (Huso et al, 2016). They are also at risk from collision with powerlines and other infrastructure connected to the facility and from electrocution (Hathcock, 2018), as well as light attraction from lights connected with the solar fields and surrounding infrastructure. Once downed, these birds often cannot take off again due to injuries, the lack of a water runway (Huso et al, 2016), inadequate wind, insufficient slope, etc. While research into these issues is still in its infancy and is poorly funded, multiple studies have demonstrated these risks, including:

3.1. Waterbirds

- Horvath et al (2009) note that artificial polarizers (smooth, dark buildings, or other human-made objects, that create linear polarization by reflecting light off or by scattering in the atmosphere or hydrosphere at unnatural times or locations) can serve as 'ecological traps that threaten populations of polarization-sensitive species' and that landing on these artificial reflectors can be lethal.
- Grippo et al. (2014) note that water polarizes sunlight and serves as a visual cue that attracts waterbirds; solar panels polarize light more strongly than water and as a result, attract waterbirds 'resulting in mortality'. At California Valley Solar Ranch, H.T. Harvey and Associates (2015) observed two American coots (*Fulica americana*) and one pied-billed grebe (*Podilymbus podiceps*) fatalities during monitoring work and concluded that they likely had "*confused the arrays for water bodies and either collided with a panel or landed in the array…… Considering the life history of these species and the lack of suitable habitat on-site, the three fatalities were considered collision*". During the period of 16 August 2013 to 17 November 2014, a total of 453 avian fatalities, of 36 identified species and 5 unknown species groups, were recorded. According to the consultants, seventy-three (17.0%) were believed to have died as a result of a collision (65 with powerlines, 7 with solar panels, and 1 with a perimeter fence).
- Kagan et al. (2014) also studied the Desert Sunlight Solar Farm, which had long banks of photovoltaic panels, providing a continuous, sky/water appearance (the site also had ponds present). Waterbirds had particularly high mortality at Desert Sunlight. Birds found dead at the facility included individuals from 11 different waterbird species including various ducks, American avocet (*Recurvirostris americana*) and black-crowned night-heron (*Nycticorax nycticorax*) (analogous to Hawaiian duck, Hawaiian stilt and black-crowned night heron). Blunt force impact trauma was determined to have been the cause of death for 19 birds at Desert Sunlight including two Western grebes (*Aechmophorus occidentalis* - analogous to Hawaiian coot, Hawaiian moorhen and one each of 16 other species. (Kagan et. al. 2014). Predation was also an issue and was associated with strandings and trauma from non-fatal impact with the panels, leaving the birds vulnerable to resident predators." Kagan notes that '*A desert environment punctuated by a large expanse of reflective, blue panels may be reminiscent of a large body of water. Birds for which the primary habitat is water, including*

coots, grebes, and cormorants, were over-represented in mortalities at the Desert Sunlight facility.'

- Walston et al (2016) note that collision-related mortality resulting from the direct contact of the bird with a solar project structure has been documented at solar projects of all technology types. He found that different solar technologies and project designs may influence avian mortality risk; project designs that utilize constructed cooling ponds, or reflect polarized sunlight in such a way so as to be perceived as waterbodies, may attract birds and their prey (e.g., insects), thereby increasing the risk of bird collisions with project structures
- On Kaua'i, in 2018, a dead endangered Hawaiian coot was brought to the Save Our Shearwaters Program – the bird had been found dead at the Lawai Solar Facility.

3.2. Seabirds

Little data is available on the potential impact to endangered seabirds, but it seems possible that fledgling seabirds in particular could be attracted to these facilities during the fallout season – polarized light reflecting off photovoltaic panels could look like the ocean, resulting in birds landing on them. This could be further amplified by surrounding lighting, which is already a major source of grounding on multiple Hawaiian Islands.

Two endangered seabird species – the Newell's shearwater *Puffinus newelli* and the Hawaiian petrel *Pterodroma sandwichensis* – are extremely vulnerable to light attraction, with tens of thousands of birds grounded since the late 1970s on Kaua'i (Reed et al. 1985, Telfer et al. 1987, Raine et al. 2017). Maui and Lāna'i also have light attraction issues for Hawaiian petrels. The same is true for Wedge-tailed shearwater *Ardenna pacifica,* large numbers of which are attracted to lights across the Hawaiian Islands annually. If not retrieved, such birds have a very high mortality rate as they are disorientated, have great difficulty getting airborne once on flat ground and either die due to dehydration and starvation, are killed by cats and dogs, or run over by cars. While fledglings are the main age group attracted to light, small numbers of adults are also downed every year – particularly if bright lights are found near breeding colonies or on regular transit coridors (flyways) to these colonies (such as the fallout events that occurred on Kaua'i at the Koke'e Airforce Station in 2015).

4. Existing Solar Facilities and Current Monitoring

The islands already have a large number of solar facilities, with 70 in total either operational or in development across the state (Kauai 10, Maui 9, Lāna'i 1, Hawai'i 8, O'ahu 40, Kaho'ohawe 1, Molokai 1) and this sector is growing rapidly. For example, the Hawaiian Electric RFP resulted in eight contracts (six new projects on Oahu and two on Maui) for new grid scale renewable energy projects in 2020. Monitoring requirements are not standard, and in most cases, may not be adequate to fully assess bird impacts; planning approval may be being granted with inadequate consideration of the likely impacts to endangered birds in many cases. It is imperative that action is taken now to ensure that this situation is reversed

See Appendix 2 for a full list of facilities.

5. Best Management Practices

To ensure that bird mortality is kept to a minimum at existing and future solar facilities across the state of Hawaiʻi, we have developed the following suite of recommendations.

5.1. Initial pre-construction proposal assessment

- Sites for new solar development should be selected using the precautionary principle (BirdLife International, 2020). That must include avoiding areas in the vicinity of wetlands, seabird colonies or on confirmed major seabird flyways.
- Jenkins et al. (2017) provides details on what should be considered under an EA to ensure avian impacts are fully understood.

