Appendix 1A

Evaluation of Species Considered for Coverage

Pursuant to the federal Endangered Species Act (federal ESA) and Hawai'i Revised Statutes, incidental take authorizations may be required for species covered under the KIUC HCP (i.e., covered species) to implement the covered activities over the term of the KIUC HCP. Species KIUC considered for coverage were all state- or federally listed species that could be present in the Plan Area.

Table 1A-1 presents the evaluation process and results of the process for each of the species considered. As a result of this evaluation, KIUC identified nine species as meeting the criteria for inclusion as covered species in the KIUC HCP; Chapter 1, *Introduction and Background*, Table 1-1 lists these species. Attachments 1 and 2 to this appendix provide more detailed rationale for excluding particular species from the KIUC HCP covered species list. Where necessary, the attachments also include avoidance and minimization measures KIUC must implement to ensure take of listed species is avoided.

Attachment 1. Evaluation of Hoary Bat ('ōpe'ape'a) Coverage in KIUC HCP

Attachment 2. Measures to Avoid Adverse Effects on Listed Plant Species

Table 1A-1. Evaluation of Special-Status Animals and Plants for Coverage under the KIUC HCP

	Selection Criteria For Coverage[c]					
Scientific Name/ Common Name/Hawaiian Name[a]	**Status** [b] **(Federal/ State)**	**Likely to Occur in the Plan Area**	**Potential to Adversely Affect**	**Sufficient Information**	**Proposed for Coverage**	**Comments and Rationale**
Mammals						
*Lasiurus cinereus semotu/*Hawaiian hoary bat/ʻōpeʻapeʻa	E/E	+	±	+	No	Take unlikely with implementation of the avoidance and minimization measures described in Attachment 1.
*Monachus schauinslandi/*Hawaiian monk seal/ʻīlio-holo-i-ka-uaua	E/E	+	-	+	No	Take from covered activities unlikely.
Birds						
*Puffinus auricularis newelli/*Newell's shearwater/ʻaʻo	T/T	+	+	+	Yes	Recommended for coverage under the Plan.
*Pterodroma sandwichensis/*Hawaiian petrel/ʻuaʻu	E/E	+	+	+	Yes	Recommended for coverage under the Plan.
Oceanodroma castro/band-rumped storm-petrel/ʻakēʻakē	C/E	+	+	+	Yes	Recommended for coverage under the Plan.
Himantopus mexicanus knudseni/ Hawaiian stilt/aeʻo	E/E	+	+	+	Yes	Recommended for coverage under the Plan.
*Anas wyvilliana/*Hawaiian duck/koloa maoli	E/E	+	+	+	Yes	Recommended for coverage under the Plan.
Fulica alai/Hawaiian coot/ʻalae keʻokeʻo	E/E	+	+	+	Yes	Recommended for coverage under the Plan.
Gallinula galeata sandvicensis/ Hawaiian gallinule/ʻalae ʻula	E/E	+	+	+	Yes	Recommended for coverage under the Plan.
Branta sandvicensis/Hawaiian goose/ nēnē	E/E	+	+	+	Yes	Recommended for coverage under the Plan.

Scientific Name/ Common Name/Hawaiian Name[a]	Selection Criteria For Coverage[c] Status [b] (Federal/ State)	Likely to Occur in the Plan Area	Potential to Adversely Affect	Sufficient Information	Proposed for Coverage	Comments and Rationale
Myadestes palmeri/Kauaʻi thrush/ puaiohi	E/E	+	-	+	No	Take from covered activities unlikely.
Oreomystis bairdi/Kauaʻi creeper/ ʻakikiki	E/E	+	-	+	No	Take from covered activities unlikely.
*Loxops caeruleirostris/*Kauaʻi akepa/ akekeʻe	E/E	+	-	+	No	Take from covered activities unlikely.
Drepanis coccinea/scarlet honeycreeper/ʻiʻiwi	T/E	+	-	+	No	Take from covered activities unlikely.
Reptiles						
Chelonia mydas/green sea turtle Central North Pacific distinct population segment/honu	T/T	+	+	+	Yes	Recommended for coverage under the Plan.
Eretmochelys imbricata/hawksbill turtle/ʻea	E/E	+	-	+	No	Take from covered activities unlikely.
Lepidochelys olivacea/olive ridley sea turtle	T/T	+	-	+	No	Take from covered activities unlikely.
Caretta caretta/loggerhead sea turtle	T/T	+	-	+	No	Take from covered activities unlikely.
Demochelys coriacea/leatherback sea turtle	E/E	-	-	+	No	Take from covered activities unlikely.
Invertebrates						
Adelocosa anops/Kauaʻi cave wolf spider/peʻe peʻe makaʻole	E/E	+	-	+	No	Take from covered activities unlikely.
*Spelaeorchestia koloana/*Kauaʻi cave amphipod/ʻuku noho ana	E/E	+	-	+	No	Take from covered activities unlikely.

	Selection Criteria For Coverage[c]					
Scientific Name/ Common Name/Hawaiian Name[a]	**Status [b] (Federal/ State)**	**Likely to Occur in the Plan Area**	**Potential to Adversely Affect**	**Sufficient Information**	**Proposed for Coverage**	**Comments and Rationale**
Plants						
Adenophorus periens/pendant kihi fern/palai lāʻau	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Astelia waialeale/paʻiniu	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Bonamia menziesii/Hawaiʻi lady's nightcap	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Brighamis insignis/vulcan palm/ʻālula, hāhā	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Canavalia napaliensis/Mākaha Valley Jack-bean/ʻāwikiwiki, puakauhi	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Centaurium sebaeoides/lavaslope centaury/ʻāwiwi	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
*Charpentiera densiflora/*Nā Pali Coast pāpala/pāpala	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Cyrtandra kealiae subsp. *kealiae* (formerly *C. limahuliensis*)/haʻiwale, kanawao keʻokeʻo	T/T	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.

Scientific Name/ Common Name/Hawaiian Name[a]	Selection Criteria For Coverage[c]					Comments and Rationale
	Status [b] (Federal/ State)	Likely to Occur in the Plan Area	Potential to Adversely Affect	Sufficient Information	Proposed for Coverage	
Cyrtandra oenobarba/shaggystem cyrtandra/hāʻiwale, kanawao keʻokeʻo	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Cyanea eleeleensis/hāhā	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Cyanea kolekoleensis/ Kolekole cyanea/hāhā	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Cyanea kuhihewa/Limahuli Valley cyanea/hāhā	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Cyanea recta/upright cyanea/hāhā	T/T	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Cyanea remyi/Remy's cyanea/hāhā	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Cyanea rivularis (listed as Delissea)/ plateau cyanea/hāhā	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Cyrtandra cyaneoides/māpele/ kanawao keʻokeʻo	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
*Delissea kauaiensis/*leechleaf delissea/ ʻoha	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.

Scientific Name/ Common Name/Hawaiian Name[a]	Selection Criteria For Coverage[c] Status [b] (Federal/ State)	Likely to Occur in the Plan Area	Potential to Adversely Affect	Sufficient Information	Proposed for Coverage	Comments and Rationale
Delissea rhytidosperma/Kauaʻi delissea/ʻoha	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
*Doryopteris angelica/*Kauaʻi digit fern	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Dryopteris crinalis var. *podosorus*/ serpent woodfern/palapalai ʻaumakua	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Dubautia imbricata subsp. *imbricata*/ bog dubautia/naʻenaʻe, kūpaoa	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Dubautia kalalauensis/naʻenaʻe, kūpaoa	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Dubautia kenwoodii/Kalalau rim dubautia/naʻenaʻe, kūpaoa	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Dubautia waialealae/Waiʻaleʻale dubautia/naʻenaʻe, kūpaoa	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Euphorbia haeleeleana/Kauaʻi spurge/ ʻakoko	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Euphorbia eleanoriae/Nā Pali sandmat/ʻakoko	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.

Scientific Name/ Common Name/Hawaiian Name[a]	**Selection Criteria For Coverage**[c]					**Comments and Rationale**
	Status [b] **(Federal/ State)**	**Likely to Occur in the Plan Area**	**Potential to Adversely Affect**	**Sufficient Information**	**Proposed for Coverage**	
Euphorbia remyi var. *kauaiensis*/ Remy's sandmat/ʻakoko	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Euphorbia remyi var. *remyi*/Remy's sandmat/ʻakoko	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Exocarpos luteolus/leafy ballart/heau, au	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Flueggea neowawraea/mēhamehame	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Hesperomannia lydgatei/Kauaʻi island-aster	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Hibiscadelphus woodii/Wood's hau kuahiwi	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Hibiscus waimeae subsp. *hannerae*/ Hibiscus waimeae/aloalo, kokiʻo keʻokeʻo, kokiʻo kea	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Ischaemum byrone/Hilo murainagrass, Hilo ischaemum	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Isodendrion longifolium/longleaf isodendrion/aupaka	T/T	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.

Scientific Name/ Common Name/Hawaiian Name[a]	**Selection Criteria For Coverage**[c] **Status** [b] **(Federal/ State)**	**Likely to Occur in the Plan Area**	**Potential to Adversely Affect**	**Sufficient Information**	**Proposed for Coverage**	**Comments and Rationale**
Kadua cookiana/Cook's bluet/ʻāwiwi	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Kadua st-johnii/Nā Pali beach starviolet	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Keysseria erici/Alakaʻi Swamp island-daisy	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Keysseria helenae/Mt. Waiʻaleʻale island-daisy	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Labordia helleri/Nā Pali Coast labordia/kāmakahala	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Labordia lydgatei/Wahiawa Mountain labordia/kāmakahala	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Labordia pumila/Kauaʻi labordia/ kāmakahala	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Lobelia niihauensis/Niʻihau lobelia	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Lysimachia daphnoides/Pacific loosestrife/ehua makanoe, kolokolo kuahiwi, kolekole lehua, kolokolo lehua	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.

Scientific Name/ Common Name/Hawaiian Name[a]	Selection Criteria For Coverage[c] Status [b] (Federal/ State)	Likely to Occur in the Plan Area	Potential to Adversely Affect	Sufficient Information	Proposed for Coverage	Comments and Rationale
Lysimachia scopulensis/ shiny-leaf yellow loosestrife/ehua makanoe, kolokolo kuahiwi, kolekole lehua, kolokolo lehua	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Melicope degeneri/Kōkeʻe Stream melicope/alani, alani kuahiwi	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Melicope pallida/pale melicope/alani, alani kuahiwi	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Melicope paniculata/Līhuʻe melicope/ alani, alani kuahiwi	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Melicope puberula/hairy melicope/ alani, alani kuahiwi	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Myrsine linearifolia/narrowleaf colicwood/kōlea	T/T	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Myrsine mezii/ Hanapēpē River colicwood/kōlea	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Peucedanum sandwicense/makou	T/T	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Phyllostegia renovans/red-leaf phyllostegia	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.

Scientific Name/ Common Name/Hawaiian Name[a]	Selection Criteria For Coverage[c] Status [b] (Federal/ State)	Likely to Occur in the Plan Area	Potential to Adversely Affect	Sufficient Information	Proposed for Coverage	Comments and Rationale
Phyllostegia wawrana/fuzzystem phyllostegia	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Pittosporum napaliense/royal cheesewood/hōʻawa, hāʻawa	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Plantago princeps var. *anomola*/ale/ laukahi kuahiwi	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Plantago princeps var. *longibracteata*/ ale/laukahi kuahiwi	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Plantanthera holochila/Hawaiʻi bog orchid	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Platydesma rostrata/pilo kea lau liʻi	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Poa manii/Olokele Gulch bluegrass	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Poa sandvicensis/Hawaiian bluegrass	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Polyscias bissattenuata/ʻoheʻohe	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.

Scientific Name/ Common Name/Hawaiian Name[a]	Selection Criteria For Coverage[c]					Comments and Rationale
	Status [b] (Federal/ State)	Likely to Occur in the Plan Area	Potential to Adversely Affect	Sufficient Information	Proposed for Coverage	
Polyscias flynii/ʻoheʻohe	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Polyscias racemosum/Munroidendron	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Pritchardia hardyi/Hardy's loulu/loulu	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Pritchardia napaliensis/Nāpali loulu/ kōpiko	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Psychotria hobdyi/Hobdy's wild-coffee/kōpiko	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Pteralyyxia kauaiensis/kaulu	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Remya montgomeryi/Kalalau Valley remya	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Scheidea kauaiensis/Kauaʻi schiedea	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Schiedea lychnoides (listed as *Alsinidendron lychnoides*)/ kuawāwaenohu	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.

Scientific Name/ Common Name/Hawaiian Name[a]	Selection Criteria For Coverage[c] Status [b] (Federal/ State)	Likely to Occur in the Plan Area	Potential to Adversely Affect	Sufficient Information	Proposed for Coverage	Comments and Rationale
Stenogyne kealiae/Keal's stenogyne	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Stenogyne campanulata/Kalalau Valley stenogyne	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Tetraplasandra kavaiensis/ʻoheʻohe	E/E	+	±	-	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.
Wilkseya hobdyi/dwarf iliau	E/E	+	±	+	No	Adverse effects from covered activities, including conservation measures, unlikely with implementation of the avoidance and minimization measures described in Attachment 2.

[a] When available, all three names are listed in order from scientific name, common, and Hawaiian name.

[b] **Federal**

E = listed as endangered under the ESA
T = listed as threatened
C = candidate for listing under ESA

[b] **State**

E = listed as endangered
T = listed as threatened

[c] **Criteria met or not**

\+ = Yes, the species meets the selection criteria
– = No, the species does not meet the selection criteria
U = Uncertain whether species meets selection criteria. More investigation required.

Attachment 1. Evaluation of Hawaiian Hoary Bat (ʻōpeʻapeʻa) Coverage in KIUC HCP

Memorandum

Date:	August 13, 2020
To:	Dawn Huff, Kauaʻi Island Utility Cooperative (KIUC)
From:	Dave Johnston, Paul Conry, Ron Duke, and Scott Terrill (HT Harvey) David Zippin, Torrey Edell, Ellen Berryman (ICF)
Subject:	**Evaluation of Hawaiian hoary bat (ʻōpeʻapeʻa) coverage in KIUC HCP**

The purpose of this memorandum is to document KIUC's evaluation to determine whether listed Hawaiian hoary bats (ʻōpeʻapeʻa) (*Lasiurus cinereus semotus*) should be included as covered species in the KIUC Habitat Conservation Plan (KIUC HCP).

Criteria for Coverage

KIUC used the following criteria to evaluate potential covered species in the HCP. KIUC decided to cover species in the HCP if they met all four of the criteria described below.

1. **Listing status.** The species is currently listed under the federal Endangered Species Act (federal ESA) or the Hawaiʻi ESA (Hawaiʻi Revised Statute [HRS] 195D-4).
2. **Geographic range**. The species is currently known to occur throughout the Plan Area (Island of Kauaʻi) based on knowledge of the species' geographic range and the presence of suitable habitat.
3. **Effects of covered activities.** The species has a reasonable likelihood of "take" as defined by the federal ESA and Hawaiʻi ESA by HCP covered activities that are currently occurring within the Plan Area or are likely to occur over the life of the permits.
4. **Adequacy of existing data on the species.** Sufficient data is available regarding the species' life history, habitat requirements, and presence in the Plan Area to adequately evaluate effects on the species and develop appropriate conservation measures to satisfy the permit issuance criteria of the ESA Section 10 and HRS Section 195D-2.

The Hawaiian hoary bat (ʻōpeʻapeʻa) was state- and federally listed as endangered on October 13, 1970 (U.S. Fish and Wildlife Service 1970). No critical habitat has been designated for the Hawaiian hoary bat (ʻōpeʻapeʻa). This species is widespread on the island of Kauaʻi (U.S. Fish and Wildlife Service 1998). Based on data from the islands of Hawaiʻi (Bonaccorso et al. 2015) and Maui (H.T. Harvey and Associates 2019), bat activity occurs in many habitats and females nursing young are generally expected at lower elevations (less than 1,000 feet [304.8 meters] in elevation) during summer months. Thus, the species is expected to raise young throughout much of the lowland areas with appropriate larger trees with dense foliage.

The Hawaiian hoary bat (ʻōpeʻapeʻa) meets the first two criteria described above because it is both listed and known to occur on Kauaʻi. Additionally, the species meets the fourth criteria because sufficient data is available to evaluate effects on the species and develop appropriate conservation measures to satisfy permit issuance criteria. The remainder of this memo focuses on the third criterion: the effects of covered activities on the Hawaiian hoary bat (ʻōpeʻapeʻa) and the likelihood of take, and commitments from KIUC to avoid take of this species.

Effects of Covered Activities

The only KIUC activity with the potential to affect Hawaiian hoary bats (ʻōpeʻapeʻa) is the pruning or removal of trees, but KIUC can avoid take of Hawaiian hoary bats (ʻōpeʻapeʻa) resulting from this activity through the implementation of avoidance measures. While the operation of streetlights may influence Hawaiian hoary bats (ʻōpeʻapeʻa) behavior by attracting bats, no adverse effects of the streetlights are anticipated. Each of these covered activities is detailed below.

Tree Pruning and Removal

Nursing females typically leave their pups in the roost tree while they forage (Barclay 1989), leaving young Hawaiian hoary bat (ʻōpeʻapeʻa) pups unable to leave a tree that is being trimmed or removed. Non-flying pups are therefore vulnerable until they can fly on their own. To avoid and minimize impacts on endangered Hawaiian hoary bats (ʻōpeʻapeʻa), the U.S. Fish and Wildlife Service (USFWS) recommends that projects: (1) do not disturb, remove or trim woody plants more than 15 feet (4.6 meters) tall during the bat birthing and pup rearing season of June 1 through September 15; and (2) do not use barbed wire for fencing (U.S. Fish and Wildlife Service 2020). Similarly, the State of Hawaiʻi Department of Land and Natural Resources, Division of Forestry and Wildlife (DOFAW) provides guidance that site clearing should be timed to avoid disturbance during the bat birthing and pup rearing season from June 1 through September 15. However, if site clearing cannot be avoided, including for emergency work, woody plants more than than 15 feet (4.6 meters) tall should not be disturbed, removed, or trimmed without consulting DOFAW (Appendix A; State of Hawaiʻi Department of Land and Natural Resources, Division of Forestry and Wildlife 2015, 2020).

Take of Hawaiian hoary bats (ʻōpeʻapeʻa) pups is more likely when dense vegetation is trimmed along lightly traveled roads, because this species is much more likely to use these areas than heavily travelled roadways with sparse vegetation (H.T. Harvey and Associates 2014). Based on recent radio-tracking data from Maui, bats roosted occasionally along quiet neighborhood streets with large densely foliated trees, but did not roost in trees under 15 feet (4.6 meters) tall or in trees that had relatively sparse leaves (e.g., albizia [*Falcataria moluccana*]) (H.T. Harvey and Associates 2019). During 2 years of data collection, on only a single night was a a male bat observed roosting in a tree along a busy two-lane highway (Kula Highway); a Chinese elm (*Ulmus parvifolia*) with large mats of vines making a very densely foliated tree (i.e., a tree with foliage too dense to be able to see light coming through the tree) (H.T. Harvey and Associates 2019). Females, on the other hand, were never observed roosting along busy two-lane highways (H.T. Harvey and Associates 2019).

To evaluate the potential for Hawaiian hoary bats (ʻōpeʻapeʻa) take from vegetation trimming and removal, KIUC commissioned and implemented a pre-trimming bat monitoring program during the bat pup rearing seasons between 2013 and 2015, using thermal imaging. Tree trimmers were trained by KIUC's consulting biologist on the use and methodology for searching vegetation on a daily basis in areas to be trimmed during the bat pup rearing season prior to vegetation clearing. The tree trimmers were trained using live mice in small cages that were hidden in vegetation along typical line-clearing segments by KIUC and its biologist. Training and blind searcher efficiency trials were conducted each year. During 3 years of monitoring during the bat pup rearing season (June 1 through September 15), KIUC and its contractors failed to find a single bat in over 662 tree-trimming unit-days. Even though no bats had been detected during tree-trimming activities, at the end of the 2015 season KIUC agreed to refrain from trimming in potential habitat during the pup rearing season. USFWS agreed that, with implementation of this measure and additional measures outlined below under *Avoidance Measures,* KIUC will avoid take of Hawaiian hoary bats (ʻōpeʻapeʻa) (Appendix A; U.S. Fish and Wildlife Service 2015).

Street Light Attraction

The Hawaiian hoary bat (ʻōpeʻapeʻa) regularly forages at streetlights (Belwood and Fullard 1984), and concentrations of moths around streetlights likely reduces the foraging time for bats (Acharya and Fenton 1999). Thus, these streetlights concentrate large moths, which also maximizes energy returns for the bats (Acharya and Fenton 1999).

Currently no data exist on the predation of the Hawaiian hoary bat (ʻōpeʻapeʻa) by owls or other predators (State of Hawaiʻi Department of Land and Natural Resources, Division of Forestry and Wildlife 2015). Based on the ecology of other fast-flying open aerial foragers that forage at streetlights (Rydell et al. 1996), predation by owls at streetlights is unlikely. Rydell et al. (1996) found that smaller bats tend to begin foraging later than larger bats, possibly to avoid avian predation that is likely a greater risk with more available light. However, larger and therefore faster flying insectivorous bats, such as the Hawaiian hoary bat (ʻōpeʻapeʻa), start foraging earlier than slower bats, even when differences in diet and foraging habitat are controlled for (Jones and Rydell 1994). Because the Hawaiian hoary bat (ʻōpeʻapeʻa) often begins foraging at or just prior to sunset (Bonaccorso et al. 2015) while light values are relatively high compared to an hour or more later, this species does not appear to be avoiding predation. Therefore, it is unlikely that predation on the Hawaiian hoary bat (ʻōpeʻapeʻa) occurs when light values are high, such as is the case at streetlights.