5.2. Recommended Monitoring Protocols

A well-designed monitoring strategy should be developed with defensible methodologies. These should include regular surveys, carcass removal trials and searcher efficiency trials, as well as having observers at the facilities (both general staff and specialist observers). Similar monitoring of this nature has already been carried out on Kauaʻi by the Kauai Endangered Seabird Recovery Project (see, for example, Travers et al., 2016) in light attraction hotspots. Huso et al., (2016) note that monitoring must estimate total mortality as well as identifying location (exact location and likely cause), season (e.g. during fall out season for seabirds or when seabirds are on island, seasonal fluctuations in predators, etc.) and day/night patterns (to accurately assess both nocturnal and diurnal species) to help managers take appropriate actions to reduce mortality and assess the effectiveness of those management actions. The following should be considered:

- Survey frequency

Surveys for downed birds should be conducted at sufficient frequency to locate all birds before they can be scavenged or seek shelter in dense undergrowth or crawlspaces. For example:

- Kagan et al (2014) recommend daily surveys for at least 2 years (and in addition to any other monitoring protocol) to ensure all bird deaths are recorded accurately.
- The Wind industry has developed searcher efficiency protocols which will be useful for the solar industry. These include Carcass removal (CARE) and searcher efficiency (SEEF) trials. This work allows researchers to assess the take through carcass removal but also create an estimate of unobserved direct take. These estimates are based on results from searcher efficiency and carcass removal results, accounting for individuals that may be killed but that are not found during the monitoring effort for various reasons, including heavy vegetation cover and scavenging (SWCA Environmental Consultants, 2011).
- Huso et al. (2016) also provide a full explanation of the requirements of searcher efficiency.
- On Kauai, under the Kauai Seabird Habitat Conservation Plan, entities are to conduct two daily searches at their facilities for fallout birds – one three hours after dark and one two hours before dawn

- Grounded birds - Survey timing

Surveys in the late afternoon are likely to be optimal for some water bird carcasses. For endangered seabirds, the peak of fallout generally occurs between 15 Sep and 15 Dec, starting an hour after sunset. Searches should therefore commence 3-4 hours after sunset. An additional search should take place within 1-2 hours before sunrise to find birds that were grounded during the night; this will also pick up waterbirds that were moving at night.

- Survey seasonality / time period

The full spectrum of “seasonal” variation present within a complete annual cycle must be sampled (Jenkins et al., 2017), and should take into account all of the species under consideration as well as seasonal fluctuations in predator populations. Thus, for waterbirds in Hawaiʻi, surveys should be conducted throughout the year to take into account all potential waterbird movement patterns. Where threatened and endangered seabirds are present, surveys should be increased further during the seabird fallout season (Sep to Dec), with increased numbers of surveys under the correct timing for fallout as indicated above. Longer terms studies are important to assess change over time and response to management, with particular attention paid to areas where downed birds could hide (such as piles of machinery, dense vegetation, culverts, pipes and other crawl spaces).

- Survey geographical extent

Huso et al. (2016) note that strandings occur when a bird cannot take off due to collision injuries or, after landing safely, lack a body of water or sufficient wind to take off again, or cannot do so due to disorientation. These birds may move away from the point of impact to seek shade. If killed on impact, corpses may be scavenged and moved from the immediate area. Therefore, any searches need to include a wide area to ensure that corpses and hiding birds are discovered.

- Video and dog surveillance.

Kagan et al (2014) recommend installing video cameras with 360 coverage to monitor bird arrival and departure or injury; and using dogs to find dead or injured birds. Cameras have been installed along the perimeter fence and near crawl spaces at Kōkeʻe Air Force Station by the Kauaʻi Endangered Seabird Recovery Project to survey throughout the seabird season for grounded birds. This has been shown to be an effective tool (in conjunction with other monitoring) on at least one occasion, when a downed Newell’s shearwater was recorded on a camera on August 24th 2020; this bird was never physically seen and would have otherwise gone unreported (A Raine, 2020, pers. comm).

5.3. Recommended Minimization Actions

- **Siting**
  Smith and Dwyer (2016) suggest the following:

(1) Avoiding areas of high bird use (e.g., regularly used flight paths, migration corridors, and aggregation areas); (2) Avoiding areas inhabited by sensitive species or those of conservation concern; (3) Avoiding topographical features that promote foraging or that are used by migrating birds for uplift (e.g., the tops of slopes; Kitano and Shiraki 2013); (4) Avoiding areas of high biodiversity, endemism, and ecological sensitivity; (5) Developing conservation buffers for vulnerable species based on thresholds determined through empirical research;

- **Predator control and / or fencing** for rats including *Rattus rattus, Rattus exulans* and *Rattus norvegicus*, cats (*Felis catus)*, barn owl (*Tyto alba)*, dogs (*Canis lupus familiaris)*, pigs (*Sus scrofa)* and mongoose (*Herpestes auropunctatus)* should be carried out at all sites as standard practise so that if birds are attracted to the solar fields and injured on impact or unable to get airborne again, they are not depredated before they can be found (Hathcock, 2018). Predator control on Hawaiʻi for feral cats in particular requires an expert to ensure that cats do not have the chance to become trap shy.
- **Lighting.** See Appendix E of the Kauaʻi Seabird Habitat Conservation Plan (KSHCP) for full details on lighting requirements to prevent seabird attraction (included as Appendix 3 of this document and at https://dlnr.hawaii.gov/wildlife/files/2016/03/DOC439.pdf). Lighting should be orientated so it does not reflect off of white or reflective walls of buildings https://dlnr.hawaii.gov/wildlife/files/2019/09/0-KSHCP_Draft_compiled-1.pdf
- **Markers or reflectors on wires** should be affixed to all possible powerline and support wire collision hazards. Wires should be assessed for their risk to seabirds and amended if necessary (Kagan et al., 2014). Recent work on Kauai by KESRP have shown that attaching diverters (either non-lit or LED) may be particularly useful for reducing seabird collisions on powerlines (Travers et al 2021)
- Steps should be taken to **reduce the attractiveness of solar panels** to birds:
  - Leroy et al (2015) describe the Lake Effect Hypothesis which suggests that water-dependent bird species may potentially mistake the extensive solar arrays for water features on which the birds can land, usually at night. Such collisions often do not result in direct mortality, but the birds sometimes cannot take off after collisions because they are adapted to take off from water, not dry land – collisions can also lead to broken wings or legs. One possible solution is to use panels which can tilt upright overnight, and thus look less like water. Endangered seabirds only fly at night and waterbirds tend to make longer distance flights only at night. Research into this mitigation option could be written into project proposals.
  - Horvath et al (2010) also found that white borders are effective in reducing the attractiveness of solar panels to aquatic insects (Anderson, 2014). Black and Robertson (2019) also found that the addition of white, non-polarizing gridding with 2–20 mm line width to solar panels can reduce the attractiveness of solar panels to insects, with a line width of 1-5mm. It is unclear if this will also help birds to avoid the panels. Research into this mitigation option could be written into project proposals.
  - Fear of predation is an effective deterrent. The sounds of predators or the distress calls of prey species are the basis for many deterrent technologies and could be trialled, as could plastic decoys such as owls or raptors to scare off native bird species. This could be a particularly cost-effective solution.

    - Bio-acoustic deterrent can be combined with bird radar connected to speakers: DeTect Inc. have been developing this technology to detect incoming birds then activating speakers playing distress calls / sirens etc.
- It has been suggested that technologies such as three-dimensional solar cells, that use vertically aligned arrays of carbon nanotubes, may generate less polarized light pollution (Camacho et al. 2007; Currie et al. 2008 Horvath et al 2010).