Even though the Hawaiian hoary bat (ʻōpeʻapeʻa) is widely distributed on Kauaʻi, there are no data suggesting that bats have collided, or will likely collide, with utility structures on Kauaʻi. Currently, the only documented risk to the Hawaiian hoary bat (ʻōpeʻapeʻa) from anthropogenic structures are bats having been caught on barbed wire fencing and colliding with rotating wind turbines.

Avoidance Measures

During the KIUC HCP permit term, KIUC will commit to the following measures to avoid take of Hawaiian hoary bat (ʻōpeʻapeʻa).

1. KIUC will refrain from vegetation trimming or removal during the pup rearing season (June 1 to September 15) where vegetation is over 15 feet (4.6 meters) tall.[1]
2. Based on results from 3 years of comprehensive bat search protocols, vegetation maintenance in areas along heavily traveled roadways that lack vegetation over 15 feet (4.6 meters) tall may be trimmed during the Hawaiian hoary bat (ʻōpeʻapeʻa) bat pupping season (June 1 to September 15) (U.S. Fish and Wildlife Service 2015).

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[1] This measures excludes grasses over 15 feet (4.6 meters) tall (i.e., Guinea grass) that are characterized by the lack of overhanging foliage (Willis and Brigham 2005).

3. In the very rare circumstances when removing/trimming/disturbing trees is necessary to correct a location-specific service problem (such as a trouble call reporting that a tree limb had fallen against lines or due to wind repeatedly striking a line, causing light flickering or breaker openings) during the bat pup rearing season, KIUC will only perform the minimum amount of tree trimming absolutely necessary to alleviate the immediate service problem. These very rare situations are not expected to involve take by removing only the minimum amount of vegetation necessary to correct the service problem and avoid imminent danger to lives and property. DOFAW and USFWS will be consulted via email with information on the event (e.g., location, date of removal, type of vegetation) before any vegetation more than 15 feet (4.6 meters) tall is disturbed, removed, or trimmed during the pup rearing season (June 1 through September 15).
4. No barbed wire will be used for conservation fencing.

Conclusion

The Hawaiian hoary bat (ʻōpeʻapeʻa) does not meet all four criteria for coverage under the KIUC HCP. Although the species is federally listed and occurs in the HCP permit area, and sufficient information exists to assess effects on the species and develop a conservation strategy, KIUC activities will avoid take of Hawaiian hoary bat (ʻōpeʻapeʻa). Vegetation trimming or removal will not result in take of Hawaiian hoary bats (ʻōpeʻapeʻa) with implementation of the avoidance measures described above. Furthermore, streetlights are not expected to result in take of Hawaiian hoary bat (ʻōpeʻapeʻa) for the reasons described above. Therefore, the KIUC HCP will not cover Hawaiian hoary bat (ʻōpeʻapeʻa).

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Appendix A. Agency Guidance Regarding Avoidance and Minimization Measures for Hawaiian Hoary Bat (ʻōpeʻapeʻa)

1. U.S. Fish and Wildlife Service December 16, 2015 letter regarding bat monitoring.
2. Division of Forestry and Wildlife August 6, 2020 email regarding guidance on bat take avoidance.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122
Honolulu, Hawai'i 96850

In Reply Refer To:
01EPIF00-2016-TA-0119

DEC 1 6 2015

Mr. Carey Koide
Transmission and Distribution Manager
Kaua'i Island Utility Cooperative
4463 Pahe'e Street, Suite 1
Līhu'e, HI 96766

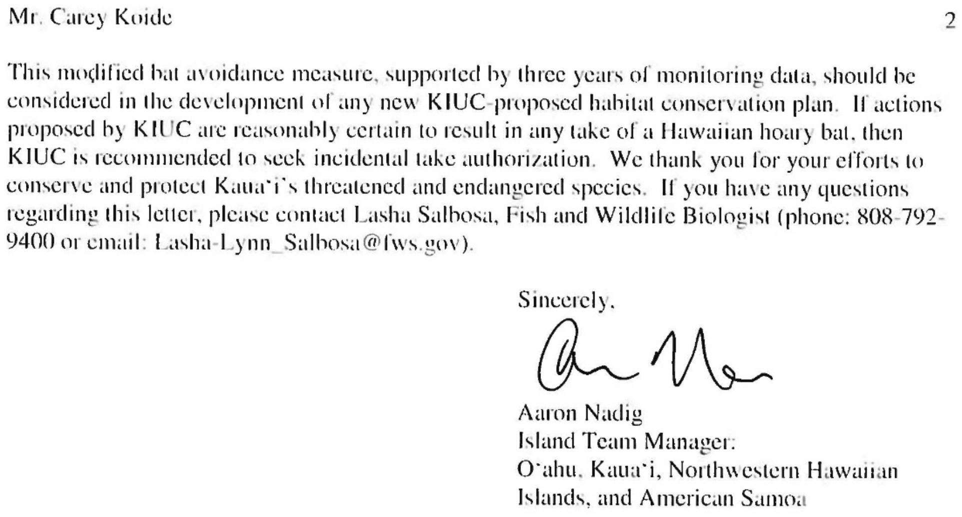
Subject: Kaua'i Island Utility Cooperative Request to Forego Further Bat Monitoring

Dear Mr. Koide:

This responds to your December 2, 2015 letter requesting to modify avoidance measures to prevent take of the Hawaiian hoary bat (*Lasiurus cinereus semotus*) during Kaua'i Island Utility Cooperative's (KIUC) maintenance operations. The KIUC has implemented comprehensive bat search protocols over the course of three bat pupping seasons (each June through September) in order to prevent the take of bats during tree trimming operations, as a component under KIUC's 2011 Service-approved Short Term Habitat Conservation Plan (ST HCP). The comprehensive bat monitoring protocols, approved by the Service in 2013 (Service File 2013-TA-0306) include the use of thermal imaging devices to scan for the absence of non-volant young in tree canopies prior to trimming, as well as annual field training for all personnel involved and blind searcher efficiency trials to test the ability for tree-trimming crews to accurately detect and avoid take of bats.

The Service received KIUC's 2015 bat monitoring report on December 1, 2015. Reviewing KIUC's monitoring data reports for 2013, 2014, and 2015 indicates that the tree-trimming teams have completed a total of 662 tree-trimming unit-days of monitoring of lowland vegetation clearing without encountering a single bat. Results from the searcher efficiency trials shows that tree-trimming teams have a very high likelihood of detecting a bat, if a bat were present.

Based on this information, the Service agrees with KIUC's decision to modify bat avoidance measures and forego comprehensive bat search protocols and instead limit tree-trimming during the bat pupping season (June through September) to areas along heavily traveled roadways that lack dense vegetation. The rationale behind that decision was based on the concern that in areas of very dense vegetation and along lightly traveled back roads there is a greater likelihood that bats might use that vegetation for roosting, and therefore the KIUC would not perform tree-trimming operations in these areas during the bat pupping season.



This modified bat avoidance measure, supported by three years of monitoring data, should be considered in the development of any new KIUC-proposed habitat conservation plan. If actions proposed by KIUC are reasonably certain to result in any take of a Hawaiian hoary bat, then KIUC is recommended to seek incidental take authorization. We thank you for your efforts to conserve and protect Kaua'i's threatened and endangered species. If you have any questions regarding this letter, please contact Lasha Salbosa, Fish and Wildlife Biologist (phone: 808-792-9400 or email: Lasha-Lynn_Salbosa@fws.gov).

Sincerely,

Aaron Nadig
Island Team Manager:
O'ahu, Kaua'i, Northwestern Hawaiian
Islands, and American Samoa

From:	Taylor, Lauren
To:	Ilana Nimz
Cc:	Phil Taylor; Siddiqi, Afsheen A; tkoike@honolulu.gov; Aloha Arborist Association; Angela Liu-kelly; john_vetter@fws.gov; Steve; Dave Johnston; Bookless CIV Lance; william.grannis@us.af.mil; angela.kieranvast@navy.mil; dayna.fujimoto@navy.mil; Matthew Burt; Tyler Bogardus; keith.roberts1@usmc.mil; Stan Oka; kevin_donmoyer@fws.gov; joy_browning@fws.gov; nanea_valeros@fws.gov; Berry, Lainie; Matsuoka, Koa; Montoya-Aiona, Kristina; KAWELO, Hilary K (Kapua) CIV (US); Craig.Gorsuch@colostate.edu; angelia.binder@us.af.mil; matthew.welsh.2.ctr@us.af.mil; Moura, Sean; Katie Temple
Subject:	RE: [EXTERNAL] Notes from HHB in Urban Forest meeting
Date:	Thursday, August 6, 2020 4:44:09 PM

Aloha all,

Since this meeting DOFAW has had some inquiries about tree trimming during the bat pupping season. I would like to reiterate the State’s current guidance on bat take avoidance and am happy for you to disseminate to your colleagues.

> The State endangered Hawaiian Hoary Bat or ʻOpeʻapeʻa (*Lasiurus cinereus semotus*) has the potential to occur throughout the islands and roosts in a variety of trees. If any trees must be removed during the bat breeding season there is a risk of injury or mortality to juvenile bats. Site clearing should be timed to avoid disturbance during the bat birthing and pup rearing season (June 1 through September 15). If this cannot be avoided, including for emergency work, woody plants greater than 15 feet (4.6 meters) tall should not be disturbed, removed, or trimmed without consulting DOFAW at (808) 587-0160.
>
> Currently we do not have data or research to support a method for reliably detecting roosting bats in trees. Therefore, to avoid the potential for take, the State recommends avoiding trimming during the pupping season.

Hawaii Revised Statutes Chapter 195D prohibits take of State listed species except when accompanied by an Incidental Take License and Habitat Conservation Plan. Our first priority in all instances is to assist in avoiding take of listed species. For take that cannot be avoided, we will work with the project proponent to minimize and mitigate the impacts of take. For anyone interested in pursuing an Incidental Take License, you may contact Koa Matsuoka (koa.matsuoka@hawaii.gov) or me for a consultation.

Respectfully,

Lauren Taylor
Protected Species Habitat Conservation Planning Coordinator
Endangered Species Biologist
Pacific Cooperative Studies Unit in cooperation with
Department of Land and Natural Resources

Division of Forestry and Wildlife
1151 Punchbowl Street, Room25
Honolulu, HI 96813
(808) 587-0010

Attachment 2. Measures to Avoid Adverse Effects on Listed Plant Species

KIUC will implement the following avoidance measures to ensure the KIUC HCP conservation measures do not adversely affect state- and federally listed plant species.

1. Prior to implementation of covered activities in potentially suitable habitat for listed plant species, including implementation of the conservation strategy minimization and conservation actions, a qualified botantist will conduct a botanical survey for listed plant species within the work area defined as the area where direct and indirect effects are likely to occur. Botanical surveys should optimally be conducted during the wettest part of the year (typically October to April) when plants and identifying features are more likely to be visible, especially in drier areas. If surveys are conducted outside of the wet season, plant presence will be assumed. If observed, listed plant locations will be mapped. The botanist should mark the boundary of the area occupied by listed plants with flagging.
2. KIUC will coordinate with a qualified botanist to implement measures ensuring the covered activities will avoid adverse effects on listed plants. KIUC will time their activities to occur when the listed plant species are less vulnerable to impacts (e.g., after seed has set), to the maximum extent possible. Buffer distances will be implemented for the actions listed in Table A2-1. The buffer distances will reduce direct and indirect impacts on listed plants from management actions. However, where covered activities occur within the recommended buffer distances, additional consultation with USFWS and DOFAW will be conducted. Impacts on the listed plant species within the buffer area may be reduced by placing temporary fencing or other barriers at the boundary of the disturbance, as far from the affected plants as practicable. KIUC may also implement erosion or siltation control measures to ensure listed plants in the vicinity of the management area are not adversely affected.
3. Prior to any work activities within management areas near or within a listed plant species buffer, the qualified botanist will conduct a worker environmental awareness training for all staff. The training will cover the listed plant species and their habitats. The training will cover the natural history, appearance (using representative photographs), and legal status of species, regulatory protections, benefits of compliance, as well as the avoidance and minimization measures that must be implemented to avoid impacts. Participants will be required to sign a form that states they have received and understand the training.
4. All activities, including sureys and monitoring, risk introducing invasive species into work areas. All equipment, personnel and supplies will be properly checked to ensure they are free of contamination (weed seeds, organic matter, or other contaminants) before entering work areas. Quarantines and or management activities occurring on specific priority invasive species proximal to project areas need to be considered or adequately addressed. This information will be obtained by contacting local experts such as those on local invasive species committees (Kauaʻi: https://www.kauaiisc.org/). To avoid the potential spread of Rapid ʻŌhiʻa Death (ROD), ROD decontamination proctocols will be followed.

Table A2-1. Buffer Distances to Avoid and Minimize Potential Adverse Impacts on Listed Plant Species

Action		Buffer Distance (feet (meters))—Keep Work Activity This Far Away from Listed Plant	
		Grasses/Herbs/Shrubs and Terrestrial Orchids	**Trees and Arboreal Orchids**
Walking, hiking, surveys/monitoring		3 ft (1 m)	3 ft (1 m)
Cutting and removing vegetation by hand or hand tools (e.g., weeding)		3 ft (1 m)	3 ft (1 m)
Mechanical removal of individual plants or woody vegetation (e.g., chainsaw, weed eater)		3 ft up to height of removed vegetation (whichever greater)	3 ft up to height of removed vegetation (whichever greater)
Removal of vegetation with heavy equipment (e.g., bulldozer, tractor, “bush hog”)		2x width equipment + height of vegetation	820 ft (250 m)
Use of approved herbicides (following label)	Ground-based spray application; hand application (no wand applicator; spot treatment)	10 ft (3 m)	Crown diameter
	Ground-based spray application; manual pump with wand, backpack	50 ft (15 m)	Crown diameter
	Ground-based spray application; vehicle-mounted tank sprayer	50 ft (15 m)	Crown diameter
	Aerial spray (ball applicator)	250 ft (76 m)	250 ft (76 m)
	Aerial application – herbicide ballistic technology (individual plant treatment)	100 ft (30 m)	Crown diameter
	Aerial spray (boom)	Further consultation required	Further consultation required
Ground/soil disturbance/outplanting/fencing (hand tools, e.g., shovel, ʻōʻō; small mechanized tools, e.g., auger)		20 ft (6 m)	2x crown diameter
Ground/soil disturbance (heavy equipment)		328 ft (100 m)	820 ft (250 m)
Surface hardening/ soil compaction	Trails (e.g., human, ungulates)	20 ft (6 m)	2x crown diameter
	Roads/utility corridors, buildings/structures	328 ft (100 m)	820 ft (250 m)

Appendix 3A
Species Accounts

3A.1 Newell's Shearwater (ʻaʻo) (*Puffinus auricularis newelli*)

3A.1.1 Listing Status and Taxonomy

The Newell's shearwater (ʻaʻo) (*Puffinus auricularis newelli*), listed as threatened under the federal Endangered Species Act (federal ESA) in 1975, is endemic to the Main Hawaiian Islands (MHI) (Niʻihau, Kauaʻi, Oʻahu, Molokaʻi, Maui, Lānaʻi, Kahoʻolawe, and Hawaiʻi). This species is in the seabird family Procellariidae (Ainley et al. 1997a, 2020). The Newell's shearwater (ʻaʻo) was until recently considered by both the U.S. Fish and Wildlife Service (USFWS) and the North American Classification Committee (NACC) as a *super species* containing the Townsend's shearwater (*P. auricularis townsendi*) and Newell's shearwaters (ʻaʻo) collectively treated as *Puffinus auricularis newelli.* In 2015, NACC decided that both were full species (Chesser et al. 2015), given their non-overlapping breeding and foraging ranges, and morphological and phenological differences (Ainley et al. 2020). USFWS, however, continues to treat both Townsend's shearwater and Newell's shearwater (ʻaʻo) as subspecies of *Puffinus auricularis* (U.S. Fish and Wildlife Service 2016a). Newell's shearwaters (ʻaʻo) and Townsend's shearwaters separate based on breeding phenology and distribution, behavior, and plumage (Ainley et al. 1997a, 2020). The species is also listed as threatened under Hawaiʻi Revised Statutes (HRS), Chapter 195D, Section 195D-4, Endangered and Threatened Species. The species is ranked as critically endangered under the International Union for Conservation of Nature (IUCN) Red List (BirdLife International 2019). No critical habitat has been designated for the Newell's shearwater (ʻaʻo) (50 Code of Federal Regulations 17.11).

3A.1.2 Life History

The Newell's shearwater (ʻaʻo) breeds only in the southeastern Hawaiian Islands (Pyle and Pyle 2017a). As summarized in Ainley et al. (2020), when not at breeding colonies, the Newell's shearwater (ʻaʻo) is highly pelagic, frequenting tropical and subtropical waters overlying depths greater than 6,562 feet (ft) (2,000 meters [m]), mostly east and south of the Hawaiian Islands. It captures prey by pursuit-plunging, an uncommon foraging method among warm-water seabirds (Ainley 1977) and can regularly reach depths of 164 ft (50 m) in pursuit of prey (Ainley et al. 2020). Flight is strong, with rapid wing beats interspersed with short glides, a style requiring predictable prey availability; thus, this flight style is also uncommon among warm-water seabirds (Spear and Ainley 1997a, 1997b). These shearwaters rely heavily on tuna, especially yellowfin tuna (*Thunnus albacares*) and other large, predatory fish that drive prey (predominantly ommastrephid squid) toward the ocean surface (Spear et al. 2007; Ainley et al. 2014).

Newell's shearwaters (ʻaʻo) arrive on colonies in early April, exhibit a pre-laying exodus from late April to mid-May (typical of procellarids), and lay eggs from late May to early June, with chicks fledging late September to mid-November, predominantly in October (Ainley et al. 2020). Females lay a single egg in a chamber at the end of a deep burrow. Incubation is 52–55 days; the chick-rearing period lasts approximately 92 days (Telfer 1986; Ainley et al. 2020).

3A.1.3 Habitat Requirements and Ecology

This species breeds in burrows or deep rock crevices, within dense vegetation at higher elevations, or on sheer coastal cliffs and slot canyons (i.e., long, narrow, deep canyon) (Troy et al. 2016; Ainley et al. 2020; Raine et al. 2021a). On the Island of Kauaʻi, Newell's shearwaters (ʻaʻo) breed at locations between 525 and 3,927 ft (160 and 1,197 m) above sea level (mean 1,509 ft [460 m] ± 394 ft [120 m] SD, *n* = 17; Ainley and Holmes 2011), and in Puna District on Hawaiʻi, at 620–1,083 ft (189–330 m) above sea level (Reynolds and Ritchotte 1997). Newell's shearwaters (ʻaʻo) no longer breed in lowlands, where wedge-tailed shearwaters (ʻuaʻu kani) (*Ardenna pacifica*) are abundant—a species that does not breed at higher elevations (Brattstrom and Howell 1956; Harrison 1990). One exception is a small Newell's shearwater (ʻaʻo) colony established artificially at Kīlauea Point, Kauaʻi, as part of a cross-fostering experiment (Byrd et al. 1984; Telfer 1986; Haber et al. 2010); this population consisted of six to nine breeding pairs in 2017 and nine pairs in 2019 (Raine et al. 2018a, 2020a). While Newell's shearwaters (ʻaʻo) and wedge-tailed shearwaters (ʻuaʻu kani) can co-occur, wedge-tailed shearwaters (ʻuaʻu kani) regularly evict breeding Newell's shearwater (ʻaʻo) pairs (Ainley et al. 2020; Raine et al. 2020a).

The Newell's shearwater (ʻaʻo) is absent in the Leeward Hawaiian Islands where other species of shearwaters, such as the wedge-tailed (ʻuaʻu kani) and Christmas (*Puffinus nativitatus*) shearwaters breed abundantly. These islands, however, are low in elevation, with sparse vegetation, which are factors not typical of Newell's shearwater (ʻaʻo) habitat (Troy et al. 2016; Young et al. 2019).

Due in part to the presence of pigs (*Sus scrofa*), rats (*Rattus* spp.), and cats (*Felis catus*), Newell's shearwaters (ʻaʻo) now nest on steep slopes ranging 28° to 48° on Kauaʻi (median = 39°; Troy et al. 2016), but also on near-vertical volcanic crater walls on Hawaiʻi (Reynolds and Richotte 1997; Ainley et al. 2020). Newell's shearwater (ʻaʻo) usually nest where terrain is vegetated by an open canopy of ʻōhiʻa lehua (*Metrosideros polymorpha*) and other native, wet, montane forest species, with an understory of densely matted false staghorn (uluhe) ferns (*Dicranopteris linearis*) (Troy et al. 2016). Raine et al. (2021a) documented that the three most important microhabitat variables for Newell's shearwater (ʻaʻo) are ʻōhiʻa lehua in the canopy, elevation, and percentage of false staghorn (uluhe) in the understory. The species also breeds, or at least recently bred, in the dry cliff faces of the Waimea Canyon and slot canyons of the Nā Pali Coast, Kauaʻi, both areas of sparse vegetation (Ainley et al. 2020). These birds may occasionally climb nearby trees or rock outcrops to take flight because they have difficultly taking off from flat ground (Telfer et al. 1987; Ainley et al. 2020); however, they have been observed to fly away on flat, unobstructed areas (shopping center parking lots) after becoming grounded when winds were adequately strong (Ainley et al. 1995).

Nesting colonies are situated inland from the coast—as much as 8.7 miles (mi) (14 kilometers [km]) on Kauaʻi. Inland-breeding Newell's shearwaters (ʻaʻo) on Kauaʻi repeatedly use the same routes when flying between breeding areas and the sea. Based on tracking work conducted by Raine et al. (2017a), key features the birds use to route to nesting colonies on Kauaʻi are terrain (specifically ridge tops) and prevailing wind, and while they have a few defined key routes, they appear to choose which route to take depending on prevailing wind direction and wind speed. On the other hand, outbound flights follow a broad swath out to sea, generally using the shortest possible distance between burrow and sea level.

Rainfall in Kauaʻi mountains, where Newell's shearwater (ʻaʻo) nest, is among the heaviest anywhere on Earth. Mean annual rainfall at Mount Waiʻaleʻale is 450 inches (1,143 centimeters [cm]); mean annual rainfall in Puna District and Waipiʻo Valley, on the windward east side of the island of

Hawaiʻi, is 108–213 inches (274–541 cm) (Encyclopedia Britannica 2020; Carlquist 1980; Giambelluca et al. 2013). Heavy rainfall facilitates dense vegetation growth.

3A.1.4 Distribution and Population Trends

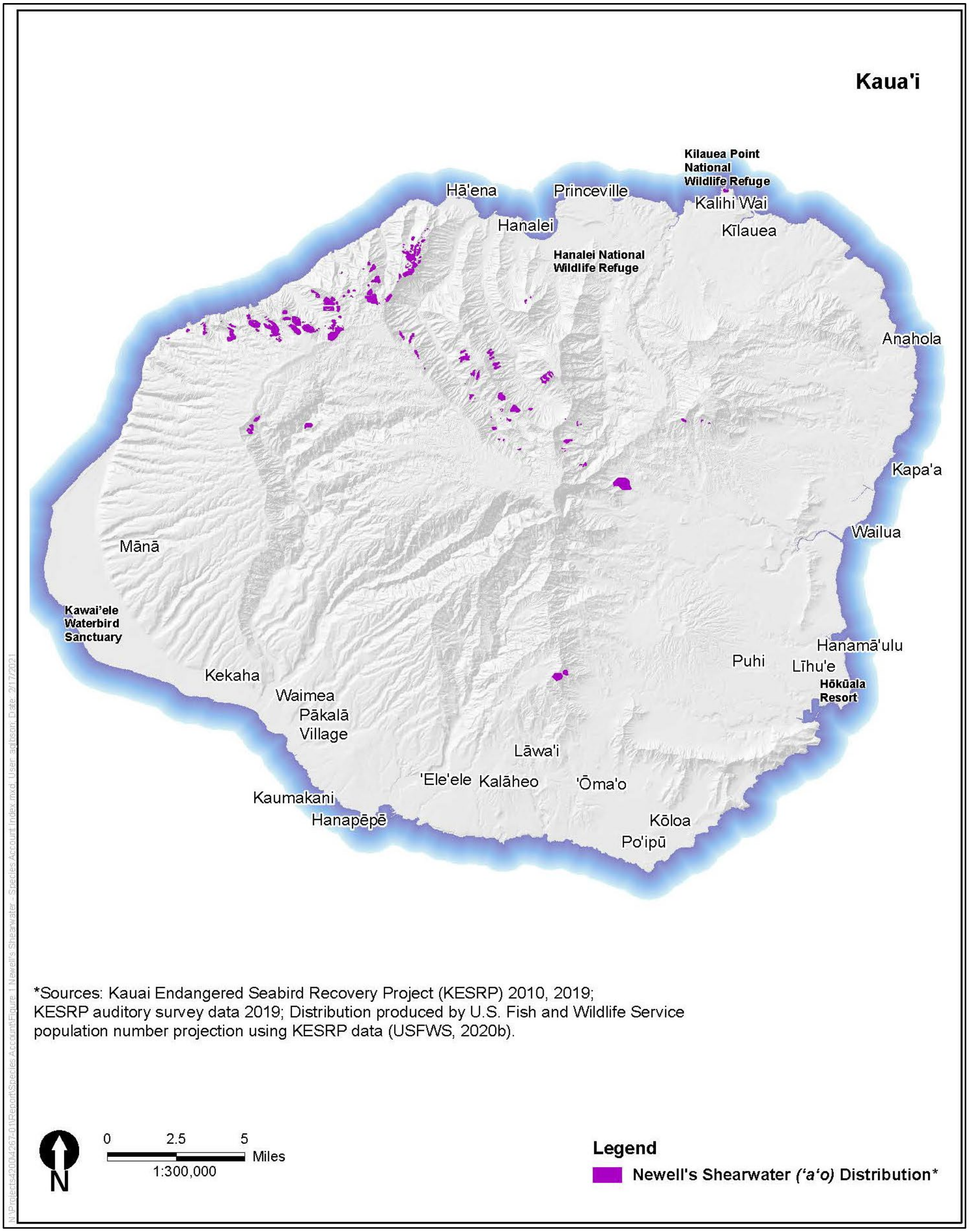
3A.1.4.1 Current and Historic Distribution

As noted in Ainley et al. (2020), Newell's shearwaters (ʻaʻo) occur year-round in the eastern tropical Pacific Ocean, especially in the Equatorial Countercurrent, from equatorial waters lying south of the Hawaiian Islands east to about 120°W and north to the subtropical waters surrounding the MHI (22°N). During breeding season, low densities occur short distances west and north of Hawaiʻi to about 25°N (King and Gould 1967; Spear et al. 1995a; Joyce et al. 2011). Also, during that time of year, the central part of the marine range projects slightly northward, likely an artifact of more adults and subadults commuting to and from breeding colonies (Ainley et al. 2020). Telemetry work conducted by the Kauaʻi Endangered Seabird Recovery Project (KESRP) shows that during the breeding season, Newell's shearwaters (ʻaʻo) predominately use water north of Kauaʻi, up to 93.2 mi (150 km), while non-breeding or failed breeders can range more widely (Raine et al. 2021b). Nesting pairs engage in a short-long alteration of foraging trips, with one member of each pair making daily trips while the other is farther at sea for about a week; then they switch routines (Ainley et al. 2020).

Within the Hawaiian Islands, Newell's shearwaters (ʻaʻo) are found in the fossil and subfossil deposits of Oʻahu and other islands, and are believed, or are known, to have colonized Hawaiʻi, Maui, Molokaʻi, Oʻahu, and Kauaʻi Islands (Pyle and Pyle 2017a; Ainley et al. 2020). While the early Hawaiians knew the seabird well, naming it ʻaʻo after its distinctive call, the species was thought to be extinct after 1908, due largely to habitat loss and predation (Pyle and Pyle 2017a). Since then, Newell's shearwaters (ʻaʻo) have been detected on Kauaʻi, Oʻahu, Hawaiʻi, and Maui. Currently, breeding is only known to occur on Kauaʻi, Maui and Hawaiʻi, but song meter recordings made in 2016 and 2017 indicate that a small number of Newell's shearwaters (ʻaʻo) regularly prospect on Oʻahu (Young et al. 2019).

3A.1.4.2 Within the Plan Area

The majority of the Newell's shearwater (ʻaʻo) breeding areas are in the northwestern portion of Kauaʻi (Figure 1). These breeding populations are found primarily in mountainous areas within deep valleys and along the edges of steep ridges (Ainley and Holmes 2011; Ainley et al. 2020). The only current coastal nesting site, established artificially, is at Kīlauea Point National Wildlife Refuge; as of 2017, a total of 25 burrows have been located at this site; 9 of these burrows were active in 2019 (Raine et al. 2020a). This population is the result of an egg swap project during 1978–1980 when approximately 100 Newell's shearwater (ʻaʻo) eggs from burrows in the Anahola Mountains and Kaluahonu were moved to Kīlauea Point and Mokuʻaeʻae Islet (Byrd et al. 1984). The current distribution of Newell's shearwaters (ʻaʻo) can in part be explained not only by the birds' preferred locations, but also range restrictions caused by predation by introduced mammals (Ainley et al. 2020) and other factors discussed above and further in Section A.1.5, *Threats*.



*Sources: Kauai Endangered Seabird Recovery Project (KESRP) 2010, 2019; KESRP auditory survey data 2019; Distribution produced by U.S. Fish and Wildlife Service population number projection using KESRP data (USFWS, 2020b).

Figure 1. Current Confirmed Distribution of the Newell's Shearwater ('a'o) Based on Contemporary Audio Surveys

Since 2006, KESRP has been using auditory surveys to locate contemporary breeding areas of this species. USFWS has estimated that the suitable breeding habitat range represents roughly 2,634 acres (1,066 hectares; U.S. Fish and Wildlife Service 2016b) that occurs predominantly in the northwestern portion of Kauaʻi. Included are Wainiha Valley, Lumahaʻi Valley, Hanalei Valley, Upper Limahuli Valley, Upper Mānoa Valley, and in the valleys along the Nā Pali Coast from Hanakāpiʻai to Nuʻalolo (Raine et al. 2018b). Habitat suitability modeling by Troy et al. (2014) indicates that a moderate portion of the sloped interior of Kauaʻi could potentially be suitable nesting habitat for Newell's shearwater (ʻaʻo); however, in combination with a habitat/threat-isolation index (Troy et al. 2014), is much more restricted to portions of Kauaʻi isolated from anthropogenic factors. The bulk of the known active Newell's shearwater (ʻaʻo) burrows are in the Hono o Nā Pali Natural Area Reserve and Upper Limahuli Preserve (Raine et al. 2019a).

3A.1.4.3 Population

Kauaʻi supports approximately 90 percent of the known total Newell's shearwater (ʻaʻo) population (Pyle and Pyle 2009; Ainley et al. 2020). An assessment based on at-sea survey data collected by the National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center from 1998 to 2011, estimated the total Newell's shearwater (ʻaʻo) population at 27,011 (95 percent CI = 18,254–37,125), which would include juveniles, sub-adults, and adults (Joyce et al. 2016). An updated assessment by Joyce et al. (2019) largely confirmed the 2016 estimate, concluding there to be 28,779 Newell's shearwaters (ʻaʻo) (95 percent CI = 17,574–43,011) (Joyce et al. 2019). However, these estimates are incomplete because the at-sea survey data analyzed by Joyce et al. (2016, 2019) only partially covered the full oceanic range of the species. Satellite-tagged Newell's shearwaters (ʻaʻo) from Kauaʻi have been tracked beyond the two at-sea survey boundaries, and the observed locations of tagged birds indicate that the available at-sea survey effort missed a substantial percentage of the population/at-sea range (Raine et al. 2021b). For example, those surveys did not include Newell's shearwaters (ʻaʻo) seen more than 300 mi (482.8 km) north of Kauaʻi (Joyce et al. 2016). Covering approximately the same ocean area, as well as decades earlier, Newell's shearwater (ʻaʻo) population estimates made based on 1986–1998 at-sea surveys are somewhat higher at 16,700–19,300 breeding pairs (Spear et al. 1995a), although as Joyce et al. (2016) stated the two estimates were not directly comparable due to different survey areas and methods. The lower population estimate of Joyce et al., compared to Spear et al., nevertheless is consistent with the decrease seen both by long-term radar studies by KESRP and the Save Our Shearwaters (SOS) fledgling fallout data (Raine et al. 2017b).

Given there is no correction factor to account for the negative bias in the at-sea survey estimates of abundance, Archipelago Research and Conservation (ARC) has developed island-based spatial estimates for the number of Newell's shearwater (ʻaʻo) breeding pairs in different areas of Kauaʻi. These estimates expand on previous studies (Raine et al. 2019b), which developed methods to estimate breeding pairs in acoustically monitored conservation sites in northwestern Kauaʻi (i.e., Upper Limahuli Preserve, Pihea, Pōhākea, North Bog, Hanakāpiʻai, and Hanakoa). In 2017, arrays of automated acoustic monitoring devices (also known as "song meters") were deployed in these conservation sites in areas where burrow monitoring surveys are also performed. The burrow monitoring surveys provide, among other things, estimates of active nest densities within the study areas. Further, studies within the burrow monitoring areas have demonstrated that the correlation between recorded call rates and active nest densities is highly significant (Raine et al. 2019b). In other words, areas with higher active nest densities have higher call rates, and the relationship between the two has been estimated through regression modeling. This allows the number of breeding pairs to be estimated from call rates measured by acoustic arrays that have been deployed to cover the footprint of monitored conservation sites (Archipelago Research and Conservation 2021). Additionally, this relationship has been used to estimate breeding pairs in other areas where acoustic monitoring data has been collected along the Nā Pali Coast and in the Lumahaʻi and Hanalei Valleys (Raine pers. comm.).

For other areas of Kauaʻi, where acoustic monitoring data are not available, ARC has used alternative methods to estimate breeding pairs, including a modified version of the Troy et al. (2014) habitat suitability model for Newell's shearwater (ʻaʻo) on Kauaʻi. The habitat suitability model was modified in several respects for this purpose, including filtering the estimated suitable habitat to reflect that, in areas without predator mitigation measures, the remaining breeding pairs are currently restricted to nesting in less accessible areas than those found in the conservation sites. Likewise, a correction factor was applied to account for active burrows being more dispersed in unmanaged areas (i.e., a reduction in densities of breeding pairs), due to (1) a lack of invasive predator control, resulting in higher predation rates on nesting birds in colonies outside the conservation sites, and (2) greater vulnerability to powerline collisions and light attraction in areas outside the more remote and undeveloped northwestern region of the island.

This approach resulted in a minimum estimate of 10,186 breeding pairs on Kauaʻi and a minimum island-wide population of 34,546, and as stated above, assuming the Kauaʻi population is 90 percent of the entire population, a minimum total of 11,318 breeding pairs and a minimum population of 38,384 in the State of Hawaiʻi.

3A.1.4.4 Decline/Trend

Based on radar and SOS data collected between 1993 and 2013 the Newell's shearwater (ʻaʻo) population exhibited a significant decline in numbers commuting to and from montane breeding areas (Raine et al. 2017b; Ainley et al. submitted); in the last decade the trend flatlined (Raine and Rossiter 2020; Ainley et al. 2020; Ainley et al. submitted). Ornithological radar was first used to detect prevalence of Newell's shearwaters (ʻaʻo) and Hawaiian petrels (ʻuaʻu) (*Pterodroma sandwichensis*) in the various parts of Kauaʻi during 1992–1993 from May through mid-July (i.e., during the incubation and early chick-rearing stage) (Day et al. 2003a, 2003b). The effort was based on methods developed to monitor marbled murrelets (*Brachyramphus marmoratus*) in the Pacific Northwest (Cooper et al. 2001). The radar effort continued, and Day et al. (2003b) reported a mean annual decrease of 11.2 percent in the Newell's shearwater (ʻaʻo) population between 1993 and 2001.

Updating the analyses presented in Day et al. (2003b), a subsequent study using radar data collected at the same monitoring sites between 1993 and 2013 confirmed the continued decline in the number of shearwaters transiting across eastern and southern Kauaʻi (Raine et al. 2017b). Radar surveys have only been conducted in coastal areas of eastern, southern, and portions of northern Kauaʻi, which are the sections of coast accessible to vehicle-mounted radar equipment. Therefore, these radar data do not apply to the Nā Pali Coast, where the population is now concentrated (Figure 1). The study found an overall decrease in passage rates of 94 percent in 20 years. All the 13 monitored sites showed a substantial decrease in movement rates, with movement rates at 12 (92 percent) of the 13 sites showing statistically significant decreases (Raine et al. 2017b). Based on the radar data as a proxy for the breeding population, the Newell's shearwater (ʻaʻo) population was deemed to have decreased at an annual mean rate of approximately 13 percent over the 20-year period between 1993 and 2013 (Raine et al. 2017b). This updated rate of decrease is comparable to the mean annual rate of 11.2 percent between 1993 and 2001 reported by Day et al. (2003b).

Parallel to the radar data, the number of Newell's shearwater (ʻaʻo) fledglings retrieved by the SOS program on Kauaʻi has also decreased significantly. These fledglings are predominantly grounded due to light attraction, a phenomenon called "fallout", which affects primarily hatch year juveniles. Fledglings may fly into elevated structures (i.e., buildings) or land on the ground. On the ground they have difficulty regaining flight unless the area is open and there is sufficient wind (Section A.1.3, *Habitat Requirements and Ecology*). On the ground they become vulnerable to further injury or death caused by vehicles on roadways, exhaustion and dehydration, and predation by feral animals. Prior to Hurricane ʻIniki in 1992, annual numbers of fledglings collected by SOS were on average 1,511 ± 79, but from 1992 (the year of Hurricane ʻIniki) to 2015, numbers declined strongly, from 955 to 157 annually (Raine et al. 2017b). The order-of-magnitude drop in SOS program retrievals mirrored the decrease observed in radar-based counts of Newell's shearwaters (ʻaʻo) made in the same portion of Kauaʻi monitored by SOS (Raine et al. 2017b). The shearwaters that nest in areas in northern Kauaʻi (Nā Pali Coast) do not appear to be flying where radar (limited to locations accessible by vehicle) would detect them, nor are they flying near civilization where citizens might encounter any that are grounded by light attraction (Raine et al. 2017a). Similarly, the SOS program is concentrated in the same portions of the island that are surveyed by radar. Troy et al. (2011) suggest that there are very few portions of Kauaʻi from which young Newell's shearwaters (ʻaʻo) could successfully fledge without potentially viewing artificial light along their post-natal nocturnal flights to the ocean. And although it is not known how these birds respond to viewing lights on land once they are at sea, studies indicate that the birds can be attracted by light back to shore (Podolsky et al. 1998). Indeed, nesting only along the beach, seaward of any lights or on offshore islets, wedge-tailed shearwaters (ʻuaʻu kani) are attracted back to land from the sea (Urmston et al. 2022).

Raine and Rossiter (2020) and Ainley et al. (submitted) have shown that the trends in both radar and SOS data have leveled out since about 2009, indicating that after a very large population decline the population trend appears over the last decade to be flat. Although data from the most recent radar survey in 2020 did not change the overall significant downward trajectory on Kauaʻi of Newell's shearwater (ʻaʻo) over the entire period since 1993 (93 percent decline in overall numbers with an average rate of 6.9 percent a year), the regression for the last decade (2010–2020) is flat, with no significant change (Raine and Rossiter 2020). It is thought that with the rise in human population, along with its domestic animals added to the rats and pigs already present on Kauaʻi as well as infrastructure collisions, populations of areas surveyable by radar are now much reduced. At the same time, the impact of recent conservation efforts (i.e., reduced coastal lighting) may also have contributed to reducing the rate of decline (Ainley et al. 2020; Raine et al. 2017c; Raine and Rossiter 2020). At conservation sites that have been acoustically monitored, and at which predators have been reduced or eliminated, there have been statistically significant increases in call rates between the first year of monitoring (either 2014 or 2015, depending on the site) and 2020. The rates of increase in call rates range between 8.23 percent at Hanakoa and 18.29 percent at North Bog (Archipelago Research and Conservation 2022).

Consistent with these observations indicating an overall population decrease at least for eastern and southern Kauaʻi, several historical breeding sites have been depleted to the point of extirpation over the past decade (Griesemer and Holmes 2011; U.S. Fish and Wildlife Service 2016b; Raine and Rossiter 2020). The Makaleha breeding site in northeastern Kauaʻi, into which predators have access, has been regularly monitored using auditory surveys performed from an adjacent ridge overlooking the colony. A decade ago, the Makaleha breeding site had high call rates like the Upper

Limahuli Preserve managed breeding site; today, call rates are sporadic at best (Raine pers. comm.). Elsewhere, decreasing numbers have occurred in breeding areas that border, or are contained in, the more urban portions of Kauaʻi. Formerly well-recognized breeding sites at Sleeping Giant, Kāhili/Kalāheo, North Fork Wailua, and Kaluahonu have similarly exhibited reduction to near extirpation levels (Raine pers. comm.).

3A.1.5 Threats

Threats to the Newell's shearwater (ʻaʻo) include collision with powerlines, attraction to artificial lighting and subsequent grounding, predation from introduced species, habitat loss and degradation, and threats at sea which, while poorly known presumably include depletion of predatory fish (e.g., yellowfin tuna), bycatch, ocean pollution, and in general ocean alteration due to climate change. All told, the effects of these various factors have resulted in a significant decline of approximately 13 percent per year over the period of 1993 to 2013 (Raine et al. 2017b; U.S. Fish and Wildlife Service 2017), with a rapid decline of the species from 2003 to 2007 (U.S. Fish and Wildlife Service 2016c). In addition to human-caused factors, stochastic events, such as storms, and ecologically disruptive processes driven by climate change are likely to have an effect on metapopulation numbers (U.S. Fish and Wildlife Service 2016c). The following subsections describe each known threat.

3A.1.5.1 Powerline Collisions

Collisions with utility lines have been shown to have a significant impact on endangered seabirds on Kauaʻi, and data collection since the 1990s has provided robust documentation of the mortality for this species due to powerline collisions in the Plan Area (Cooper and Day 1998; Podolsky et al. 1998; Ainley et al. 2001; Travers and Raine 2016, 2020; Travers et al. 2019). Birds moving to and from the ocean and montane breeding sites in the dark may not see the powerlines and as a result may collide with them (Travers et al. 2014, 2019; Travers and Raine 2020). Extensive studies conducted by KESRP since 2011 as part of the Kauaʻi Island Utility Cooperative (KIUC) Short-Term Habitat Conservation Plan (HCP) using acoustic monitoring devices and direct observations, indicate that every powerline construction type and every region with powerlines on Kauaʻi has resulted in seabird mortality due to collisions (Travers et al. 2020). As a result of collision, seabirds may be killed upon impact or may become grounded with life-threatening injuries. Once grounded, birds can succumb to their injuries and are at risk for vehicular collision, predation, starvation, or dehydration. Collisions with powerlines and their effect on Newell's shearwaters (ʻaʻo) are discussed in detail in Chapter 5, *Effects*, and therefore are only summarized here.