5.3.1 Recommended Mitigation

Recognizing that solar facilities are likely to result in the death of endangered birds (given the overwhelming evidence for this on the mainland), mitigation projects should be developed in tandem with solar facility designs. An early start is important because mitigation projects usually have a lag time before they start producing birds. In Europe, the European Commission proposes that such mitigation projects be supported using a percentage of revenue from solar facilities (Science for Environment Policy, 2015). That might include creating or restoring wetlands elsewhere; financially supporting existing endangered seabird or waterbird conservation projects; and supporting research projects to better understand the impacts of solar facilities on endangered seabirds and waterbirds in Hawaiʻi.

6 Conclusion

As yet, there is little information on the level of threat that solar fields present to endangered waterbirds and seabirds in Hawaiʻi. There is however clear evidence that waterbirds can be attracted to these types of facilities on the mainland, and that they can die of collision injuries or predation because of this. Seabirds may be similarly at risk. Hawaiʻi has a large number of threatened and endangered seabirds and waterbirds that might be at risk from solar arrays. One endangered bird has already been found dead at a solar array in the islands. It is therefore critical that a well-designed monitoring, minimization and mitigation strategy should be developed in advance with defensible methodologies as outlined above for existing and future solar facilities across the state.

This should include more attention to detailed and stringent EA requirements, as outlined in Jenkins et al. (2017); and a requirement for all solar facilities to carry out ongoing, year-round, geographically appropriate and high-quality bird strike and attraction monitoring including SEEF and CARE protocols. Useful tools may include video and dog surveillance.

Minimization activities should include following the precautionary principle and siting solar arrays away from wetlands, seabird colonies, confirmed major seabird flyways and other considerations as outlined in Smith and Dwyer (2016); predator control and / or fencing; reduced lighting, particularly in seabird fallout season; markers or reflectors on wires; and measures to reduce the attractiveness of solar panels to birds. Developers should also consider mitigation programs early.

Thoughtful preparation and planning can avoid costly and delaying litigation and expensive retrofitting. We all want solar power to succeed but it requires planning rather than reacting.

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Appendix 1 – Vulnerability matrix for endangered, threatened and migratory birds in Hawaiʻi

Hawaiian Name	Common Name	Scientific Name	IUCN Status	USFWS status	DLNR Sp Gt. Cons Concer	Vulnerability to solar	Vulnerability notes	Key Islands	Population size HI	Pop size globally
Waterfowl										
Nēnē	Hawaiian Goose	*Branta sandvicensis*	VU	EN (cand. downlisting)	x	H	avoid locations with high counts of Nene	Kauai, Hawaii, Maui, Molokai	3,159 birds (Maui 512, Molokai 28, Kauai 1545, Hawaii 1072, Oahu 2)	HI endemic
Koloa Maoli	Hawaiian Duck	*Anas wyvilliana*	EN	EN	x	H	avoid locations near wetlands	Kauai, Niihau, Hawaii	908 +/-176 birds	HI endemic
Auku'u	Black-crowned Night-Heron	*Nycticorax nycticorax hoactli*	LC		x	H	avoid locations near wetlands	Kaua'i, O'ahu, Moloka'i, Maui, and Hawai'i	400 (?) birds	570,000-3,730,000
Migratory Waterfowl										
n/a	Snow Goose, *Chen caerulescens* ; Cackling Goose*, Branta hutchinsii; American Wigeon* , *Anas Americana* ; Eurasian Wigeon, *Anas Penelope; Ring-necked Duck* Mallard, *Anas platyrhynchos;* Northern Shoveler, *Anas clypeata* ; Northern Pintail, *Anas acuta;* Green-winged Teal, *Anas crecca* ; Blue-winged Teal, Spatula discors Lesser Scaup, *Aythya affinis* ; Pied-billed Grebe, *Podilymbus podiceps* ; White-faced Ibis, *Plegadis chihi* (red - sp. cons concern)	Although Hawaii not important for US or global populations, several species designated as Cons Concern by DOFAW; flyway has been negatively affected by habitat change in	LC		x	H	avoid locations near wetlands	All		
Waterbirds										
ʻAlae ʻUla	Hawaiian Common Gallinule	*Gallinula galeata sandvicensis*	*n/a*	EN	x	H	avoid locations near wetlands	Kauai, Oahu (50% each)	834 birds +/-170	HI endemic
Alae ke'oke'o	Hawaiian Coot	*Fulica alai*	VU	EN	x	H	avoid locations near wetlands	larger MHI	1729 birds +/- 357	HI endemic
Aeʻo	Hawaiian Stilt	*Himantopus mexicanus knudseni*	n/a	EN	x	H	avoid locations near wetlands	larger MHI	TBC	HI endemic
Shorebirds										
Kolea	Pacific Golden-Plover	*Pluvialis fulva*	LC	n/a	x	M	may be attracted to grassy areas	all	15,000 – 20,000 birds (MHI only - 2004). NWHI ?	190,000-250,000
Kioea	Bristle-thighed Curlew	*Numenius tahitiensis*	VU		x	L	rarely present on kauai	MHI (Oahu mainly), NWHI	up to 65 in MHI (mainly oahu), NWHI (800)	6400 breeding pairs globally
	Black-bellied Plover, *Pluvialis squatarola* ; Semipalmated Plover, *Charadrius semipalmatus* ; Lesser Yellowlegs, *Tringa flavipes* ; Sharp-tailed Sandpiper, *Calidris acuminate* ; Pectoral Sandpiper, *Calidris melanotos* ; Spotted Sandpiper, *Actitis macularius* ; Wandering Tattler, *Tringa incana* ; Ruddy Turnstone, *Arenaria interpres* ; Sanderling, *Calidris alba* ; Least Sandpiper, *Calidris minutilla* ; Long-billed Dowitcher, *Limnodromus scolopaceus* ; Dunlin, *Calidris alpina;* Red Phalarope, *Phalaropus fulicarius* (red - sp cons concern), Whimbrel *Numenius phaeopus.*	*As above*	LC		x	M		all	n/a	

Hawaiian Name	Common Name	Scientific Name	IUCN Status	USFWS status	DLNR Sp Gt. Cons Concer	Vulnerability to solar	Vulnerability notes	Key Islands	Population size HI	Pop size globally
Seabirds										
Mōlī	Laysan Albatross	*Phoebastria immutabilis*	NT	SC	x	M	depends on location; avoid locations near colonies	NWHI, MHI	1.7 million birds (over 850,000 breeding pairs); 610 MHI, mainly Kauai, Oahu, Lehua, remainder NWHI.	NWHI is >99% global pop
Ka'upu	Black-footed Albatross	*Phoebastria nigripes*	NT	SC	x		currently not present but may be translocated	NWHI, MHI	67,830 breeding pairs NWHI (mainly Midway & Laysan), 45 MHI (Lehua, Kaula)	70,069 breeding pairs
Ua'u	Hawaiian Petrel	*Pterodroma sandwichensis*	EN	EN	x	H	attraction possible at night	MHI	5,995 pairs (Kauai 1,500, Molokai 50, lanai 2,500, Maui 1,600, Hawaii 300)	HI endemic
	Kermadec Petrel	*Pterodroma neglecta*	LC			L	depends on location, pair attempting breeding for first time in Kauai	up to 3 birds prospecting or possibly breeding, Kilauea, Kauai,	0-3 birdsividuals	150,000-200,000 birds.
Ua'u kani	Wedge-tailed Shearwater	*Ardenna pacifica*	LC		x	H	depends on location; avoid locations near colonies	NWHI, MHI, MARI, *REMO, ASAM*	87,825 breeding pairs MHI (mainly Lehua, Kauai, Oahu, Maui), 230,050 MWHI (mainly Laysan, Nihoa, Lisianski)	5,200,000 individuals
'A'o	Newell's Shearwater	*Puffinus newelli*	EN	TH	x	H	attraction possible at night	MHI	MHI 10,330 (mainly Kauai, small numbers Molokai, Maui, Hawaii)	HI endemic
ʻAkeʻake	Band-rumped Storm-Petrel	*Oceanodroma castro*	LC	EN	x	M	attraction possible at night	MHI (Kauai, Kahoolawe, Hawaii), suspected Lehua, Maui, Molokai	330 breeding pairs (250 Kauai, 30 Maui, 50 Hawaii)	Worldwide pop unknown, but likely less than 25,000 breeding pairs.
Koa'e'kea	White-tailed Tropicbird	*Phaethon lepturus dorotheae*	LC		x	M	depends on location; avoid locations near colonies	NWHI, MHI, *MARI, REMO, ASAM*	1,500 breeding pairs MHI (mainly Kauai), NWHI 5 pairs on Midway	50,000 individs
Koa'e'ula	Red-tailed Tropicbird	*Phaethon rubricauda*	LC		x	M	depends on location; avoid locations near colonies	1035 MHI (mainly Kauai and kaula), 12,800 NWHI (mainly midway, laysan, Kure, lisianski)	12,800 pairs NWHI; 1025 MHI	32,000 individs
Iwa	Great Frigatebird	*Fregata minor palmerstoni*	LC		x	L		NWHI, MHI, *MARI, REMO, ASAM*	MHI ? (Moku Manu 0 - 1, Kaʻula 250 – 350). NWHI 10,445 breeding pairs: Nihoa 4000, Laysan 3500, FFS 700, Necker 800, Lisianski 800, Pearl &	up to 1,000,000
ʻĀ	Red-footed Booby	*Sula sula rubireps*	LC		x	L		NWHI, MHI, *MARI, REMO, ASAM*	MHI 4,500 breeding pairs (mainly Kauai, lehua, oahu). NWHI 7950 (mainly FFS, Nihoa, Kure)	345,000 pairs
Migratory Seabirds										
	Black-winged Petrel, *Pterodroma nigripennis* ; Sooty Shearwater, *Ardenna grisea* ; Leach's Storm-Petrel, *Oceanodroma leucorhoa* ; Pomarine Jaeger, *Stercorarius pomarinus;* Laughing Gull, *Leucophaeus atricilla;* Glaucous-winged Gull, *Larus glaucescens* ; Ring-billed Gull, *Larus delawarensis*	*These are non breeders, generally seen on migration only. Hawaii unlikely to be very important for global pop*	LC (expt sooty shear - NT, leach's storm petrel - VU)			L				
Birds of Prey										
Pueo	Hawaiian Short-eared Owl	*Asio flammeus sandwichensis*	sub sp not recognised?	x (listed EN Oa		H	may be attracted to grassy areas	all	unknown statewide. Only 11 birds in Oahu?	HI endemic

Appendix 2 – Solar Facilities in Hawai‘i

Project Name	Developer	Owner	Location	Capacity	Status	Tax Map Key	Acres	Landowner
KAUAI				P - Proposed / developing. O - operational				
AES Kekaha Solar (PMRF)	AES Distributed Energy, Kauai Island Utility Cooperative		Barking Sands, Kekaha	14MWac + 70MWh Storage	P/U	(4)1-2-002:013		
AES Lawai Solar	AES Distributed Energy, Inc.		Lawai	20MWac + 100MWh Storage	O	(4)2-6-003:001		
Kapaa Solar Project	Kapaa Solar, REC Solar		Kapaa	1 MW	O	(4)4-3-003:001		
KRS1 Anahola Solar Farm	Kauai Island Utility Cooperative, REC Solar, Homestead Community Development Corporation	Homestead Community Development Corporation ?	Anahola	12 MWac	O	(4)4-7-004:002	55	DHHL
KRS2 Koloa Solar Farm	Kauai Island Utility Cooperative, SolarCity, Grove Farm	Homestead Community Development Corporation ?	Koloa	12 MWac	O	(4)2-8-002:002	67.25	DHHL
MP2 Kaneshiro Solar Project	Kauai Island Utility Cooperative (KIUC), REC Solar		Lawai	300 kW	O	(4)2-7-003:005		
Port Allen (McBryde) Solar Facility	Alexander & Baldwin / McBryde Resources, Hoku Solar, Helix Electric		Eleele	6 MW	O	(4)2-1-001:051		
SolarCity Tesla Solar Project	Kauai Island Utility Cooperative (KIUC), SolarCity Corp., Tesla, Inc.	Tesla	Lihue	13 MWac / 17 MWdc	O	(4)3-8-003:001		Grove Farm
Waimea Research Center (Pioneer) PV	Pioneer Hi-Bred International, Inc., Dupont, REC Solar		Waimea Research Center	250 kW	O			
Wilcox Memorial Hospital Solar Farm	Sunetric, Hawaii Pacific Health Partners		Lihue	504 kW	O			
MAUI								
AES Kuihelani Solar	AES Distributed Energy, Inc.		Waikapu	60MWac + 240MWh Storage	P/U	(2)3-8-005:002	500	A&B
Kahana Solar	Innergex		Napili-Honokowai	20 MWac + 80 MWh	P/U	(2)4-3-001:017	220	Maui Land and Pineapple Inc
Kamaole Solar	SB Energy Corp.		Kihei	40 MWac + 160 MWh	P/U	(2)2-2-002:050 & 001	320	
KIRC Solar Array + Storage	Kahoolawe Island Reserve Commission, Maui Community College		Kahoolawe	100 kW	O	(2)2-1-001:001		
Kuia Solar Project	Hawaii Pacific Solar, Haleakala Energy Associates, Kenyon Energy (SSA Solar of HI 2), M+W Energy, Bay4 Energy, Sun Financial		Lahaina	2.87 MWac / 3.794 MWdc	O	(2)4-5-018:003	11	Kamehameha Schools
Paeahu Solar	Innergex Renewable Energy, Inc.		Wailea	15 MW + 60 MWh BESS	P/U	(2)1-9-008:001	200	Ulupalakua Ranch
Pulehu Solar	Longroad Energy		Pulehu	40 MWac + 160 MWh	P/U	(2)2-5-001:003 & 004	336	Haleakala Ranch
South Maui Renewable Resources Solar Project	Hawaii Pacific Solar, Haleakala Energy Associates, Kenyon Energy (SSA Solar of HI 3), M+W Energy, Bay4 Energy, Sun Financial		Kihei	2.87 MWac / 3.794 MWdc	O	(2)2-2-002:084	12	
University of Hawaii-Maui Solar + Battery Project	Johnson Controls		Kahului - parking lot canopies	2.8 MW + 13.2 MWh BESS	O	(2)3-8-007:040		