As mentioned above, one method to track powerline strikes is to directly observe nighttime seabird collisions using night vision goggles. Avian powerline morality initially was quantified through ground searches (Podolsky et al. 1998); however, this does not account for birds that become grounded but are not located (whether because they are able to crawl away, they are quickly depredated, or they glide and become grounded later) or are not mortally injured but may also suffer from reduced reproductive success. It is also very difficult to search underneath many powerlines on Kauaʻi due to the rugged terrain (Travers et al. 2020). From 2012 to 2020, Travers et al. (2021) documented 112 Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) (30 percent/70 percent) collisions, of which 29 percent had negative impacts on flight capabilities.

To better understand strikes from powerlines in remote, unsearchable areas, KESRP developed a novel method to acoustically detect powerline collisions using autonomous recording devices. Increased monitoring coverage resulted in, for the first time, data collection rates that allowed for rapid quantification of the scale of seabird powerline collisions. Several models were then created by KESRP using this data, with the most recent being a Bayesian model (Travers et al. 2020). When seabirds collide with powerlines the grounding rate has been calculated as 28.8 percent (Travers et al. 2021). When this grounding rate is applied to the total number of acoustic strikes, it provides the number of grounded birds. This sampling method provided evidence that powerline strikes represent a serious threat to Newell's shearwater (ʻaʻo) (and other Hawaiian seabirds) on Kauaʻi. For more information on KESRP's powerline strike modeling, please see Appendix 5D, *Bayesian Acoustic Strike Model*.

3A.1.5.2 Light Attraction

Newell's shearwaters (ʻaʻo) fly to and from their breeding sites only at night. Artificial lighting causes disorientation, especially in fledglings during their first journey from their breeding site to the sea. They tend to circle lights and, in the process, may collide with structures or may land. This is called *fallout*. Furthermore, some portion of fledglings that successfully reach the sea are attracted back toward land by coastal lights, where they may be then susceptible to fallout (Troy et al. 2013).

Fledglings are the most susceptible to fallout on Kauaʻi (Telfer et al. 1987). Attraction to bright lights also occurs inland but seems to have a limited/negligible effect compared to coastal areas (Raine et al. 2019c). Even Newell's shearwaters (ʻaʻo) in northwestern Kauaʻi, where there are few lights, can be attracted back to land by bright lights (Troy et al. 2013).

Since the issue was first identified in the 1970s and 1980s, efforts have been implemented on Kauaʻi to minimize effects of light attraction–related fallout. Problematic light sources once identified were altered (e.g., Reed et al. 1985). Otherwise, most of the information available on the effect of light attraction on Newell's shearwaters (ʻaʻo) comes from the SOS Program, which was developed to minimize the effects of fallout on Kauaʻi's seabird populations through resident collection and delivery of downed birds to SOS stations for rehabilitation and release (Rauzon 1991; Telfer et al. 1987).

During the last 5 years of the SOS Program (2014–2018), SOS received 179 downed Newell's shearwaters (ʻaʻo) annually on average (Anderson 2019), 83 percent of which were released and observed flying to sea. Observations indicate that, in the absence of debilitating injuries or other threats, once grounded, shearwaters may be able to reorient themselves and are able to fly away if there is sufficient slope, sufficient wind to provide lift and an unobstructed pathway (Ainley et al. 1995, 2001). Unfortunately, it is thought that most grounded birds, if not found and recovered, are unable to gain flight and die from predation, vehicle strikes, or starvation and dehydration (Raine et al. 2020b).

Although it is not known what proportion of downed seabirds are discovered and turned in to SOS, or that fly away by themselves, previous studies have used several discovery or detection rates (Podolsky et al. 1998; Travers et al. 2012). The KIUC HCP assumes a detectability rate of 50 percent for areas that are systematically searched (i.e., facilities) (Ainley et al. 2001; U.S. Fish and Wildlife Service 2018a; State of Hawaiʻi Division of Forestry and Wildlife 2020), and a much lower rate of 10.4 percent for areas that are not systematically searched (i.e., streetlights). Please refer to Appendix 5A, *Light Attraction Modeling*, for a detailed discussion of detectability rates.

To assess whether birds released from SOS survived, a comparison was made using satellite tags affixed to SOS-released shearwater fledglings and those that naturally fledged from the Upper Limahuli Preserve. The results found that some birds that are released after rescue and rehabilitation by SOS do survive (thus highlighting the importance of SOS); however, the survival rates of birds released from SOS were lower than those that fledged naturally and flew directly out to sea (Raine et al. 2020b).

3A.1.5.3 Predation

Predation by introduced predators is likely the most significant threat to the Newell's shearwater (ʻaʻo) and has been since Kauaʻi was first settled by Polynesians (Ainley et al. 2001; Griesemer and Holmes 2011; Raine et al. 2019a, 2019c–g, 2020c). Being burrow nesters, Newell's shearwaters (ʻaʻo) are particularly vulnerable, as eggs, chicks, or adults, to predation by introduced species (Ainley et al. 2019; Raine et al. 2019a, 2019d–h, 2020c). Predation has been documented at all existing management sites (Nagendra et al. 2019; Raine et al. 2019a, 2019d–h). Predation on Newell's shearwaters (ʻaʻo) by feral cats, feral pigs, rats (particularly black rats [*Rattus rattus*]), dogs (*Canis familiaris*), barn owls (*Tyto alba*), and feral honeybees (*Apis* spp.), have all been documented as having serious impacts on this species (Raine et al. 2019a, 2019d–h). Although not confirmed as present on Kauaʻi (U.S. Fish and Wildlife Service 2019), predation by Indian mongoose (*Herpestes auropunctatus*) continues to be an issue on other islands with devastating effects on seabirds in the absence of ongoing predator control (Simons 1985; VanderWerf and Young 2014). Mongoose have been caught on Kauaʻi in recent years (Kauaʻi Invasive Species Committee 2021) and would become a serious threat if they become established. The same would be true of brown tree snakes (*Boiga irregularis*), which are rampant on several Southwestern Pacific islands such as Guam.

Observations made during the implementation of KIUC's Short-Term HCP and early implementation for this HCP have revealed how each predator affects the Newell's shearwater (ʻaʻo) population (see Raine et al. 2020c). Rats mainly target eggs and chicks; cats target chicks, subadults, and adults; and barn owls target subadults and adults. Burrow destruction and depredation by pigs has been documented as a significant source of mortality, including substantial adult mortality at unfenced breeding sites (Raine and McFarland 2014). Predation by owls is also an important issue and likewise particularly difficult to control (Raine et al. 2019c).

Limited research has been conducted on feral cat movement in Hawaiʻi. The Hono o Nā Pali Natural Area Reserve has been the focus of cat tracking efforts (Pias et al. 2017). Frequently, individual cats are detected on multiple camera traps within a monitored seabird breeding site and some cats have been observed on cameras at multiple breeding sites. For example, one cat was detected reliably across three breeding areas, at six camera traps, eight times over 53 days (Pias and Dutcher 2018). Information from studies conducted within Hono o Nā Pali Natural Area Reserve indicate that cats inhabiting the Natural Area Reserve move among adjacent seabird breeding sites and travel over large areas estimated to exceed 1,500 acres (607 hectares).

3A.1.5.4 Habitat Modification

Habitat loss, conversion, and modification historically presumably has had a major negative effect on Newell's shearwaters (ʻaʻo) as civilization has expanded into wild lands where it breeds, along with its accompanying pets, farm animals, vehicles, and other infrastructure (U.S. Fish and Wildlife Service 2016c). Among the MHI, 75 percent of native forest has been lost to agriculture and human growth (Cuddihy and Stone 1990). Human activities associated with agriculture contribute to the exposure and increased predation of ground-nesting birds (Reynolds and Ritchotte 1997). Recently it has become evident that habitat modification via invasive plant species or natural catastrophic events (e.g., hurricane, wildfire) facilitates predation because the reduction in dense native vegetation can provide access for predators into breeding areas (U.S. Fish and Wildlife Service 2016b). Further, pigs and goats modify the habitat by eating and trampling native vegetation and spreading invasive plants (such as guava [*Psidium cattleianum*] and ginger [*Hedychium gardnerianum*]) that modify the habitat, making it impenetrable to breeding seabirds (U.S. Fish and Wildlife Service 2016c). Troy et al. (2014) showed that Newell's shearwaters (ʻaʻo) nesting habitat is covered more by native vegetation than random sites, suggesting invasive vegetation might provide less suitable habitat. Asner et al. (2008) suggest invasive vegetation such as, but not limited to, strawberry guava and ginger, can affect seabird habitat use. Invasive vegetation including young strawberry guava can form nearly impenetrable stands of vegetation, limiting physical access to the ground and to burrows and potential nest sites (Duffy 2010; Van Zandt et al. 2014), and has been associated with at least one abandoned Newell's shearwater (ʻaʻo) colony on Kauaʻi (Raine pers. comm.). Extreme weather events such as hurricanes ʻIniki (1992) and ʻIwa (1982) have caused significant disruptions in forest habitat and, coupled with colonization of invasive plants, have resulted in permanent habitat loss for forest birds (Pratt 1994), though the magnitude of these effects on Newell's shearwater (ʻaʻo) have not been documented.

3A.1.5.5 Fisheries

Newell's shearwaters (ʻaʻo) depend on tuna (*Thunnuss* spp.) and other predatory fish to force prey within reach of seabirds (Harrison 1990; Spear et al. 2007; Ainley et al. 2014). The commercial tuna longline fishery is an important economic industry in Hawaiʻi, as well as in other nations, whose fleets fish within the Newell's shearwater (ʻaʻo) range. Several tuna species are now depleted, with possible secondary adverse effects on Newell's shearwater (ʻaʻo) feeding patterns (Ainley et al. 2014). A particular target of the tuna industry is yellowfin tuna, to which Newell's shearwaters (ʻaʻo) are especially attracted (Spear et al. 2007). More studies are needed to estimate the extent and magnitude of the effect on Newell's shearwater (ʻaʻo). Climate change is expected to shift the migratory home ranges of many tuna and other predatory fish species, which may or may not have additional implications for Newell's shearwater (ʻaʻo) food availability. While bycatch is important to scavenging seabirds, it is likely less of an issue for Newell's shearwater (ʻaʻo) (and other bird species that eat only live prey). Likewise, ingestion of plastics, a significant issue for scavengers and surface-feeding species (see Spear et al. 1995b), is unknown for Newell's shearwaters (ʻaʻo); the inspection of stomachs of downed SOS birds found no plastic (Ainley et al. 2014). Plastic ingestion was found to be the cause of death for three translocated Hawaiian petrel (ʻuaʻu) fledglings (U.S. Fish and Wildlife Service 2022); however, more research is needed to determine if this was an anomaly or a widespread threat.

3A.1.5.6 Stochastic Weather Events

Because many Hawaiian plant and animal species persist in low numbers or in restricted ranges, natural disasters such as hurricanes, volcanic eruptions, or tsunamis can be particularly devastating (Mitchell et al. 2005). Volcanic eruptions, which in 1984 destroyed forest bird habitat on Mauna Loa (Mitchell et al. 2005), occur only on the newer, easternmost islands of the chain (Hawaiʻi, Maui), and tsunamis would not be an issue given their upland nesting of Newell's shearwater (ʻaʻo). Among the MHI, hurricanes rarely reach Kauaʻi. Nevertheless, hurricanes ʻIwa (November 1982) and ʻIniki (September 1992) reached Kauaʻi, the last ones to do so, and were implicated in the extinction of several highly endangered forest birds (Pratt 1994). These storms downed a significant number of trees in Kauaʻi's forests, likely affecting breeding attempts for Newell's shearwaters (ʻaʻo) (Day and Cooper 1995; Ainley et al. 1997b; Mitchell et al. 2005; Griesemer and Holmes 2011). Raine et al.

(2017b) referred to a drop in the Newell's shearwater (ʻaʻo) population, as indexed by SOS data, after Hurricane ʻIniki, and reasoned that while the hurricane itself caused no direct mortality of adults—because it struck the island during the day while adults were at sea—it caused the removal of considerable amounts of vegetation that, prior to the storm, shielded powerlines, and this reduction in shielding subsequently led to an increase in powerline collisions (and subsequent reduction in Newell's shearwater [ʻaʻo] population). Ainley et al. (2001), on the other hand, also noted the decrease in SOS birds following impacts associated with Hurricane ʻIniki but ascribed the decrease to a documented reduction of human activity on the island, along with a reduction in associated urban lighting, leading to lower rates of fallout. Additionally, many native-dominated areas on Kauaʻi now contain smaller pockets of invasive species that became established following these hurricanes (Mitchell et al. 2005). Given that the majority of the Newell's shearwater (ʻaʻo) population breeds on Kauaʻi, catastrophic events like hurricanes represent a significant threat to the species (Mitchell et al. 2005).

3A.1.5.7 Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC), human activities have caused a 1.8 degrees Fahrenheit (°F) (1 degree Celsius [°C]) increase in tropospheric temperature above pre-industrial levels, and with the current rate of warming, could reach an increase of 2.7°F (1.5°C) by the year 2030 (Intergovernmental Panel on Climate Change 2019).

With increasing atmospheric temperature, the size and intensity of large-scale storms, which differ in many respects from the normal stochastic weather events discussed in Section A.1.5.6, *Stochastic Weather Events*, are expected to increase in coming years in various parts of the globe. Although Kauaʻi is quite used to heavy rainfall, these large-scale storms such as Kona storms may well result in greater landscape-scale damage to habitat (e.g., landslides, flooding) and subsequent loss of burrows/individuals and their future reproductive capacity. In 2021, a Hawaiian petrel (ʻuaʻu) chick was rescued from a flooded burrow in the Natural Area Reserve (Archipelago Research and Conservation 2021). Additional examples include hurricanes ʻIwa and ʻIniki, which devasted forests in 1982 and 1992, dramatically reducing available nesting habitat (Day and Cooper 1995). Large-scale storms also facilitate the incursion of invasive plants and animals (e.g., feral pigs, goats) to native habitat, altering and degrading the forest's ability to support native biota (Mitchell et al. 2005; U.S. Fish and Wildlife Service 2011a). Existing climate zones on high islands are generally projected to shift upslope in response to climate change. Some invasive plants may outcompete native species, as some invasive plants disproportionately benefit from increased carbon dioxide, disturbances from extreme weather and climate events, and an ability to invade higher-elevation habitats as the climate warms (Bradley et al. 2010). Climate change may also result in reduced rainfall that will additionally stress native Pacific Island flora and fauna, especially in high-elevation ecosystems with increasing exposure to invasive species (Leong et al. 2014).

Climate change brings rising sea levels, and this will seriously affect seabirds nesting among the low, northwestern Hawaiian Islands (e.g., Reynolds et al. 2015). However, seabirds confined to nesting in the uplands of coastal environments and mountainous interior of the MHI would not be affected by coastal inundation caused by rising sea levels. Other at-sea issues resulting from climate change that may also arise include effects on the distribution of prey species and ocean acidification due to increased ocean temperatures.

3A.2 Hawaiian Petrel (ʻuaʻu) (*Pterodroma sandwichensis*)

3A.2.1 Listing Status and Taxonomy

The Hawaiian petrel (ʻuaʻu) (*Pterodroma sandwichensis*), is endemic to the MHI, and was listed under the federal ESA as endangered in 1967 (U.S. Fish and Wildlife Service 1967). It is a member the seabird family Procellariidae. The Hawaiian petrel (ʻuaʻu) and Galápagos petrel (*Pt. phaeopygia*) were initially considered to be subspecies of the dark-rumped petrel (*Pt. phaeopygia*), but 20 years ago were split into two separate species, on the basis of differences in vocalizations, morphology, behavior, disjunct nesting and at-sea distributions (Banks et al. 2002; Tomkins and Milne 1991), and genetics (Browne et al. 1997; see also Spear et al. 1995a; U.S. Fish and Wildlife Service 2011b). The species is also listed as endangered under HRS, Chapter 195D, Section 195D-4, Endangered and Threatened Species. No critical habitat has been listed for the Hawaiian petrel (ʻuaʻu) (U.S. Fish and Wildlife Service 2020a). The Hawaiian petrel (ʻuaʻu) is listed as endangered on the IUCN Red List (BirdLife International 2018).

3A.2.2 Life History

Hawaiian petrels (ʻuaʻu) are long-lived, reaching 35 years of age; average age of first breeding is 6 years (Simons and Hodges 1998). In addition to physiological maturation, it is likely that competition for nest sites plays a role when an individual first breeds. It is also likely that nest-site availability can play an important role in the number of breeding birds in a colony, as seen in other burrow and cavity-nesting species—there could be a "floating population" composed of mature birds that have not yet found a nesting cavity (Warham 1997).

The Hawaiian petrel (ʻuaʻu) breeding cycle is synchronous with egg-laying spread over just about a month (Simons 1985). An estimated 89 percent of the adult population breeds in a given year (Simons and Hodges 1998). Phenology differs between the islands, with birds on Kauaʻi, arriving a month later than those on Maui and 2 weeks later than those on Lānaʻi (Judge et al. 2014). On Kauaʻi birds arrive to breeding grounds in mid-March and start pair formation. After pairing, nest building, and burrow maintenance, a distinct pre-laying exodus occurs in April, when breeding adults leave the colony just ahead of egg-laying, presumably to allow females time to acquire the reserves necessary for egg production and males to store energy for incubation. Egg-laying occurs in early May to mid-June. Incubation continues until mid-July. The chick-rearing period runs from mid-July until the end of the September, when the first chicks start to fledge. Fledging peaks in November with the last birds fledging towards the middle of December (Archipelago Research and Conservation 2021). Once the chicks leave they do not return to land again for a few years. Breeding colonies are generally empty by the end of November or early December.

3A.2.3 Habitat Requirements and Ecology

Hawaiian petrels (ʻuaʻu) forage widely in the North Pacific Ocean (Pitman 1986; Warham 1990; Spear et al. 1995a; Adams 2007; Wiley et al. 2012), using a long-trip, short-trip foraging strategy. Satellite-tagged birds from Maui and Lānaʻi have been tracked traveling more than 6,000 mi (10,000 km) on a single foraging trip to and from their breeding colonies, moving northwestward to the Kuroshio Current/Transition Zone then eastward to the California Current before returning to

Hawaiʻi (Adams and Flora 2010). Birds from Kauaʻi follow the same long-trip foraging routes, although for short trips they forage a few hundred kilometers north of Kauaʻi (Raine et al. 2017a). They are among the group of seabirds known as *tuna birds*, owing to their association with tuna that drive prey to the surface. The satellite tracking indicates some affinity to the realm of albacore (*Thunnus alalunga*). Assuming equivalence to the closely related Juan Fernandez petrel (*Pterodroma externa*), whose foraging has been extensively investigated (Spear et al. 2007), Hawaiian petrels (ʻuaʻu) feed mainly during daylight hours, but to a lesser degree at night. In summary, their diet consists of flying squid, flying fish, goatfish, lantern fish, hatchetfish, and similar species (see also Ballance et al. 1997; Simons 1985).

The species' nesting habitat is variable, as described by Simons and Hodges (1998). On Hawaiʻi and Maui, Hawaiian petrels (ʻuaʻu) nest in the cavities of lava flows in xeric conditions at high altitude (summit slopes of Mauna Loa and Haleakalā). On the lower islands of Lānaʻi and Kauaʻi, however, breeding areas are in dense, montane wet forest, mainly along valley headwalls, particularly those of steep slopes covered with uluhe fern (*Dicranopteris* spp.; Troy et al. 2016; see Figure 2). Raine et al. (2021a) documented that the three most important microhabitat variables for Hawaiian petrels (ʻuaʻu) are ʻōhiʻa lehua in the canopy, elevation, and maximum canopy height. Such attributes are consistent with the habitat suitability model of Young et al. (2019) developed to search for potential nesting colonies on Oʻahu, as well as the studies of Van Zandt et al. (2014) on Lānaʻi. Raine et al. (2021) found that Hawaiian petrels (ʻuaʻu) tend to utilize habitat at higher elevations but that were less steep and less vegetated than Newell's shearwater (ʻaʻo).