Project Name	Developer	Owner	Location	Capacity	Status	Tax Map Key	Acres	Landowner
LANAI								
La Ola Solar Farm (Lanai Sustainability Research)	Castle & Cooke, SunPower, Xtreme Power, Pulama Lanai		Lanai City	1.2 MWac	O	(2)4-9-002:001	10	
HAWAII								
AES Waikoloa Solar	AES Distributed Energy, Inc.		Waikoloa	30MWac + 120 MWh Storage	P/U	(3)6-8-002:050		
Cyanotech Solar Array	Cyanotech Corporation, Neighborhood Power Company (NPC)		Kailua-Kona	500kW	O	(3)7-3-043:063		
Hale Kuawehi Solar	Innergex Renewable Energy Inc., Paniolo Power Co.		Waimea	30 MW + 120 MWh BESS	P/U	(3)6-7-001:025		
Hawaii SunShot Desal Project	Natural Energy Laboratory of Hawaii Authority (NELHA), Trevi Systems Inc., Hawaii First Water LLC, Cyanotech		Kailua-Kona	Demonstration	P/U	(3)7-3-043:080		
Ocean View FIT Solar Projects (26)	SPI Solar, Inc., Calwaii Power Holdings, LLC, various LLCs		Ocean View	250 kW x 26 (6.5 MW)	P/U	Various		
Parker Ranch Microgrid	Parker Ranch (Paniolo Power), Go Electric Inc., Rising Sun Solar		Waimea	400 kW	P/U	(3)6-7-001:025		
Puako Solar PV + Battery Storage	ENGIE Development LLC		Puako, South Point	60 MWac + 240 MWh	P/U	(3)6-8-001:024		
Waikoloa Village Solar	EDF Renewables, Inc.		Waikoloa	60 MWac + 240 MWh	P/U	(3)6-8-002:018 & 019		

Project Name	Developer	Owner	Location	Capacity	Status	Tax Map Key	Acres	Landowner
LANAI								
La Ola Solar Farm (Lanai Sustainability Research)	Castle & Cooke, SunPower, Xtreme Power, Pulama Lanai		Lanai City	1.2 MWac	O	(2)4-9-002:001	10	
HAWAII								
AES Waikoloa Solar	AES Distributed Energy, Inc.		Waikoloa	30MWac + 120 MWh Storage	P/U	(3)6-8-002:050		
Cyanotech Solar Array	Cyanotech Corporation, Neighborhood Power Company (NPC)		Kailua-Kona	500kW	O	(3)7-3-043:063		
Hale Kuawehi Solar	Innergex Renewable Energy Inc., Paniolo Power Co.		Waimea	30 MW + 120 MWh BESS	P/U	(3)6-7-001:025		
Hawaii SunShot Desal Project	Natural Energy Laboratory of Hawaii Authority (NELHA), Trevi Systems Inc., Hawaii First Water LLC, Cyanotech		Kailua-Kona	Demonstration	P/U	(3)7-3-043:080		
Ocean View FIT Solar Projects (26)	SPI Solar, Inc., Calwaii Power Holdings, LLC, various LLCs		Ocean View	250 kW x 26 (6.5 MW)	P/U	Various		
Parker Ranch Microgrid	Parker Ranch (Paniolo Power), Go Electric Inc., Rising Sun Solar		Waimea	400 kW	P/U	(3)6-7-001:025		
Puako Solar PV + Battery Storage	ENGIE Development LLC		Puako, South Point	60 MWac + 240 MWh	P/U	(3)6-8-001:024		
Waikoloa Village Solar	EDF Renewables, Inc.		Waikoloa	60 MWac + 240 MWh	P/U	(3)6-8-002:018 & 019		
OAHU								
AES West Oahu Solar Plus Storage	AES Distributed Energy, Inc.		Kapolei	12.5MWac + 50MWh Storage	P/U	(1)9-2-002:007		
Aloha Solar Energy Fund I	Aloha Solar Energy Fund I, LLC, Altus Power America, Inc.		Nanakuli	5MWac	O	(1)8-7-010:020		
Aloha Solar Energy Fund II	Aloha Solar Energy Fund II, LLC, ECC Energy Solutions, LLC, REC Solar		Kalaeloa	5MWac	O	(1)9-1-013:070		
Barbers Point Solar	Innergex		Kapolei	15MWac + 60MWh Storage	P/U	1(1)9-1-013:038 & 040		
Coconut Island Microgrid	Hawaii Natural Energy Institute		Kaneohe Bay	500kW	P/U			
Dole Plantation Solar Arrays	REC Solar		Wahiawa	647 kWdc	O	(1)6-4-003:008		
H-POWER Photovoltaic Systems	City and County of Honolulu		Kapolei (Campbell Industrial Park)	3 - 3.5 MW	P/U	(1)9-1-026:030		
Hawaii American Water Solar Array	Hawaii American Water Co., Islandwide Solar LLC		Hawaii Kai	250 kW	O	(1)3-9-015:025		