3A.2.4 Distribution and Population Trends

3A.2.4.1 Current and Historic Distribution

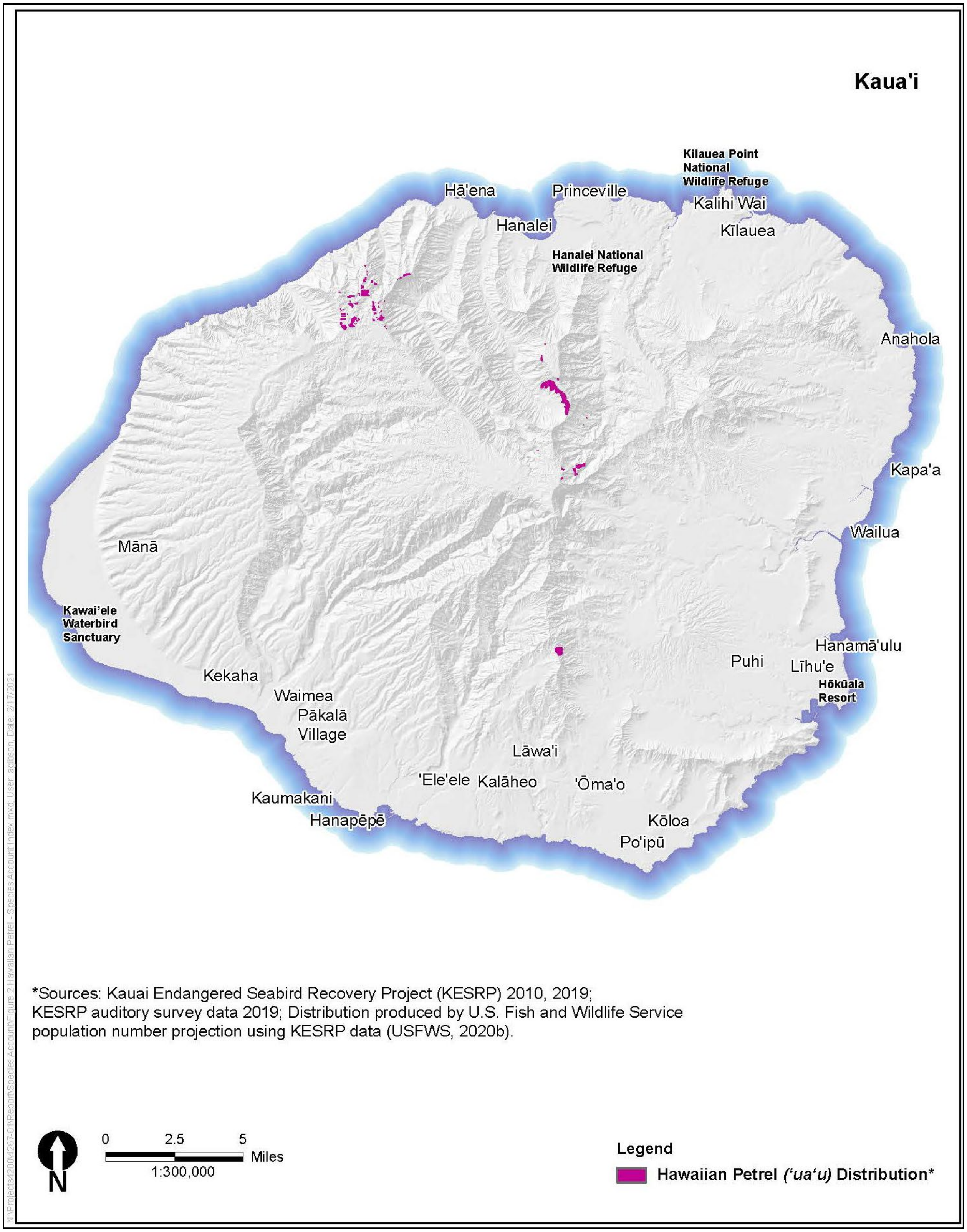
Based on current distribution and subfossil remains, Hawaiian petrels (ʻuaʻu) are thought to have once been prevalent on all of the high islands in the Hawaiian Archipelago including Hawaiʻi, Maui, Lānaʻi, Kahoʻolawe, Molokaʻi, Oʻahu, and Kauaʻi (Ainley et al. 1997c; Olson and James 1982a, 1982b; Telfer 1983; Pyle and Pyle 2017b). Historic accounts reveal abundant Hawaiian petrel (ʻuaʻu) presence on the Hawaiian Archipelago since the late 1800s and/or early 1900s (Banko 1980; Simons and Simons 1980), including on low-elevation coastal plains on Oʻahu, Kauaʻi (e.g., Makauwahi Cave), and other islands (Olson and James 1982a, 1982b). By at least the mid-20th century, Hawaiian petrel (ʻuaʻu) colonies were restricted to high elevations (Pyle and Pyle 2017b).

It appears that the historic decrease in Hawaiian petrel (ʻuaʻu) populations on all of the Hawaiian Islands and the historic extirpation of Oʻahu populations were initiated by Polynesians, especially with the introduction of invasive predatory species they brought to the islands (pigs, rats; Banko 1980; Olson and James 1982a, 1982b; Simons 1985). The Hawaiian petrel (ʻuaʻu) decline was accelerated with the introduction of cats by Europeans (Simons 1985).

Extant Hawaiian petrel (ʻuaʻu) breeding sites are known to exist at five high-elevation regions on Maui, Hawaiʻi, Kauaʻi and Lānaʻi. A large proportion of the Hawaiian petrel (ʻuaʻu) population breeds on the island of Maui within Haleakalā National Park (~27 percent; Pyle and Pyle 2017b). Presence there is aided by a long-standing commitment to predator control by the park. Some fragmented breeding locations with fewer than 10 burrows have been reported in areas outside the main known breeding sites (Simons and Hodges 1998), and radar studies indicate that breeding may occur on Molokaʻi (Day and Cooper 2002). Reportedly, the number of Hawaiian petrels (ʻuaʻu) in breeding areas on Lānaʻi and Maui are significantly greater than previously inferred. Survey work conducted at a rediscovered breeding site on Lānaʻi in 2005 and 2008 indicated that thousands of birds are present, rather than hundreds of birds as first thought (State of Hawaiʻi Department of Land and Natural Resources 2015), and in 2019, KESRP and Pūlama Lānaʻi monitored a total of 311 Hawaiian petrel (ʻuaʻu) burrows at multiple managed colonies (Raine et al. 2020d). Recent habitat suitability modeling indicates that 8,000–10,000 individuals and 4,000–5,000 breeding pairs reside in Haleakalā National Park (National Parks Service 2021). A recent study based on historical records, acoustic monitoring, and habitat suitability modeling suggests that a small number of Hawaiian petrels (ʻuaʻu) may be breeding on Oʻahu (Young et al. 2019).

3A.2.4.2 Within the Plan Area

The current breeding population of Hawaiian petrels (ʻuaʻu) on Kauaʻi is confined to higher elevations, especially ridge crests, in the northwest portion of the island (Figure 2).



*Sources: Kauai Endangered Seabird Recovery Project (KESRP) 2010, 2019; KESRP auditory survey data 2019; Distribution produced by U.S. Fish and Wildlife Service population number projection using KESRP data (USFWS, 2020b).

Figure 2. Current Confirmed Distribution of the Hawaiian Petrel (ʻuaʻu) Based on Contemporary Audio Surveys

3A.2.4.3 Population

Kauaʻi supports approximately 33 percent of the total Hawaiian petrel (ʻuaʻu) population (Raine pers. comm.). An assessment based on at-sea survey data collected by the NMFS Southwest Fisheries Science Center from 1998 to 2011 estimated the total Hawaiian petrel (ʻuaʻu) population within the study area at 71,496 birds with lower and upper 95 percent confidence intervals of 58,010 and 85,645 (Joyce et al. 2016). The estimate includes juveniles, subadults and adults. More recently, Joyce et al. (2019) estimated the Hawaiian petrel (ʻuaʻu) population to be 65,856 individuals (Bootstrap 95 Percentile, 19,717 to 91,097) also based on surveys at sea. This largely confirmed the estimate from the Joyce et al. 2016 study and is significantly higher than previous assessments based on pelagic surveys in the same general region, where the Hawaiian petrel (ʻuaʻu) population was estimated at 19,000 (95 percent confidence interval = 11,000–34,000) including juveniles, subadults, and adults, and 4,500–5,000 breeding pairs (Spear et al. 1995a). As stated above for Newell's shearwater (ʻaʻo) (Section A.1.4.3, *Population*), the observations of both Joyce et al. (2016, 2019) and Spear et al. (1995a) cover a major portion but not the entire at-sea range and so are underestimates. Further, Ainley et al. (1997b) posited that Spear et al. (1995a) had underestimated the population by about 5 percent due to seasonal patterns of spatial occurrence. Nevertheless, the higher estimate of Joyce et al. (2019), with at-sea surveys conducted a couple of decades later, might well reflect the successful conservation efforts at Haleakalā National Park over the past 40 years.

In 2020, to remedy the gaps in the at-sea abundance data, ARC developed a theoretical population estimate for Hawaiian petrel (ʻuaʻu) that does not rely on the at-sea survey data analyzed by Joyce or Spear. The general approach used for estimating breeding pairs of Hawaiian petrel (ʻuaʻu) follows that used for Newell's shearwater (ʻaʻo)(Section A.1.4.3, *Population*). Briefly, this approach involves a combination of acoustic call rate data (Archipelago Research and Conservation 2021), which has been demonstrated to have a highly significantly relationship with active breeding pairs (Raine et al. 2019b), as well as habitat suitability modeling (Troy et al. 2017), and correction factors to account for lower densities of breeding pairs in colonies outside managed conservation sites (Raine pers. comm.). This approach resulted in a minimum estimate of 8,051 breeding pairs on Kauaʻi, which equates to a minimum island-wide population of 25,277 and, assuming the Kauaʻi population is 33 percent of the entire population, a maximum total of 24,396 breeding pairs and total minimum population of 76,598 in the State of Hawaiʻi.

3A.2.4.4 Decline/Trend

The Hawaiian petrel (ʻuaʻu) population decreased severely over the past few centuries, since the arrival of humans on the islands (Olson and James 1982a). Genetic analysis conducted within the last decade has revealed strong genetic differentiation among Hawaiian populations on separate islands (Welch and Fleischer 2011), underlining the importance of understanding population trends for this species on an island-by-island basis (Stiebens et al. 2013).

As with the Newell's shearwater (ʻaʻo), between 1993 and 2013 the Hawaiian petrel (ʻuaʻu) population declined steeply (Raine et al. 2017b). The study found an overall decrease in passage rates of 78 percent in 20 years, and 62 percent of the 13 sites showed a statistically significant decrease in movement rates over the entire period (Raine et al. 2017b). Based on the radar data as a proxy for the breeding population, the Hawaiian petrel (ʻuaʻu) population has decreased at an annual mean rate of 6 percent over the 20-year period (Raine et al. 2017b).

Radar surveys have only been conducted from May through mid-July, i.e., during the incubation and early chick-rearing stage, in coastal areas of northeastern, eastern, and southern Kauaʻi, or those areas accessible to vehicle-mounted radar equipment. Therefore, these radar data do not apply to the Nā Pali Coast where the Hawaiian petrel (ʻuaʻu) population is concentrated on Kauaʻi (Figure 2).

Following on from the population crash between 1993 and 2013, Raine and Rossiter (2020) and Ainley et al. (submitted) have shown that the trends in both radar and SOS data have been level for approximately the last decade. Although data from the more recent radar surveys through 2020 did not change the overall significant downward trajectory on Kauaʻi of Hawaiian petrel (ʻuaʻu) over the entire period since 1993 (72.8 percent decline in overall numbers with an average rate of 4.7 percent per year), the trend during the last decade (2010 to 2020) has been flat with no significant change (Raine and Rossiter 2020). Similar to Newell's shearwater (ʻaʻo), call rates at acoustically monitored conservation sites in which predators have been excluded or controlled have shown statistically significant increases between the first year of monitoring (either 2014 or 2015, depending on the site) and 2020, ranging from 16.23 percent at Pihea to 26.22 percent at North Bog (Archipelago Research and Conservation 2021).

Unlike Newell's shearwater (ʻaʻo), because so few Hawaiian petrels (ʻuaʻu) are grounded by light attraction on Kauaʻi every year, it is not possible to use SOS data to chart population declines (as was undertaken for Newell's shearwater [ʻaʻo]) (Raine et al. 2017b).

3A.2.5 Threats

Most of the threats facing Hawaiian petrels (ʻuaʻu) are like those faced by Newell's shearwaters (ʻaʻo) and are explained in detail in Section A.1.5, *Threats*. Compared to the Newell's shearwater (ʻaʻo), very few Hawaiian petrels (ʻuaʻu) have been found grounded and turned in to SOS during the fledging season, likely related to a recent historical much lower population size, and long-time relegation to the North Shore away from coast lights in developed areas of Kauaʻi. For example, on average, 9.6 Hawaiian petrels (ʻuaʻu) were received by the SOS Program annually between 2014 and 2018 in comparison to 179 Newell's shearwaters (ʻaʻo) during the same time period on Kauaʻi.

3A.2.5.1 Climate Change

Threats related to climate change would be the same for Newell's shearwaters (ʻaʻo) and Hawaiian petrels (ʻuaʻu), and are discussed in Section A.1.5.7, *Climate Change.*

3A.3 Band-Rumped Storm-Petrel (ʻakēʻakē) (*Oceanodroma castro*)

3A.3.1 Listing Status and Taxonomy

The Hawaiʻi distinct population segment (HDPS) of the band-rumped storm-petrel (ʻakēʻakē) (*Oceanodroma castro*) (hereafter band-rumped storm-petrel), a member of the seabird family Hydrobatidae, was listed as an endangered species under the federal ESA in 2016 (U.S. Fish and Wildlife Service 2016d). The species is also listed as endangered under HRS, Chapter 195D, Section 195D-4, Endangered and Threatened Species. No critical habitat has been designated for the band-rumped storm-petrel (ʻakēʻakē) (U.S. Fish and Wildlife Service 2016d). Recent genetic studies have found that the Hawaiian population of this species is genetically distinct from other populations throughout its global range (Taylor et al. 2019). The band-rumped storm-petrel (ʻakēʻakē) is listed as Least Concern on the IUCN Red List (BirdLife International 2018), as a function of the global occurrence of this species on dozens of nesting islands. However, the IUCN list does not consider the HDPS.

3A.3.2 Life History

On land, at least in the Hawaiian Islands, band-rumped storm-petrels (ʻakēʻakē) are nocturnal. The only nests that have been found are on the Island of Hawaiʻi (Galase 2019; Antaky et al. 2019). Based on auditory data, both on Kauaʻi and offshore Lehua Islet, the species arrives at breeding colonies on Kauaʻi in late May, with birds fledging from late September to mid-November (Raine et al. 2017d). Other information on the breeding biology of this species can only be approximated from the Galápagos Islands, where it has been relatively well studied. The species probably does not breed until 3 years of age, and likely lives to 20 years (Ainley 1984). The nesting season in the Galápagos also occurs during the boreal summer, with adults establishing nesting territories in April or May. A single, white egg is laid. The incubation period averages 42 days (Harris 1969) and the young reach fledging stage in 64–70 days (Allan 1962; Harris 1969). In the Hawaiian Islands evidence of their presence, either vocalizations or specimens, are spread from April to November; calling is most intense at Mauna Loa between June and August (Banko et al. 1991; Galase 2019). On the basis of auditory surveys, it arrives on Kauaʻi in late May and chicks fledge from late September to mid-November (Raine et al. 2017d).

At sea, this species forages at the surface by dipping and surface seizing. Diet consists mainly of small fish, squid, and crustaceans, as well as material scavenged from floating carcasses and surface slicks (Harris 1969; Slotterback 2002, 2020). More so than the above two species, it forages at night (Spear et al. 2007).

3A.3.3 Habitat Requirements and Ecology

The band-rumped storm-petrel (ʻakēʻakē) is a tropical/subtropical species occurring in the Atlantic, Indian, and Pacific Oceans; Pacific populations breed on the Galápagos Islands, Japan, and the Hawaiian Islands (Howell 2012). At sea, the band-rumped storm-petrel (ʻakēʻakē) has been observed off the coast of the Americas from 24.80°N to 23.27°S, but not beyond 1,123 mi (1,807 km) from the mainland (Spear et al. 2007), and birds have been seen 600 mi (966 km) north of Hawaiʻi, 1,000 mi (1,609 km) south of Hawaiʻi, and between Japan and Hawaiʻi (Raine et al. 2017d; U.S. Fish and Wildlife Service 2016d). More specifically, this species has been detected in very low numbers in waters between 10°N and 10°S south and west of Hawaiʻi, particularly during fall (Crossin 1974; Pitman 1986; Spear et al. 1999, 2007). In summer they have been detected in waters immediately south of the Hawaiian Islands (Crossin 1974; Spear et al. 1999; Banko et al. 1991). Banko et al. (1991) reported that early Hawaiians found them common off the windward coasts of the islands.

Nests are placed in crevices, holes, and protected ledges along cliff faces, well above the base and well below the top (Allan 1962; Harris 1969; Galase 2019). As noted by Raine et al. (2017d), breeding colonies on Kauaʻi, based on auditory surveys, are concentrated along the Nā Pali Coast, particularly within canyons from the Kalalau Valley to Polihale, as well as the Waimea Canyon. Habitat consists of sparsely vegetated, very steep cliffs, where the species has been relegated to such habitat by invasive mammalian predators. Small pockets of these birds also occur in some of the wetter and heavily vegetated valleys that contain exposed rocky cliff faces. A large concentration of storm-petrel activity was also recorded on the southeastern slopes of Lehua Islet (Raine et al. 2017d).

3A.3.4 Distribution and Population Trends

3A.3.4.1 Current and Historic Distribution

When Polynesians arrived in Hawaiʻi about 1,500 years ago, the band-rumped storm-petrel (ʻakēʻakē) probably was common on all the MHI (Harrison 1990; Raine et al. 2017d). As indicated by bones found in middens on the island of Hawaiʻi (Harrison 1990) and in excavation sites on Oʻahu and Molokaʻi (Olson and James 1982a, 1982b; Raine et al. 2017d), it appears the band-rumped storm-petrel (ʻakēʻakē) was once numerous enough to be harvested for food and possibly for their feathers (Harrison 1990).

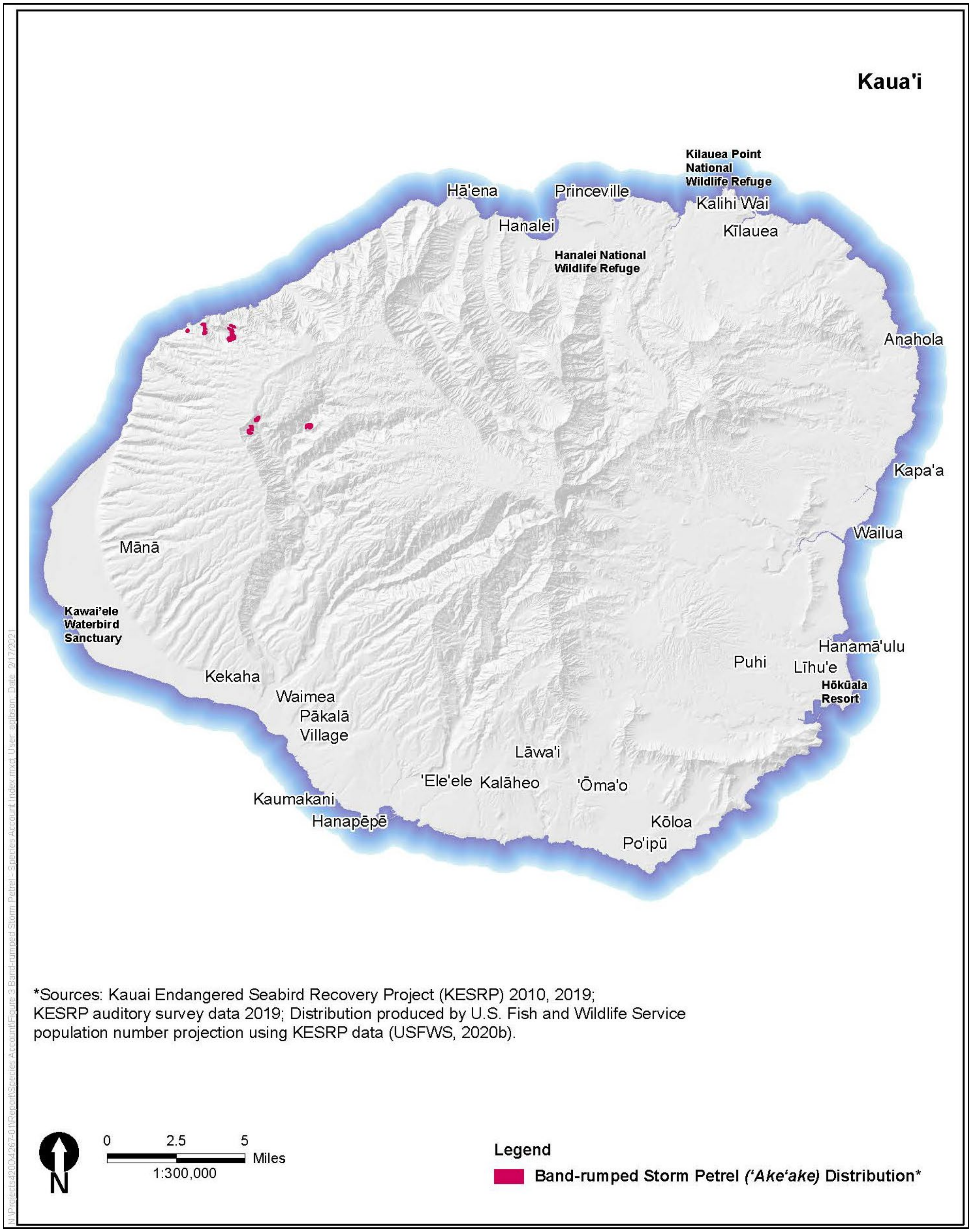
The current distribution of the band-rumped storm-petrel (ʻakēʻakē) in Kauaʻi and the other Hawaiian Islands is poorly known (Raine et al. 2017d; Ainley et al. submitted). Evidence of nesting band-rumped storm-petrel (ʻakēʻakē) is based on detection of adult birds during the breeding season and on retrieval of downed fledglings in the fall, acoustic monitoring, and recovery of carcasses. Potential breeding sites have been recorded on Hawaiʻi (Banko et al. 1991; Galase et al. 2016), Maui (Banko et al. 1991), Kahoʻolawe (Hawaiʻi Heritage Program 1992), Lehua Islet (VanderWerf et al. 2007), and Kauaʻi (Raine et al. 2017d; Wood et al. 2002). Recently, a colony of band-rumped storm-petrel (ʻakēʻakē) was discovered at 6,932.4 ft (2,113 m) elevation on the northern slope of Mauna Loa within the U.S. Army's Pōhakuloa Training Area on the Island of Hawaiʻi (Galase 2019). A breeding population of this species has also been recently identified on the island of Lānaʻi (Raine et al. 2020d). Genetic analysis reveals little differentiation among islands, as judged from specimens obtained historically from various locations (Antaky et al. 2020).

On Kauaʻi, presumed band-rumped storm-petrel (ʻakēʻakē) nesting areas are located predominantly along the northwestern coastal cliffs of the Nā Pali Coast, and in the cliff walls of Waimea Canyon in the southwestern portion of the island (Figure 3). Other small breeding sites are suspected within more vegetated areas in the northern valleys such as Lumahaʻi and Wainiha (Raine et al. 2017d; VanderWerf et al. 2007; Wood et al. 2002).