Project Name	Developer	Owner	Location	Capacity	Status	Tax Map Key	Acres	Landowner
OAHU cont.								
Hawaii FIT Forty, LLC	Distributed Energy Partners		Waianae	570 kWdc	O			
Hawaii FIT Two	Distributed Energy Partners		Waianae	596.7 kWdc	O			
Hoohana Solar 1	174 Power Global, Hanwha Energy Corporation, Forest City Sustainable Resources		Kunia	52 MW + 218 MWh BESS	P	(1)9-4-002:052		
Kahumana PV	Holu Energy, Kamaaina Solar Solutions, Kahumana Community		Waianae	245 kW	O	(1)8-6-002:001		
Kalaeloa Renewable Energy Park	Hanwha SolarEnergy America, Swinerton Renewable Energy, Scatec, Hunt Development		Kalaeloa	5 MW	O	(1)9-1-013:096		
Kalaeloa Solar Power II	SunPower, Bright Plain Renewable Energy, D.E. Shaw Renewable Investments, LLC		Kalaeloa	5 MW	O	(1)9-1-013:028 / 038		
Kapolei Sustainable Energy Park	Forest City Hawaii, Hoku Scientific		Kapolei	1MW	O	(1)9-1-014:034		
Kawailoa Solar	Clearway Energy Group LLC, Global Infrastructure Partners, Moss Solar		Kawailoa / Haleiwa	49 MW	O	(1)6-1-006:001		
Kupehau Solar	174 Power Global, Hanwha Energy USA		Kunia	60 MWac + 240 MWh (4 hr)	P	(1)9-2-004:008		
Kupono Solar	Bright Canyon Energy, Pinnacle West Capital Corp.		Ewa Beach	42 MWac + 168 MWh	P	(1)9-1-010:011		
Mahi Solar	Longroad Energy		Kunia	120 MWac + 480 MWh	P	(1)9-2-001:001		
Mauka FIT 1	Mauka FIT One, LLC, Solar Power, Inc. (SPI)		Kahuku	3.5 MW	P	(1)5-6-005:014		
Mehana Solar	Onyx Development Group LLC, Arion Energy, LLC		Kalaeloa	6.6 MWac / 26.4 MWh	P	(1)9-1-013:029		
Mililani I Solar	Clearway Energy Group LLC, Global Infrastructure Partners		Mililani	39 MWac + 156 MWh BESS	P	(1)9-4-005:090		
Mililani Solar II (Lanikuhana Solar)	Clearway Energy Group LLC, Global Infrastructure Partners, Moss Solar		Mililani	14.7 MW	O	(1)9-4-005:097		
Mililani Tech Solar I	Tritium3 Renewable Ventures		Mililani	270 kW	P			
Mountain View Solar	AES Distributed Energy Inc.		Waianae	7 MWdc + 35 MWh	P	(1)8-5-003:031,032, 034		
Pacific Energy Assurance and Renewables Laboratory (PEARL)	Hawaii Center for Advanced Transportation Technologies, Air Force Research Laboratory, National Guard Bureau, Hawaii Air National Guard, Naval Facilities Command, Burns & McDonnell		Pearl Harbor	1.5 MW + 500 MWh BESS	P			
Pearl City Peninsula PV	Forest City Sustainable Resources, Hoku Scientific		Pearl Harbor	1.23 MW	O			

Project Name	Developer	Owner	Location	Capacity	Status	Tax Map Key	Acres	Landowner
OAHU cont.								
University of Hawaii-Kapiolani Community College Solar + Storage Project	University of Hawaii-Kapiolani Community College, Johnson Controls		Kahala / Kaimuki	1.738 MW + 6.31 MWh BESS	P	(1)3-1-042:009		
University of Hawaii-Manoa Solar + Battery Project	University of Hawaii		Manoa	1 MW	O			
University of Hawaii-West Oahu Solar PV System	University of Hawaii - West Oahu		Kapolei	504 kW	O	(1)9-1-016:220		
Waianae (EE) Solar Project	Eurus Energy America		Waianae	27.6 MWac	O	(1)8-5-002:022 / 030		
Waianae PV-2 Solar Farm	Kenyon Energy, Blue Earth, Inc.		Waianae	500 kW	O			
Waiawa Phase 2 Solar	AES Distributed Energy Inc.		Pearl City, Waipio Village	30 MWac + 240 MWh	P	(1)9-6-004:024,025,026		
Waiawa Solar Power	Clearway Energy Group LLC, Global Infrastructure Partners		Pearl City	36 MWac + 144 MWh BESS	P	(1)9-4-006:026		
Waihonu North Solar Farm	Macquarie Infrastructure Corp. (HAWAII GAS), Meridian 158 LLC, Alexander & Baldwin, Swinerton Builders		Mililani	5 MW	O	(1)9-5-001:087		
Waihonu South Solar Farm	Macquarie Infrastructure Corp. (HAWAII GAS), Alexander & Bladwin, Meridian 158 LLC, Swinerton Builders		Mililani	1.5 MW	O	(1)9-5-001:087		
Waipio Solar (Waiwa PV)	Clearway Energy Group LLC, Global Infrastructure Partners, Moss Solar		Waiawa	46 MWac	O	(1)9-5-003:004		
Waipio Solar Facility	Pacific Energy Solutions, NextEra Energy Resources, NAVFAC Hawaii		Joint Base Pearl Harbor-Hickam	11 MWac / 14.3 MWdc	O			
West Loch PV Project	Hawaiian Electric Company, NAVFAC, Duke Energy, REC Solar, Tesla		Joint Base Pearl Harbor-Hickam	20MWac/28MWdc + 20MW BESS	O	(1)9-1-010:016		
KAHOOLAWE								
KIRC Solar Array + Storage	Kahoʻolawe Island Reserve Commission, Maui Community College			100kw	O			
MOLOKAI								
Molokai New Energy Partners	Half Moon Ventures LLC				P		2.37	Molokai Ranch

Appendix 3 – KSHCP: Guidelines for Adjusting Lighting at Facilities (HI DLNR/DOFAW, 2020)

This appendix provides detailed guidelines to inform minimization measures that can be customized to address an array of possible lighting issues at Participant facilities. A lighting minimization plan to achieve the maximum extent practicable will be included in each Participant PIP.

These guidelines represent best available science at the time of KSHCP permit issuance. Over the life theplan, likely new information and new technologies will be available, and this appendix may be updated accordingly.

Not all lighting guidelines are appropriate for all types of facilities. Some represent long term, infrastructure solutions, and others may be implemented on a seasonal basis.

Deactivate Non-Essential Lights

Prioritization of seabird and honu light attraction minimization measures involves evaluating light needs to determine if non-essential lights can be deactivated during the seabird fallout season (September 15 to December 15) and turtle nesting season (May 15-December 15).

Deactivating the lights avoids the potential for light attraction that those lights could otherwise cause. Turning off a subset of lights, both unshielded and shielded, during the fallout season (September 15 to December 15) can assist with minimizing the risk of seabird light attraction, if those lights are not necessary. In their PIPs, Applicants must provide rationale for any facility lights that cannot be deactivated during seabird fallout season, and detail what other minimization practices will be implemented on lights that will remain illuminated. The regulatory agencies will review the evaluation and justification as provided in applicant PIPs.