On Lehua Islet, the band-rumped storm-petrel (ʻakēʻakē) detections over land are mainly concentrated on the southeastern slopes, with very little activity elsewhere (Raine et al. 2017d; VanderWerf et al. 2007). On the Island of Hawaiʻi, presumed nesting birds have been found in the Pōhakuloa Training Area (Galase et al. 2016), and remains of birds have been found along the southwest rift, and in Kūlani (Banko et al. 1991). Vocalizations have been heard in Haleakalā Crater on Maui in 1992 (Wood et al. 2002), on Lānaʻi (U.S. Fish and Wildlife Service 2016d; Raine et al. 2020d), and in Hawaiʻi Volcanoes National Park (U.S. Fish and Wildlife Service 2016d). The band-rumped storm-petrel (ʻakēʻakē) is regularly observed in coastal waters around Kauaʻi, Niʻihau, and Hawaiʻi (Joyce and Holmes 2010; U.S. Fish and Wildlife Service 2016b; Harrison 1990; Spear et al. 1999; Pyle and Pyle 2017c).

3A.3.4.2 Within the Plan Area

The current breeding population of the band-rumped storm-petrel (ʻakēʻakē) on Kauaʻi appears to be confined primarily to steep terrain such as ridge crests in the northwest portion of the island (Figure 3).



*Sources: Kauai Endangered Seabird Recovery Project (KESRP) 2010, 2019; KESRP auditory survey data 2019; Distribution produced by U.S. Fish and Wildlife Service population number projection using KESRP data (USFWS, 2020b).

Figure 3. Current Confirmed Distribution of the Band-Rumped Storm-Petrel (ʻakēʻakē) Based on Contemporary Audio Surveys

3A.3.4.3 Population

There are significant differences in the various Pacific populations of band-rumped storm-petrels (ʻakēʻakē). Populations in Japan and the Galápagos are comparatively large, ranging from 30,000 to 50,000 birds, respectively (Coulter 1984; Enticott and Tipling 1997; Hasegawa 1984), while the Hawaiian population size is largely unknown. Extensive at-sea surveys of the Pacific have revealed a broad gap in distribution of the band-rumped storm-petrel (ʻakēʻakē) east and west of Hawaiʻi (Pitman 1986; Spear and Ainley 2007). The worldwide population of the species is uncertain but is most likely around 150,000 birds (Brooke 2004). Recent genetic studies have found that the Hawaiian population of this species is genetically distinct from other populations throughout its global range, hence its classification as the HDPS (Taylor et al. 2019).

3A.3.4.4 Decline/Trend

Based on the scarcity of known breeding sites in Hawaiʻi; the remote, inaccessible locations where they are suspected to occur today; and compared to historic population levels and distribution, the band-rumped storm-petrel (ʻakēʻakē) appears to be significantly reduced in numbers and range compared to before colonization by the Polynesians (Raine et al. 2017d; U.S. Fish and Wildlife Service 2016d).

3A.3.5 Threats

The threats facing the band-rumped storm-petrel (ʻakēʻakē), including environmental stressors associated with climate change, are thought to be comparable to those faced by Newell's shearwaters (ʻaʻo) and are explained in detail in Section A.1.5, *Threats*. However, it is not a "tuna bird" and so changes in the distribution/abundance of tuna would not directly affect it. Also, because it picks at small items floating at the sea surface it is more likely to ingest plastic, which in some storm-petrels has been found to have significant implications (Spear et al. 1995b). As a much smaller seabird species, predation by rats is presumably an even larger problem for this species, and rats are probably capable of taking adult birds as well as chicks and eggs (Raine et al. 2017d).

3A.3.5.1 Climate Change

Threats related to climate change are similar for all three federal ESA–listed seabirds in Hawaiʻi and are discussed in Section A.1.5.7, *Climate Change*.

3A.4 Hawaiian Stilt (aeʻo) (*Himantopus mexicanus knudseni*)

3A.4.1 Listing Status and Taxonomy

The Hawaiian stilt (aeʻo) (*Himantopus mexicanus knudseni*) is a subspecies of the black-necked stilt (*Himantopus mexicanus*). It is a long-legged, slender shorebird (*Charadriiformes*, *Recurvirostridae*), 15 inches (38 cm) in length, with a long, thin beak. It was listed under the federal ESA as an endangered species on October 13, 1970 (U.S. Fish and Wildlife Service 1970). The species is also listed as endangered under HRS Chapter 195D, Section 195D-4, Endangered and Threatened Species. The second revision of the recovery plan for Hawaiian waterbirds was approved in October

2011. A 5-year status review was completed in 2020, at which time USFWS recommended the downlisting of the Hawaiian stilt (aeʻo) to threatened (U.S. Fish and Wildlife Service 2020b). Critical habitat has not been designated.

3A.4.2 Life History

Hawaiian stilt (aeʻo) are semi-colonial nesters, but intensely territorial, with average inter-nest distances ranging from 53 to 262 ft (16–80 m) (Coleman 1981; Robinson et al. 1999). Their loose colonies occur in marshes near mudflats close to the water, especially marsh islands. They are found in that mudflat/marsh habitat year-round. Nests are shallow depressions lined with stones, twigs, and debris; nesting season extends from mid-February through August, with the peak of laying varying among years (Robinson et al. 1999). Hawaiian stilt (aeʻo) usually lay a clutch of three to four eggs incubated for 23–26 days (Coleman 1981; Chang 1990). Both parents take turns incubating day and night (U.S. Fish and Wildlife Service 2011c). Chicks are precocial, and are able to walk and swim within a few hours of hatching (U.S. Fish and Wildlife Service 2011c); they accompany adults on their daily foraging and may remain with both parents as late as February of the year after hatch (Robinson et al. 1999, 2020). Adult Hawaiian stilt (aeʻo) are aggressive against ground predators, as well as other Hawaiian stilts (aeʻo), and routinely approach humans within 15 ft (4.6 m); they use their legs to strike predators (as well as humans) from behind (Robinson et al. 1999, 2020). Adults also feign injury to distract potential predators from their nest sites and young (Dougherty et al. 1978; Robinson et al. 1999).

Stilts most commonly walk or wade over short distances rather than fly. During normal flight, stilts flap their wings continuously with an average wing-beat of approximately 40.8 beats per minute (Hamilton 1975). When flying in flocks, rapid changes of direction with complicated maneuvers are common (Hamilton 1975).

3A.4.3 Habitat Requirements and Ecology

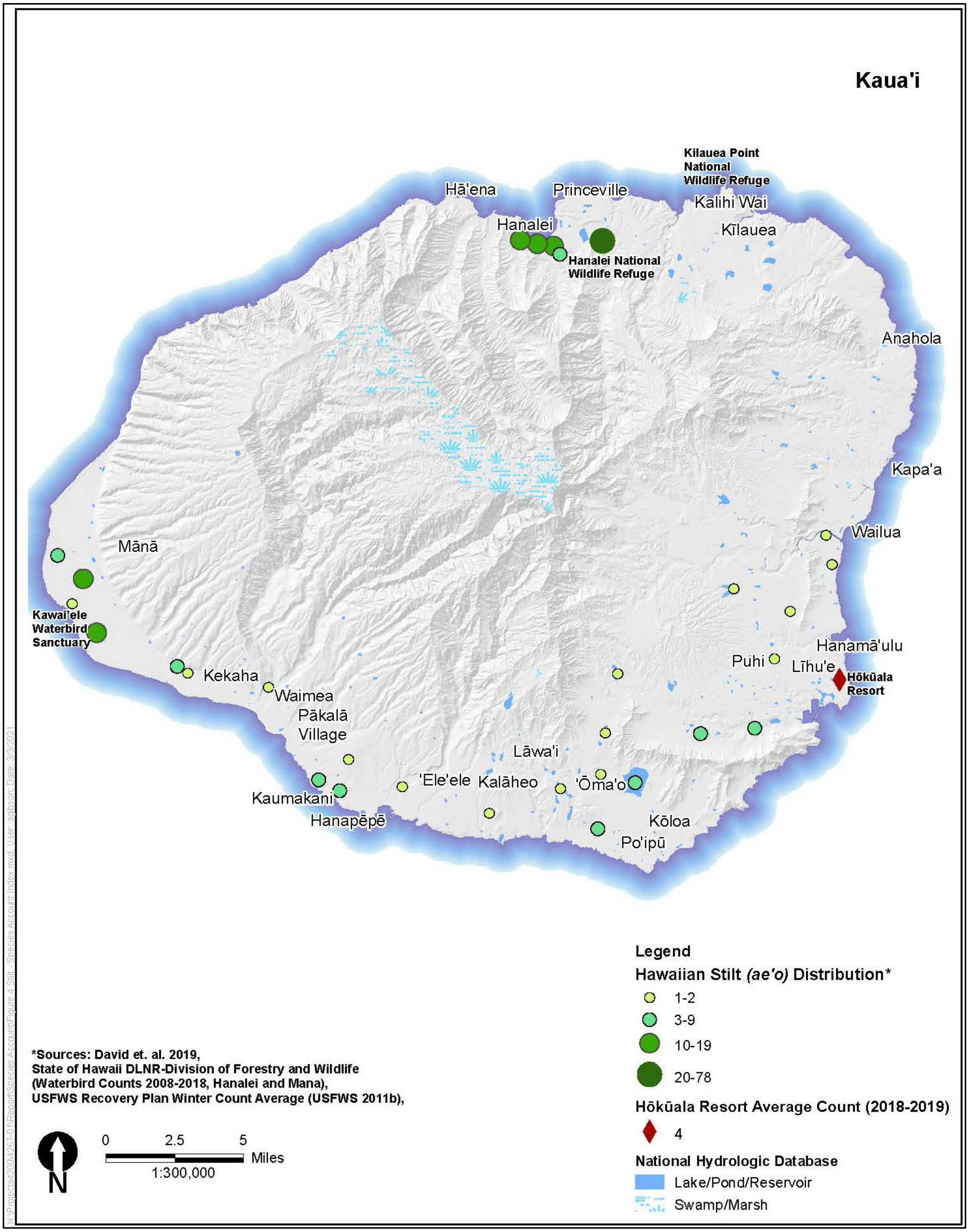
Hawaiian stilt (aeʻo) are opportunistic feeders, and use a variety of aquatic habitats but are limited by water depth (shallow) and vegetation cover. Foraging habitat is early successional marshland or aquatic habitat with a water depth less than 9 inches (22.9 cm) (U.S. Fish and Wildlife Service 2011c). Breeding habitat differs from foraging habitat, and individuals move between the two habitats daily. Movement among wetland habitats in search of food is frequent. Hawaiian stilt (aeʻo) are known to use ephemeral lakes, alkaline ponds, anchialine pools, prawn farm ponds, marshlands, and tidal flats. They eat a wide variety of invertebrates and other aquatic organisms.

3A.4.4 Distribution and Population Trends

No historical estimate of Hawaiian stilt (aeʻo) population size is available, but by the early 1940s, the statewide population was estimated to be between 200 and 1,000 birds (U.S. Fish and Wildlife Service 2011c). These population estimates did not include any Niʻihau populations. Niʻihau can potentially support a large Hawaiian stilt (aeʻo) population when the extensive ephemeral lakes are flooded.

Hawaiian stilt (aeʻo) is currently found in wetland habitats below 660 ft (201 m) elevation on all of the MHI except Kahoʻolawe. Statewide census of the Hawaiian stilt (aeʻo) population shows moderate year-to-year variability (U.S. Fish and Wildlife Service 2020b). Long-term census data indicate that the statewide population has been relatively stable and increasing over the last two decades with an average of ~1,500 birds (U.S. Fish and Wildlife Service 2020b). Surveys of the statewide Hawaiian stilt (aeʻo) population between 2012 and 2016 show the on Kauaʻi resulted in a 5-year minimum average population estimate of 1,932 (1,552–2,385) (Paxton et al. 2021). A population viability analysis has been conducted by Reed and van Rees (2019) to update the findings of Reed et al. (1998) and reassess the population size necessary for long-term viability of the species. Preliminary findings of the population viability analysis indicated an increasing population trend that intermittently exceeds 2,000 individuals statewide but not for 5 consecutive years.

On Kauaʻi, Hawaiian stilt (aeʻo) are numerous in large river valleys such as Hanalei, Wailua, and Lumahaʻi, and on Mānā. Hawaiian stilt (aeʻo) also frequent Kauaʻi's reservoirs, particularly during drawdown periods, as well as sugarcane effluent ponds in Kekaha and Waimea (Figure 4). Considerable movement of the Hawaiian stilt (aeʻo) occurs between Kauaʻi and Niʻihau, apparently in response to rainfall patterns and the flooding and drying of ephemeral lakes on Niʻihau (Engilis and Pratt 1993). From 2008 to 2018, on average, the State of Hawaiʻi Division of Forestry and Wildlife (DOFAW) documented approximately 400 individuals in the Hanalei National Wildlife Refuge and approximately 100 individuals in other wetlands in Hanalei annually during winter counts. During the same time period in Mānā approximately 15 individuals were documented at the Kawaiʻele Sanctuary and approximately 34 individuals annually at other wetlands (State of Hawaiʻi Division of Forestry and Wildlife 2021). Long-term (1986–2016) and short-term (2006–2016) trends indicate increasing population sizes for the Hawaiian stilt (aeʻo) population on Kauaʻi (Paxton et al. 2021).



*Sources: David et. al. 2019,
State of Hawaii DLNR-Division of Forestry and Wildlife
(Waterbird Counts 2008-2018, Hanalei and Mana),
USFWS Recovery Plan Winter Count Average (USFWS 2011b),

Figure 4. Distribution of the Hawaiian Stilt (ae‘o) on the Island of Kaua‘i

3A.4.5 Threats

The primary causes of the decline of Hawaiian waterbirds, including Hawaiian stilt (aeʻo), are predation by invasive animals, loss of wetland habitat, disease, and environmental contaminants. Depredation and habitat loss, however, are likely the greatest threats to the species. Human activities have led to the loss of many Hawaiian wetlands through filling and draining for agriculture, housing developments, hotels, and golf courses. Most remaining wetlands are degraded by altered hydrology, invasive species, human encroachment, and contaminants. Hydrologic alterations of wetlands, including flood control and channelization, often make wetland habitat less suitable by altering water depth and timing of water level fluctuations. The depletion of freshwater aquifers can cause saltwater intrusion into coastal groundwater, altering the salinity of associated wetlands, and reducing habitat suitability (U.S. Fish and Wildlife Service 2011b). Predation by invasive animals including rats, feral dogs, feral cats, and bullfrogs (*Lithobates catesbeianus*) also threaten the recovery of the Hawaiian stilt (aeʻo). Rats mainly target eggs and chicks, whereas feral cats and dogs target chicks, subadults, and adults. Other birds such as the black-crowned night heron (aukuʻu) (*Nycticorax nycticora*), cattle egret (*Bubulcus ibis*), Hawaiian short-eared owl (pueo) (*Asio flammeus sandwichensis*), and common mynas (*Acridotheres tristis*) have been observed preying on eggs, chicks, and subadults (U.S. Fish and Wildlife Service 2020b). Although not present on Kauaʻi (U.S. Fish and Wildlife Service 2019), predation by Indian mongoose of waterbirds including the Hawaiian stilt (aeʻo) continues to be an issue on other islands.

The most prevalent avian disease that continues to be a threat to the Hawaiian stilt (aeʻo) and other waterbirds is avian botulism. The disease can reappear annually in wetland habitats with stagnant water. The deadly effect, which includes flaccid paralysis and eventual leg paralysis, is caused by a toxin produced by the anaerobic bacteria known as *Clostridium botulinum* (type C). Wetlands with no prior history of avian botulism are less likely to experience an outbreak due to the low levels or absence of the *Clostridium botulinum* spores in the immediate environment. However, these spores can be introduced into areas with no botulism history by an infected bird (U.S. Fish and Wildlife Service 2020b). Avian botulism has been documented in the following locations: ʻŌhiʻapilo Pond on Molokaʻi, Hanalei National Wildlife Refuge on Kauaʻi, Ōpaeʻula Pond and ʻAimakapā Pond on Hawaiʻi, Keālia Pond National Wildlife Refuge and Kanahā Pond Wildlife Sanctuary on Maui, and at the lake on Laysan Island (U.S. Fish and Wildlife Service 2020b).

Two emerging avian diseases pose significant threats to the Hawaiian stilt (aeʻo): West Nile virus and avian influenza H5N1 or “bird flu”. Both diseases have yet to be identified in Hawaiian bird populations (U.S. Fish and Wildlife Service 2011b). A surveillance program for these diseases has been established to identify infected birds; however, eradication measures have not yet been proposed if detection occurs.

3A.4.5.1 Climate Change

According to IPCC, human activities have caused a 1.8°F (1°C) increase in tropospheric temperature above pre-industrial levels, and with the current rate of warming, could reach an increase of 2.7°F (1.5°C) by the year 2030 (Intergovernmental Panel on Climate Change 2019). With increasing atmospheric temperature, the size and intensity of large-scale storms are expected to increase in coming years, and recent data demonstrates Category 4 and 5 hurricanes have increased globally at a rate of 25–30 percent per °C increase in global warming (Holland and Bruyere 2014). Temperature increases may also allow avian disease, pathogens, and vectors to expand their ranges and severity. Changes in temperature, precipitation, and sea level, and the effects of these changes will be greatly exacerbated by existing non-climate-related stressors, such as predation by invasive species, fragmentation of habitat resulting from expanding land uses, and disease. Studies examining the effects of sea level rise on low-lying coastal wetlands in the MHI indicate that increased water levels, erosion, salinity, and unprecedented flooding cycles associated with sea level rise threaten habitats of endangered waterbirds. Hawaiian waterbirds are particularly sensitive to sea level rise due to the proximity of their wetland habitat to the coast and the fact that most Hawaiian Island wetlands are groundwater dependent (Hunt and DeCarlo 2000; U.S. Fish and Wildlife Service 2011c, 2011d in Kane 2014). It is unclear how groundwater flooding will affect endangered waterbird habitat, but reduction of this habitat would negatively affect the species (U.S. Fish and Wildlife Service 2018b). Marine flooding and inundation from storm surge, marine overwash (i.e., waves overtopping sand dunes), and tidal waves, also have the potential to destroy active waterbird nests and their habitat (U.S. Fish and Wildlife Service 2018b). The rate of impact caused by sea level rise–induced flooding is modeled to rapidly accelerate once the height of the sea surface exceeds a critical elevation. Estimating the critical elevation marking the end of slow flooding and the onset of rapid flooding will help wetland decision makers to plan and develop management strategies to meet the challenges presented by climate change (State of Hawai‘i Department of Land and Natural Resources 2015). In combination with habitat loss and degradation, sea level rise could severely limit available habitat for Hawaiian waterbirds (Clausen and Clausen 2014). In addition to sea level rise, the Hawaiian Islands are projected to experience more severe annual wave-driven flooding events, during which seawater overtops coastal berms, resulting in increased inland flooding (U.S. Fish and Wildlife Service 2018b). Climate change analyses in the Pacific Islands currently lack sufficient spatial resolution to make specific predictions concerning the effects of climate-related changes on waterbirds on Kaua‘i (University of Hawai‘i at Mānoa 2014). Sea level rise in Hawai‘i will not be uniform across the island chain due, in part, to local land subsidence resulting from the active growth of the Island of Hawai‘i (Polhemus 2015).

3A.5 Hawaiian Duck (koloa maoli) (*Anas wyvilliana*)

3A.5.1 Listing Status and Taxonomy

The Hawaiian duck (koloa maoli) (*Anas wyvilliana*) is endemic to the MHI. Taxonomically, Hawaiian duck (koloa maoli) is in the family Anatidae (*Anseriformes*) and closely allied with the mallard (*Anas platyrhynchos*). The Hawaiian duck (koloa maoli) was listed under the federal ESA as an endangered species in 1967 (U.S. Fish and Wildlife Service 1970). The species is also listed as endangered under HRS, Chapter 195D, Section 195D-4, Endangered and Threatened Species. The second revised Hawaiian waterbird recovery plan was approved in October 2011 (U.S. Fish and Wildlife Service 2011c). Critical habitat has not been designated for the Hawaiian duck (koloa maoli).

3A.5.2 Life History

Hawaiian ducks (koloa maoli) tend to congregate in fall and winter in lowland wetlands in flocks of 5 to 15 birds. Pairs usually form in fall and winter but can form at any time of year depending on rainfall and habitat availability. Hawaiian ducks (koloa maoli) breed year-round, with the majority of nesting occurring March–June (Engilis et al. 2002). In the Kaua‘i lowlands, they form pair bonds between November and May, with pairs dispersing to stream and marshland nesting locations (U.S. Fish and Wildlife Service 2011c). Nests are made of vegetation, lined with feathers, on the ground in tall grass. Clutch size averages eight eggs; incubation lasts about 4 weeks. Young take to the water soon after hatching but cannot fly until about 9 weeks old. Offspring become sexually mature enough to reproduce after a year. Hawaiian ducks (koloa maoli) are wary of humans, especially when nesting or during the flightless period while molting, which peaks between June and August. During the winter, Hawaiian ducks (koloa maoli) may gather in larger numbers to exploit abundant food resources, though most typically they are found in pairs (U.S. Fish and Wildlife Service 2011c).

3A.5.3 Habitat Requirements and Ecology

Hawaiian ducks (koloa maoli) are found from sea level to 9,900 ft (3,017.5 m), in a wide variety of natural and artificial wetland habitats including freshwater marshes, flooded grasslands, montane stock ponds, streams, forest swamplands, taro patches, lotus (*Nelumbo nucifera*) farms, irrigation ditches, reservoirs, and mouths of larger streams. Hawaiian ducks (koloa maoli) typically forage in water less than 6 inches (15.2 cm) deep and are opportunistic feeders, having a diet including snails, fish, aquatic insects, earthworms, grass seeds, green algae, and seeds and leaves of wetland plants (U.S. Fish and Wildlife Service 2011c). They are strong flyers and usually fly at low altitudes. Birds on open wetlands are particularly skittish, and when flushed readily burst from water's surface making sharp turns, flying within 50 m of the ground and circling the disturbance before moving off (Engilis et al. 2020). Flight speed has been clocked from a moving automobile at approximately 44–50 miles per hour (72–80 km per hour) for over a third of a mile (half a kilometer) (Swedberg 1967). Hawaiian ducks (koloa maoli) are non-migratory, although some seasonal, altitudinal, and inter-island movements occur, the timing and mechanics of which are not well understood (Engilis and Pratt 1993). On Kauaʻi, seasonal movement of birds occurs from lowland wetlands to more secluded habitats in summer (U.S. Fish and Wildlife Service 2011c). In addition, there is evidence they may travel between Kauaʻi and Niʻihau in response to above-normal precipitation, and the flooding and drying of Niʻihau's ephemeral lakes (Engilis and Pratt 1993).

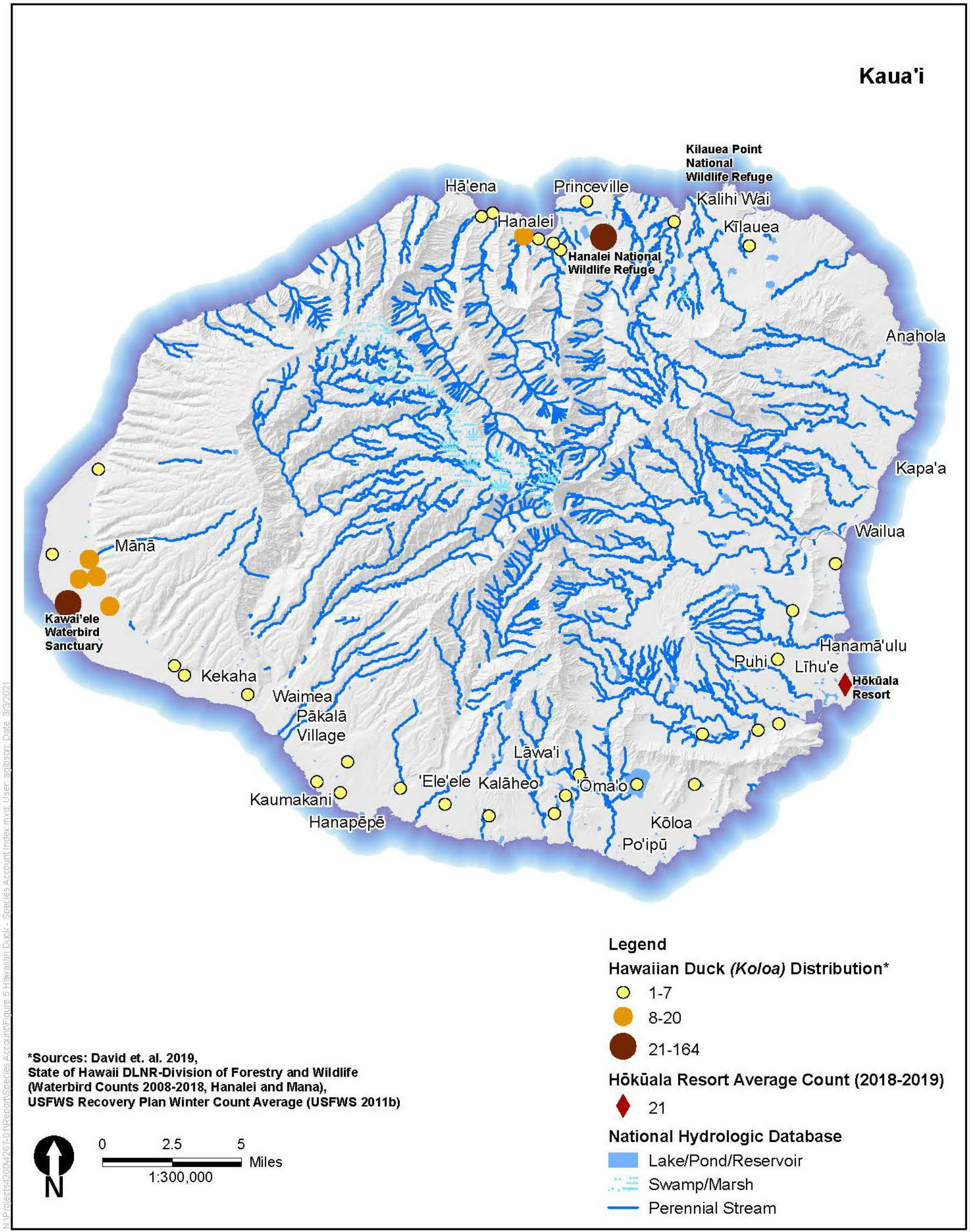
3A.5.4 Distribution and Population Trends

Hawaiian ducks (koloa maoli) were historically common across most of the Hawaiian Islands. Factors such as predation, agricultural and urban development, hybridization with feral mallards, and overhunting caused a decrease in the population in the early 20th century. At that time, Hawaiian ducks (koloa maoli) were common in the coastal marshes of all the MHI except for Lānaʻi and Kahoʻolawe (Pyle and Pyle 2017d). By the mid-20th century, the species had been reduced to 500 birds on the island of Kauaʻi, and a few isolated pairs on other islands (Schwartz and Schwartz 1953). Starting in the mid-1950s and continuing to 1990, the State of Hawaiʻi began a captive propagation and release program. During that time period, 757 captive-bred Hawaiian ducks (koloa maoli) were released on the islands of Oʻahu (326), Maui (12), and Hawaiʻi (419).

Since the species' listing under the federal ESA in 1967, the population has increased on Kauaʻi, though it is declining on other islands. The Hawaiian duck (koloa maoli) population was estimated in 2002 to be about 2,200 individuals, with 2,000 true (non-hybrid) Hawaiian ducks (koloa maoli) on Kauaʻi and Niʻihau, and 200 on the Island of Hawaiʻi (Engilis et al. 2002). The Hawaiian duck (koloa maoli) population on Kauaʻi is substantially larger than on all other islands combined. Surveys of the Kauaʻi Hawaiian duck (koloa maoli) population between 2012 and 2016 estimated a population of 947 (751–1,185) individuals (Paxton et al. 2021). This comparatively large population size on Kauaʻi is probably due to the lack of an established population of mongooses and low occurrence of hybridization unlike the other Hawaiian Islands (U.S. Fish and Wildlife Service 2011c).

Hawaiian duck (koloa maoli) survey counts on Oʻahu, Maui, and Hawaiʻi are confounded by the difficulty in distinguishing Hawaiian duck (koloa maoli) from mallards and hybrids in the field. Populations on Kauaʻi have remained relatively free of mallard genes (Pyle and Pyle 2017d).

The State's biannual surveys typically do not include remote wetlands and streams (Engilis et al. 2002), where an estimated 50 to 80 percent of Hawaiian ducks (koloa maoli) are believed to reside on Kauaʻi (Schwartz and Schwartz 1953). Therefore, because DOFAW's biannual counts only provide estimates for lowland wetlands (Figure 5), they are useful for long-term trends analysis but are not used as an estimate for the Hawaiian duck (koloa maoli) population. Global long-term (1986–2016) and short-term (2006–2016) trends indicate increasing population sizes for the Hawaiian duck (koloa maoli) population on Kauaʻi (Paxton et al. 2021).



*Sources: David et. al. 2019,
State of Hawaii DLNR-Division of Forestry and Wildlife
(Waterbird Counts 2008-2018, Hanalei and Mana),
USFWS Recovery Plan Winter Count Average (USFWS 2011b)

Figure 5. Distribution of the Hawaiian Duck (koloa maoli) on the Island of Kauaʻi

3A.5.5 Threats

Threats to the Hawaiian duck (koloa maoli) are generally the same as those for other Hawaiian waterbirds—loss of wetland habitat, predation by invasive animals, disease, and environmental contaminants. In addition, threats to Hawaiian duck (koloa maoli) include hybridization with invasive mallards that were introduced to Hawaiʻi for farming, sport hunting, and pond beautification (Uyehara et al. 2007; U.S. Fish and Wildlife Service 2011c). Hybridization is considered the largest threat to the species (U.S. Fish and Wildlife Service 2011c). This is especially problematic on the islands of Oʻahu and Maui where most of the individuals are now mallard-Hawaiian duck (koloa maoli) hybrids (U.S. Fish and Wildlife Service 2011c; Pyle and Pyle 2017d). Although instances exist of ducks, geese, and rails colliding with powerlines (Bevanger 1998; Travers et al. 2019), there is little evidence that collisions with utility structures are having a large impact on Hawaiian waterbirds on Kauaʻi. During the period of 2007 to 2019, one Hawaiian duck (koloa maoli) turned into the SOS Program (Bache 2020) was found in the vicinity of powerlines, but the cause of death was unknown.

3A.5.5.1 Climate Change

Threats related to climate change are similar for all Hawaiian waterbirds and are discussed in Section A.4.5.1, *Climate Change*, for Hawaiian stilt (aeʻo). Climate change analyses in the Pacific Islands currently lack sufficient spatial resolution to make specific predictions concerning the effects of climate-related changes on Hawaiian duck (koloa maoli) on Kauaʻi (University of Hawaiʻi at Mānoa 2014).

3A.6 Hawaiian Coot (ʻalae keʻokeʻo) (*Fulica alai*)

3A.6.1 Listing Status and Taxonomy

The Hawaiian coot (ʻalae keʻokeʻo) (*Fulica alai*), is a member of the rail family, Rallidae, and is endemic to Hawaiʻi. It is 13–16.1 inches (33–41 cm) in size, and plumage is similar to the American coot (*Fulica america*). The Hawaiian coot (ʻalae keʻokeʻo) was listed as endangered under the federal ESA in 1967 (U.S. Fish and Wildlife Service 1970). The species is also listed as endangered under HRS, Chapter 195D, Section 195D-4, Endangered and Threatened Species. The latest recovery plan for the species was published in 2011 (U.S. Fish and Wildlife Service 2011c). The last 5-year review was published in 2015. Critical habitat has not been designated for the Hawaiian coot (ʻalae keʻokeʻo).

3A.6.2 Life History

Hawaiian coot (ʻalae keʻokeʻo) are mostly sedentary, making localized flights around existing wetland habitats based on rainfall (Pratt and Brisbin 2020). Their flight is strong and direct, requiring an extended period of running along the water's surface to become airborne (Brisbin and Mowbray 2020). Flight height is typically ≤16 ft (5 m) above the water surface except over land when additional altitude is needed to clear obstacles such as trees (Brisbin and Mowbray 2020). At times, the species travels long distances, including between islands, when local food sources are depleted (Engilis and Pratt 1993). Floating nests are constructed of aquatic vegetation, and found in open water or anchored to emergent vegetation (Byrd et al. 1985). Open water nests usually consist of mats of water hyssop (*Bacopa monniere*) and Hilo grass (*Paspalum conjugatum*) (Byrd et al. 1985; Pratt and Brisbin 2020). Nests in emergent vegetation are typically platforms constructed from buoyant stems of species such as bulrush (*Scirpus* spp.) (Byrd et al. 1985). Average depth of water at Hawaiian coot (ʻalae keʻokeʻo) nest sites was 13 inches (33 cm) in natural habitats (Byrd et al. 1985).

Hawaiian coot (ʻalae keʻokeʻo) are somewhat gregarious and non-breeding birds may form large flocks. Nesting occurs primarily March through September, although some nesting occurs in all months of the year (Shallenberger 1977; Pratt and Brisbin 2020). The timing of nesting appears to correspond with seasonal weather conditions (Byrd et al. 1985; Engilis and Pratt 1993). Nest initiation corresponds to rainfall, as appropriate water levels are critical to nest success. Clutch size ranges from one to ten eggs, and young hatch after a 25-day incubation period (Byrd et al. 1985). Chicks swim from the nest soon after hatching, remaining close to parents; immature birds have been seen with parents several weeks after hatching (Pratt and Brisbin 2020). There is no information on the lifespan and survivorship of this species; however, banding records indicate the oldest American coot was at least 22 years old (Klimkiewicz and Futcher 1989).

3A.6.3 Habitat Requirements and Ecology

Hawaiian coots (ʻalae keʻokeʻo) generally occur within wetland habitats having emergent plants interspersed with open water, especially freshwater wetlands, freshwater reservoirs, cane field reservoirs, sewage treatment ponds, taro loʻi, and brackish wetlands; they exhibit limited use of saltwater habitats (Shallenberger 1977; Byrd et al. 1985; Pratt and Brisbin 2020). Ephemeral wetlands support large numbers of Hawaiian coots (ʻalae keʻokeʻo) during the non-breeding season. Habitat elevation ranges from the coastal plains at sea level to 850 ft (259 m), rarely to 3,500 ft (1,067 m) (Byrd et al. 1985). On Kauaʻi, however, some birds occur in plunge pools above 4,900 ft (1,493.5 m) and on Hawaiʻi, birds occur in stock ponds at 6,600 ft (2,012 m) in elevation (U.S. Fish and Wildlife Service 2011c).

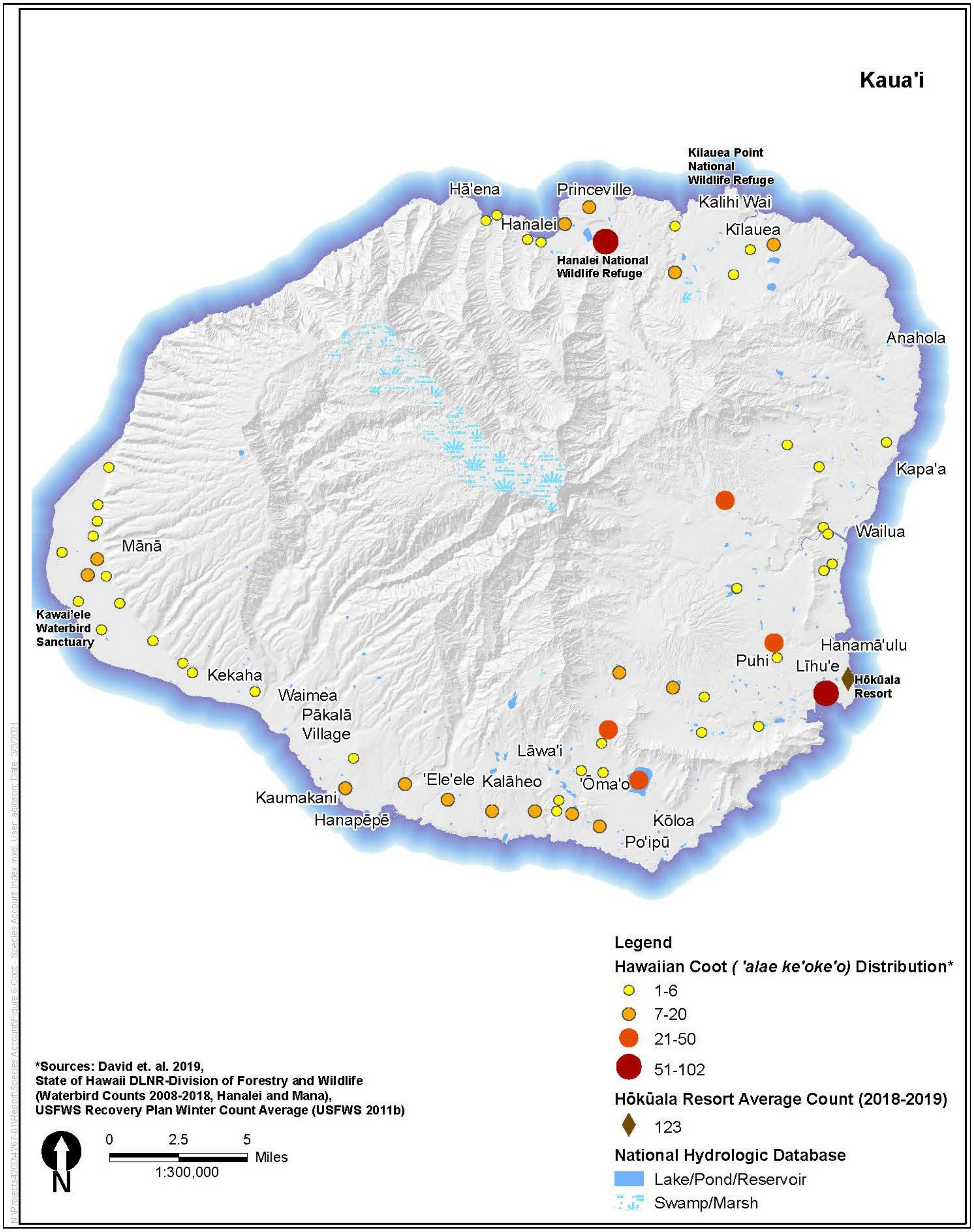
Hawaiian coots (ʻalae keʻokeʻo) are generalists and feed on land, grazing on grass adjacent to wetlands, or in the water (U.S. Fish and Wildlife Service 2011c). The species typically forages in water less than 12 inches (30.5 cm) deep, but dives in water up to 48 inches (121.9 cm) deep. Hawaiian coots (ʻalae keʻokeʻo) prefer to forage in water that is somewhat open (U.S. Fish and Wildlife Service 2011c). They use logs, rafts of vegetation, narrow dikes, mud bars, and artificial islands for resting. Food items include seeds and leaves, snails, crustaceans, insects, tadpoles, and small fish (U.S. Fish and Wildlife Service 2011c; Pratt and Brisbin 2020).

3A.6.4 Distribution and Population Trends

The Hawaiian coot (ʻalae keʻokeʻo) population was estimated to be 1,500–2,800 birds (U.S. Fish and Wildlife Service 2011c). The survey data from the biannual waterbird counts imply that the population has an overall slightly increasing trend (U.S. Fish and Wildlife Service 2011c). Surveys of the statewide Hawaiian coot (ʻalae keʻokeʻo) population between 2012 and 2016 Kauaʻi resulted in a 5-year minimum average population estimate of 1,815 (1,248–2,577) (Paxton et al. 2021).

The Hawaiian coot (ʻalae keʻokeʻo) historically occurred on all of the MHI except Lānaʻi and Kahoʻolawe. Hawaiian coots (ʻalae keʻokeʻo) have historically been most numerous on the islands of Oʻahu, Maui, and Kauaʻi (U.S. Fish and Wildlife Service 2011c). Approximately 80 percent of the current population occurs on Kauaʻi (Hanalei, Hulēʻia, ʻŌpaekaʻa), Oʻahu, and Maui (U.S. Fish and Wildlife Service 2011c). The remaining 20 percent occurs in coastal ponds and playa wetlands, including breeding populations on the islands of Hawaiʻi, Lānaʻi, Molokaʻi, and Niʻihau (U.S. Fish and Wildlife Service 2011c).

Surveys indicate that migration events between Kauaʻi and Niʻihau occur only when annual precipitation is above normal and ephemeral lakes on Niʻihau become flooded (Engilis and Pratt 1993). Numbers of Hawaiian coots (ʻalae keʻokeʻo) counted on Niʻihau during wet winters include 949 birds in 1986 and 803 birds in 1996, but Niʻihau has not been surveyed since 1999 (U.S. Fish and Wildlife Service 2005). Population trends specific to Kauaʻi have been monitored by annual surveys of Mānā from 1986 to 2004 and monthly counts in the Hanalei National Wildlife Refuge in 2010 through 2015. Between 0 and 87 Hawaiian coots (ʻalae keʻokeʻo) were observed each year in Mānā, whereas 45 to 641 individuals were detected in Hanalei (State of Hawaiʻi Division of Forestry and Wildlife 2021). Trend data collected over three decades (up to 2008) show that Hawaiian coots (ʻalae keʻokeʻo) are either stable or increasing statewide. Distribution of the Hawaiian coot (ʻalae keʻokeʻo) on Kauaʻi is shown in Figure 6. Global long-term (1986–2016) and short-term (2006–2016) trends indicate increasing population sizes for the Hawaiian coots (ʻalae keʻokeʻo) population on Kauaʻi (Paxton et al. 2021).



*Sources: David et. al. 2019,
State of Hawaii DLNR-Division of Forestry and Wildlife
(Waterbird Counts 2008-2018, Hanalei and Mana),
USFWS Recovery Plan Winter Count Average (USFWS 2011b)

Figure 6. Distribution of the Hawaiian Coot (ʻalae keʻokeʻo) on the Island of Kauaʻi

3A.6.5 Threats

Threats to Hawaiian coots (ʻalae keʻokeʻo) are generally the same as those outlined in the Hawaiian stilt (aeʻo) account (Section A.4.5, *Threats*). In addition, Hawaiian coot (ʻalae keʻokeʻo) nest and forage at wastewater treatment plants across the islands, increasing their exposure to toxins. Bumblefoot (ulcerative pododermatitis), a bacterial infection that causes foot inflammation and swelling in birds, may be a chronic condition in the population. This infection has been found on 45 percent of the Hawaiian coot (ʻalae keʻokeʻo) banded at the Kaunakakai Wastewater Reclamation Facility on Molokaʻi (U.S. Fish and Wildlife Service 2011c). The incidence in birds on Kauaʻi is unknown.

There is no indication that this species interacts to a great extent with powerlines. However, studies in Europe have shown members of the Rallidae to be susceptible to high numbers of casualties in sensitive habitats where there are thin, low-hanging lines (Haas et al. 2005). During the period of 2007–2019, five individuals were turned into the SOS Program, reportedly found under powerlines. The precise cause of death is unknown but is assumed to be powerline collisions (Bache 2020).