Similarly, turning out lights that shine directly on beaches during the turtle nesting season (May 15-December 15) can prevent hatchling disorientation. Avoid use of the following lamp styles on beachside or shore perpendicular to sides of a structure: private balcony lights, up lights; decorative lighting, not necessary for human safety or security; pond lights; and beach lighting. Timers or other similar devices should be used to ensure the selected lights remain off during the turtle nesting season. This measure may require the installation of independent light switches. Conversely, to prevent accidental activation, light fixtures can be removed for lights that will no longer be needed at a facility.

Install Full Cut-off Light Fixtures

A full cut-off fixture refers to a light fixture which that does not shine light above a 90 degree horizontal plane. For lights necessary to be activated, full cut-off fixtures provide an effective measure to achieve light minimization because they prevent light from shining directly upward. These types of lights house the light bulb up within the fixture so that no bulb protrudes below

(Figure 1). Such fixtures must be mounted at appropriate angle so they point directly down to the ground. Many light manufacturers provide light fixture information along with the light specifications to indicate if a fixture is a full cut-off design. The International Dark Sky Association (www.darksky.org) is a good source for information on full cut-off lights and provides additional references to light engineering resources and light manufactures

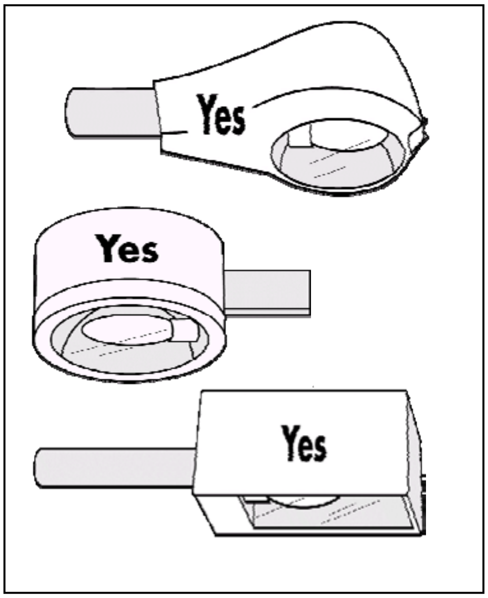

Figure 1: Examples of full cut-off light fixtures. Source: www.darksky.org.

Along shorelines, exterior fixtures on the seaward (makai) and the shore perpendicular sides of the building (and on the landward side of the building if they are visible from the beach) should be down-lit fixtures, fully shielded and full cut-off, louvered, or recessed fixtures that do not have reflective inner surfaces. These fixtures should use low wattage bulbs (e.g.,< 50w). All exterior fixtures on the landward (mauka) side of the building should be directed downward only (Witherington & Martin 2003).

Shielding Light Fixtures

This minimization measure aims to achieve the functional equivalent of a full cut-off light fixture by installing a shield, visor, hood or similar on an existing light fixture to prevent light from shining upward and reducing trespass. In addition to the shielding, to achieve the functional equivalent of a full cut-off fixture, a light fixture should be adjusted so that it points directly down perpendicular to the ground to create a level, horizontal plane between the fixture and the ground, and have the bulb housed within the light fixture (Figures 2 & 3). Reed et al. (1985) suggest that in areas where other light sources are rare, the shielding of principal lights would likely have a larger effect in decreasing seabird light attraction.

Figure 2: Installation of an appropriately sized floodlight shield. Source: www.darksky.org.

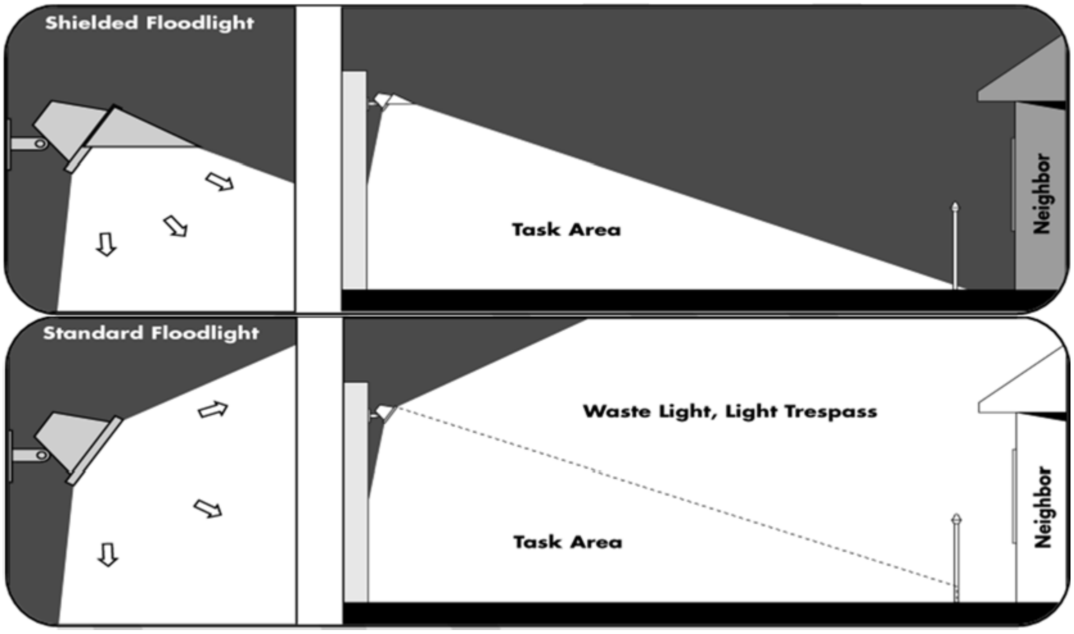

Figure 3: Before and after effects of shielding and light management designed to minimize light attraction risk to seabirds and to decrease light pollution. Source: www.darksky.org.

Angle Lights Downward

Angling and repositioning lights presents a potential alternative to shielding or replacing light fixtures and may be sufficient to make lights fully cut-off and eliminate light shining horizontally and vertically (Figure 4). To achieve the functional equivalent of a full cut-off fixture, a light fixture should be adjusted so that it points directly down perpendicular to the ground to create a level, horizontal plane between the fixture and the ground, and have the bulb housed within the light fixture. Tree strap downlights may be used to minimize seabird light attraction unless turtles may be present on the adjacent beach.

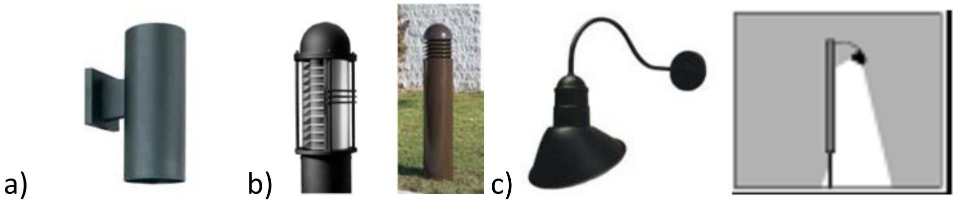

Figure 1-: (a) Wall mount cylinder down-light, (b) bollards with downward-directed louvers, and (c) sign lights angled downward. From http://myfwc.com/media/418417/SeaTurtle_LightingGuidelines.pdf (FWC 2011).

Place Lights Under Eaves

Light fixtures placed under building eaves can achieve the functional equivalent of a full cut-off fixture. The architectural eave acts as shield to prevent light from shining directly upward.

Shift Lighting According to the Moon Phase

This minimization measure addresses lighting for which the need, or purpose, for the lighting can be shifted in timing each year to coincide with the moon phase. Because a reduction in light attraction has been correlated with the full phase of the moon (Reed et al. 1985; Telfer et al. 1987) lights for essential functions, and for which that function can be shifted in timing, should coincide with the full phase of the moon and avoid the dark phase of the moon. It is important to note that a full moon that is obscured by heavy cloud cover could simulate the dark phase of the moon. By not activating those lights during the dark phase of the moon the effect of those lights is reduced. Examples of activities that could be minimized with this measure include scheduling of night time events, such as festivals or sporting events.

Install Motion Sensors for Motion-activated Lighting

Motion sensors switch lights on only when triggered, thereby limiting the time that the light stays on and reducing its potential for seabird light attraction. If a sensor light is required for security purposes, the light equipped with the sensor should be at low light levels. For example, Light Emitting Diode (LED) streetlights and parking lot lights can be activated when needed and dim when no activity is detected nearby. However for those fixtures, full cut-off designs or the functional equivalents are recommended because of the possibility of light attraction occurring when the motion-sensor light is activated or in the event that the motion sensor equipment malfunctions and the light remains on.

Where motion sensors are impractical (eg at sporting events), stadium lights should be turned off as soon as the public leaves the stadium

Decrease Lighting Levels

This measure addresses lowering light intensity levels (e.g., measured in lumens) while still meeting the need to safely complete tasks and serve the purpose of the light. Guidance on standards for the appropriate lighting level for a particular light function should be followed as provided by the appropriate agency or professional and technical organization. For example the Illuminating Engineering Society of North America (IESNA) provides recommendations for light levels for several applications including parking lots, walkways, and roads. In addition individual entities may have standards and best practices for lighting needs.

For many applications where lighting is needed, brighter lighting may not always provide the best lighting for the needed function. It is often the case where reduced lighting levels can provide for the needed function of the lighting. For example, for security purposes overly bright lights tend to create blind spots, or very dark shadows, outside the lit area that preclude effective visibility. Well placed, but reduced lighting can provide for more effective security.

Therefore, when Participants seek to enhance onsite visibility for security, while reducing risk to seabirds, the appropriate reduction of light levels (along with shielding and re-angling lights) forms a starting point to accomplish both purposes.

Decrease Visibility of Interior Lights

Facilities with large and/or numerous windows, tall building profiles, or large glass facades may also pose a risk of light attraction to Covered Seabirds on Kauaʻi. The following measures are based, in part, on efforts in cities in Canada and the mainland USA to decrease harmful effects of buildings on birds and apply to seabirds in that they can decrease the amount of light escaping from within buildings (City of Toronto 2007; Evans Ogden 2002):

- Install screens or shades over large windows that are lowered nightly during the fallout season;
- Modify buildings and decrease or eliminate light glow from within a facility;
- Create glass opacity to prevent the escape of internal light. Tinted glass or film with a visible light transmittance value of 45 percent or less should be applied to all windows and doors within line of sight of the beach;
- Install physical screens outside a building;
- Install landscaping in front of large windows;
- Close all window blinds after daylight hours until sunrise;
- Stagger the operation of lights in the evening or morning hours so that not all lights are turned on at once; and

- Maximize the number of offices or indoor rooms that turn off all lights after sunset;
- Place reminder notices on switches to turn out lights or draw curtains/blinds in oceanfront rooms. This should include coastal areas that are on the perpendicular sides of the structure;
- Turn off room and lanai lighting that are not needed;
- Relocate moveable lamps away from windows that are visible from the beach; and
- Close opaque curtains or blinds after dark to block inside light from shining outside.

Use Light-less Technologies

Where conditions and facility needs permit, technologies that do not use light, such as closed- circuit television (CCT) with infrared illuminators, may be effectively employed to “see” at night thus enabling some of the lights to be turned off. For example, any fenced areas or the dark sides of facilities can be monitored with CCT so that lights do not need to be used or installed.

Plant Vegetation Around Lights to Reduce Light Visibility

Trees and shrubs can be planted so that they over-arch lights or shield side visibility of lights along the coast or along a ridge, for example. Whether the lights are mounted on 20-foot poles, walkways, or within landscaped areas, having adjacent or overarching vegetation would further reduce the risk of seabird light attraction that any residual light scatter may pose. Long-term planning and maintenance of screening vegetation is encouraged, where appropriate to the uses and needs of the affected lights.

Lower Height of Lights

Light that is low in height has potential to reduce the effect of light attraction because lower lights may be less visible to passing seabirds. Installing ground-level lighting, such as along walkways, and reducing pole height can decrease light waste and trespass.

Use Longer Light Wavelengths

In coastal areas, use of acceptable lights such as: LPS 18w, 35w, red, orange or amber LEDs (true red, orange or amber diodes, but not filters), true red neon, and other lighting sources that produce light wavelengths of 560 nm or longer (Witherington et al. 2014). Long wavelength lights, e.g., those that produce light that measures greater than 560 nanometers on a spectroscope, are required for all construction visible from and adjacent to sea turtle nesting beaches. Turtles are most sensitive to short wavelengths of light, probably because they live in a marine environment that filters out long wavelengths. Green turtles are least attracted to longer wavelength light in the yellow-orange to red end of the spectrum (630 to 700 nm) (Witherington and Martin 2000). In the absence of other light sources, however, turtles may still be attracted to long wavelength light.

Filters designed to exclude transmission of short wavelengths (<570nm) can be fitted to high pressure sodium (HPS) vapor lights. Such filters have been found to be effective at avoiding disruption of nesting females (Salmon, 2006) but even filtered HPS light has been found to attract hatchlings, although not as strongly as unfiltered HPS lights (Sella et al, 2006). Filtering alone is thus not sufficient to avoid attraction and disruption of hatchling orientation. Bright white light fixtures, such as metal halide, halogen, fluorescent, mercury vapor and incandescent lamps, are not approved for beachside or shore perpendicular sides of a structure. Limited use of shorter wavelength lights may be approved in areas where direct and indirect light or glow could not possibly be visible from the beach due to installation of opaque “light fencing” (see below).