3A.6.5.1 Climate Change

Threats related to climate change are similar for all Hawaiian waterbirds and are discussed in Section A.4.5.1, *Climate Change*, for Hawaiian stilt (aeʻo). Climate change analyses in the Pacific Islands currently lack sufficient spatial resolution to make specific predictions concerning the effects of climate-related changes on Hawaiian coot (ʻalae keʻokeʻo) on Kauaʻi (University of Hawaiʻi at Mānoa 2014).

3A.7 Hawaiian Common Gallinule (ʻalae ʻula) (*Gallinula galeata sandvicensis*)

3A.7.1 Listing Status and Taxonomy

The Hawaiian common gallinule (ʻalae ʻula) (*Gallinula galeata sandvicensis*), previously called the Hawaiian common moorhen and the Hawaiian gallinule, is a subspecies of the common gallinule (Griiformes, Rallidae). Hawaiian common gallinule (ʻalae ʻula) was listed as endangered under the federal ESA in 1967 (U.S. Fish and Wildlife Service 1970). The species is also listed as endangered under HRS, Chapter 195D, Section 195D-4, Endangered and Threatened Species. The latest recovery plan for the species was published in 2011 (U.S. Fish and Wildlife Service 2011c). The last 5-year review was published in 2015. Critical habitat has not been designated for the Hawaiian common gallinule (ʻalae ʻula).

3A.7.2 Life History

Hawaiian common gallinules (ʻalae ʻula) are non-migratory and it is unknown whether they are capable of inter-island movement. They characteristically swim or walk on aquatic vegetation or soil and are seldom seen flying (Bannor and Kiviat 2020). They nest year-round, though concentrated nesting is March–August (Shallenberger 1977; Byrd and Zeillemaker 1981; Chang 1990). Nesting phenology appears to be related to wetland late-succession vegetation and water levels. The Hawaiian common gallinule (ʻalae ʻula) clutch averages five to six eggs (Byrd and Zeillemaker 1981;

Chang 1990); incubation ranges from 19 to 22 days (Byrd and Zeillemaker 1981). Re-nesting and multiple broods during one season often occur (Byrd and Zeillemaker 1981). Platform nests are constructed in dense vegetation over water or near the edge of a marsh. Hawaiian common gallinule (ʻalae ʻula) hatchlings are precocial; chicks are covered with down and are able to walk but are dependent on parents for several weeks (U.S. Fish and Wildlife Service 2011c). Hawaiian common gallinule (ʻalae ʻula) are secretive, preferring to forage, nest, and rest in dense wetland vegetation. When feeding along the water's edge or in open water, they quickly seek cover when disturbed.

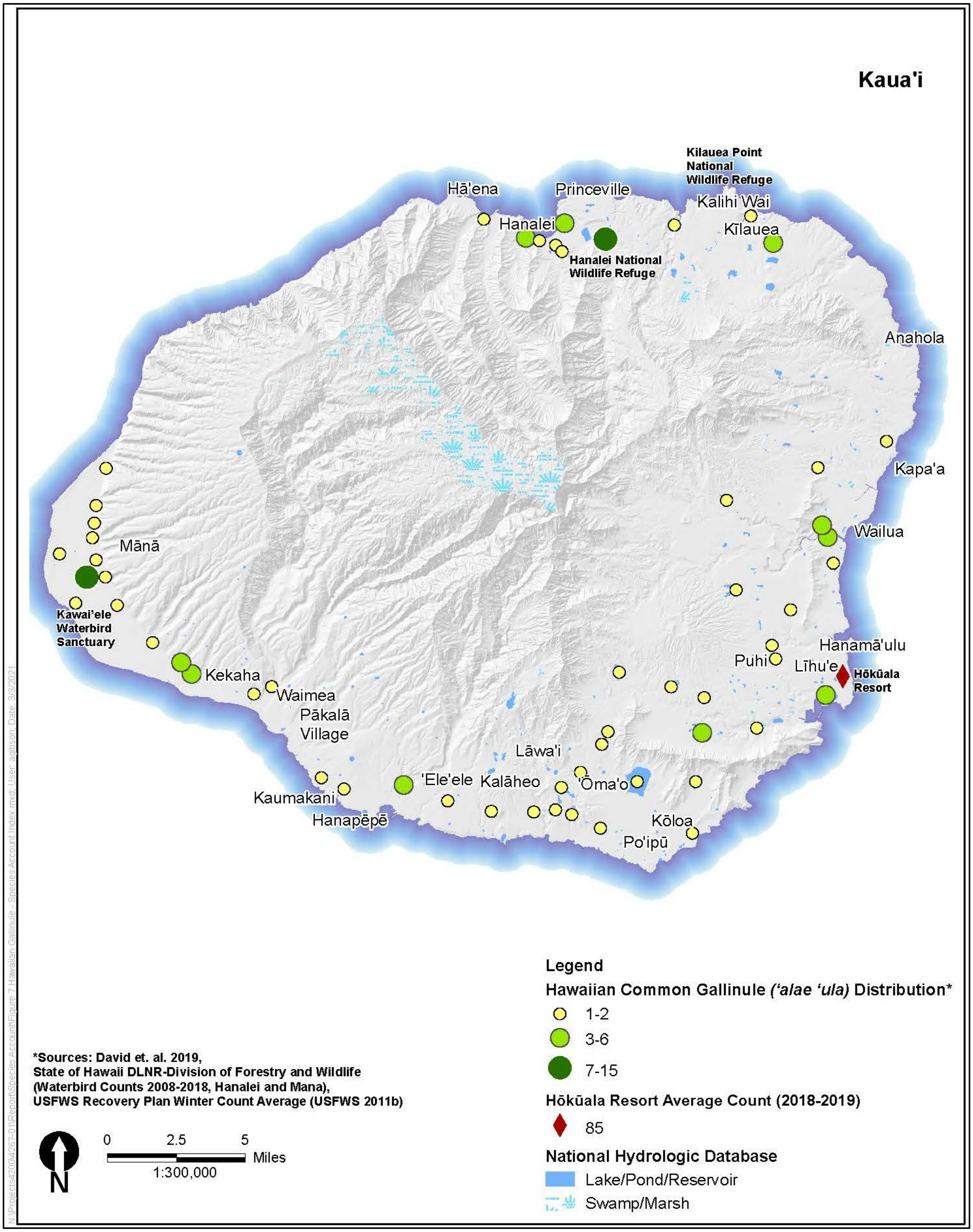
3A.7.3 Habitat Requirements and Ecology

Hawaiian common gallinules (ʻalae ʻula) predominantly occur in wetlands below 410 ft (125 m) in elevation on Kauaʻi and Oʻahu, with a few observations reported from Keʻanae Peninsula, Maui, and also from the Island of Hawaiʻi. The preferred habitat is low-elevation freshwater marshes (Engilis and Pratt 1993). Key habitat features include scattered dense stands of robust vegetation near open water, floating or barely emergent mats of vegetation, and water depth less than 3 ft (0.9 m). Hawaiian common gallinules (ʻalae ʻula) are opportunistic feeders and their diet varies with habitat, but includes algae, grass seeds, insects, snails, fish, crustaceans, mollusks, grasses, and wetland plants (U.S. Fish and Wildlife Service 2011c).

3A.7.4 Distribution and Population Trends

No historical population estimates are available prior to the first biannual waterbird count by DOFAW in 1977. It is believed that in the 19th century Hawaiian common gallinule (ʻalae ʻula) were common on all of the Hawaiian Islands, except Lānaʻi and Kahoʻolawe. The population exhibited a precipitous decline in numbers through the mid-20th century. Currently Hawaiian common gallinules (ʻalae ʻula) are only known to inhabit the islands of Kauaʻi and Oʻahu. Surveys of the statewide population between 2012 and 2016 were small but relatively stable, with a minimal 5-year average of 927 (678–1,235) individuals (Paxton et al. 2021).

On Kauaʻi, the largest populations occur in the Hanalei and Wailua River valleys, Waiakalua Reservoir, and Wilcox Ponds. However, they also occur in low numbers within the irrigation canals in Mānā in western Kauaʻi and in taro fields (Figure 7) (U.S. Fish and Wildlife Service 2011c). Between 2008 and 2018, DOFAW conducted monthly counts at Hanalei National Wildlife Refuge and other wetlands in Hanalei and observed approximately 648 individuals and 100 individuals, respectively, on an annual basis (State of Hawaiʻi Division of Forestry and Wildlife 2021). Annual counts in Mānā at the Kawaiʻele Waterbird Sanctuary averaged approximately 18 individuals and in other Mānā wetlands 34 individuals, on an annual basis (State of Hawaiʻi Division of Forestry and Wildlife 2021). While these surveys provide an estimation of population status, the methodology for the counts may be flawed and final totals are thought to be underestimated because of the species' secretive behavior (U.S. Fish and Wildlife Service 2011c). Global long-term (1986–2016) and short-term (2006–2016) trends indicate increasing population sizes for the Hawaiian common gallinules (ʻalae ʻula) population on Kauaʻi (Paxton et al. 2021).



***Sources: David et. al. 2019,
State of Hawaii DLNR-Division of Forestry and Wildlife
(Waterbird Counts 2008-2018, Hanalei and Mana),
USFWS Recovery Plan Winter Count Average (USFWS 2011b)**

Figure 7. Distribution of the Hawaiian Common Gallinule (ʻalae ʻula) on the Island of Kauaʻi

3A.7.5 Threats

Most of the threats to the Hawaiian common gallinule (ʻalae ʻula) are also common to the other Hawaiian waterbirds. See the discussion of threats for these species in Section A.4.5, *Threats*. Habitat loss and degradation and predation are likely the main threats to an increasing or stable population of Hawaiian common gallinule (ʻalae ʻula). There is no indication that Hawaiian common gallinules (ʻalae ʻula) interact with powerlines, although instances exist of ducks, geese, and rails colliding with powerlines (Bevanger 1998; Travers et al. 2019), particularly in sensitive habitats (Haas et al. 2005). During the period of 2007 through 2019, three Hawaiian common gallinule (ʻalae ʻula) were found in the vicinity of powerlines but the cause of death was unknown (Bache 2020).

3A.7.5.1 Climate Change

Threats related to climate change are similar for all Hawaiian waterbirds and are discussed in Section A.4.5.1, *Climate Change*, for Hawaiian stilt (aeʻo). Climate change analyses in the Pacific Islands currently lack sufficient spatial resolution to make specific predictions concerning the effects of climate-related changes on Hawaiian gallinule (ʻalae ʻula) on Kauaʻi (University of Hawaiʻi at Mānoa 2014).

3A.8 Hawaiian Goose (nēnē) (*Branta sandvicensis)*

3A.8.1 Listing Status and Taxonomy

The Hawaiian goose (nēnē) (*Branta sandvicensis*) is a medium-sized goose (16.1 inches [41 cm] tall) and a member of the avian family Anatidae. The Hawaiian goose (nēnē) was listed as endangered under the federal ESA in 1967. The species is also listed as endangered under HRS, Chapter 195D, Section 195D-4, Endangered and Threatened Species. In 2019, USFWS downlisted Hawaiian goose (nēnē) from endangered to threatened (83 *Federal Register* [FR] 13919). This change went into effect on January 21, 2020 (U.S. Fish and Wildlife Service 2019). Critical habitat has not been developed for this species by USFWS.

3A.8.2 Life History

The Hawaiian goose (nēnē) is non-migratory with daily, local flights typically in early morning and late afternoon, between nesting and feeding areas. Although they are capable of interisland flight, their wings are reduced in size and they are non-migratory. When taking off and landing, their long, low flight path makes them vulnerable to collisions with stationary structures and moving objects such as vehicles and aircraft (Banko et al. 2020). Historically, flocks moved between high-elevation feeding habitats and lowland nesting areas. Hawaiian geese (nēnē) reach sexual maturity after 1 year, but usually do not form pair bonds until the second year. Females are highly philopatric and nest near their natal area, while males more often disperse (U.S. Fish and Wildlife Service 2018c). Today, many Hawaiian geese (nēnē) nest in mid- and high-elevation sites, although it is believed that they once nested primarily in leeward lowlands (Banko et al. 1999; U.S. Fish and Wildlife Service 2004). Lowland areas are used by Hawaiian goose (nēnē) populations on Kauaʻi year-round (Banko et al. 1999; U.S. Fish and Wildlife Service 2004, 2019).

Hawaiian geese (nēnē) nest on the ground in a shallow scrape, shaded by shrubs or other vegetation. They have an extended breeding season, laying eggs from August to April, peaking in December (October–March); the majority of eggs hatch in December and January (Banko et al. 1999; U.S. Fish and Wildlife Service 2004, 2018c). A Hawaiian goose (nēnē) clutch typically contains three to five eggs, and incubation ranges from 29 to 32 days. Once hatched, the young may remain in the nest for 1–2 days; all hatchlings depart the nest after the last egg is hatched (U.S. Fish and Wildlife Service 2004, 2018c). Goslings are flightless for 10–12 weeks and adults are flightless (owing to wing molt) for a period of 4–6 weeks, at about the same time. During June to September, after molting and fledging, family groups congregate in post-breeding flocks, often far from nesting areas (U.S. Fish and Wildlife Service 2004, 2018c). Hawaiian geese (nēnē) are highly social within their family units and moderately social with other geese, typically associating in small local flocks that are limited in size because of small population sizes (Banko et al. 2020).

3A.8.3 Habitat Requirements and Ecology

Hawaiian geese (nēnē) exhibit seasonal movements to grasslands when the production of fruiting bodies associated with shrubland foraging habitat is low, and when wet conditions produce grass with a high water and protein content. Hawaiian goose (nēnē) grazing is opportunistic, with variation in their grazing allowing the species to survive in marginal habitats (Banko et al. 1999). Historical reports from the Island of Hawaiʻi indicate that Hawaiian geese (nēnē) bred and molted primarily in the lowlands during winter and moved upslope in the hotter and drier summer (U.S. Fish and Wildlife Service 2004, 2018c). Reproductive success is relatively low in highland habitats on Hawaiʻi and Maui, and higher in lowland habitat on Kauaʻi (Banko et al. 1999).

On Kauaʻi, where the largest population now occurs, Hawaiian geese (nēnē) typically use lowland habitats including golf courses, coastal wetlands including taro loʻi (ponds), farmlands, pastures and fallow grassy and shrubby fields; they are also found along roadsides, and in established and maintained Hawaiian goose (nēnē) release sites and wildlife sanctuaries (Banko et al. 1999). Most Hawaiian geese (nēnē) on Kauaʻi occur in coastal wetlands at Hanalei and Huleʻia National Wildlife Refuges, along the Nā Pali Coast, and in maintained wetlands and water features at resorts and golf courses in and around Līhuʻe. The range has expanded considerably as the population has increased, and Hawaiian geese (nēnē) have adapted to many urban settings (U.S. Fish and Wildlife Service 2004; David et al. 2019).

3A.8.4 Distribution and Population Trends

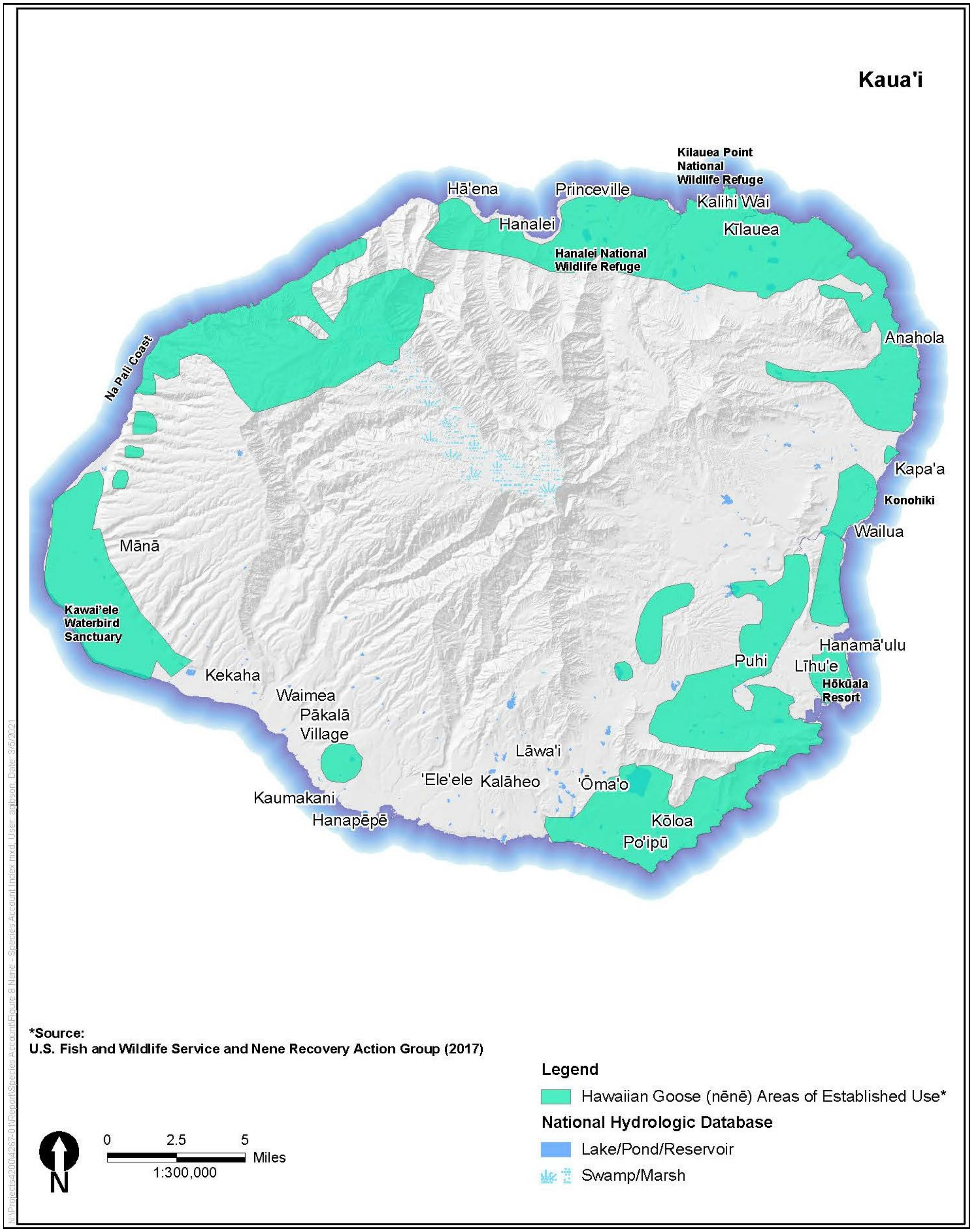
Hawaiian geese (nēnē) were once widely distributed among the MHI (Niʻihau, Kauaʻi, Oʻahu, Molokaʻi, Maui, Lānaʻi, Kahoʻolawe, and Hawaiʻi); for a detailed history, see Pyle and Pyle (2017e). Before 1778, the distribution of Hawaiian goose (nēnē) was much broader than what it became after colonization by Europeans (Banko et al. 1999). However, estimating the population size both pre-Polynesian and pre-European contact is difficult because of limited understanding of species composition or even the gross structure of the vegetation before human occupation (U.S. Fish and Wildlife Service 2004). By 1952, the world population totaled 30 Hawaiian geese (nēnē), confined to the Island of Hawaiʻi (Smith 1952). It is thought that Hawaiian goose (nēnē) populations on the higher islands, Hawaiʻi and Maui, persisted longest owing to those islands' remote rugged upland areas, where hunting and predation by introduced mammals were less intense (Banko et al. 1999).

In 2020 statewide population estimate for the Hawaiian goose (nēnē) was 3,865 individuals, with 1,099 on Hawaiʻi; 477 on Maui; 23 on Molokaʻi; 2,266 on Kauaʻi; and 0 on Oʻahu (Nēnē Recovery

Action Group 2020). Kauaʻi has the greatest amount of lowland habitat available, and it is believed that this, in combination with the lack of an established mongoose population, has resulted in the largest population of Hawaiian geese (nēnē) among the MHI (Banko et al. 1999; U.S. Fish and Wildlife Service 2004).

There are currently four areas on Kauaʻi where Hawaiian geese (nēnē) are concentrated. The current distribution of birds on all islands, including Kauaʻi, is largely due to the locations captive-bred or translocated birds were released (Banko et al. 1999). With the exception of the Nā Pali Coast population, all Kauaʻi populations occur at low elevations, ranging from sea level to 600 ft (182.9 m). Approximately 25 captive Hawaiian geese (nēnē) were released by Kīpū Kai Ranch in 1985 on the southeast coastline of Kauaʻi. These birds were originally obtained from the Shipman Estates on Hawaiʻi in the late 1960s. Another 38 captive-bred Hawaiian geese (nēnē) were released at the Kīlauea Point National Wildlife Refuge located on the northeast coastline of Kauaʻi beginning in 1991. These birds have bred successfully, and together these two populations increased to more than 350 birds (U.S. Fish and Wildlife Service 2004). In 2012, it was estimated that 650 Hawaiian geese (nēnē) occurred on lands between Hanalei and Mōkōlea Point at Kīlauea Point. This was significantly higher than the record count of 91 individuals observed at the Kawaiʻele wetlands of Mānā along the southwestern coastline of Kauaʻi that same year. A third population was initiated on the Nā Pali Coast with the release of 62 captive Hawaiian geese (nēnē) in 1995–1996. Release was at 330 ft (100.6 m) elevation with the birds subsequently moving to breed at 1,650 ft (502.9 m). This population numbered about 61 birds in 2004 (U.S. Fish and Wildlife Service 2004). Twenty-four Hawaiian geese (nēnē) were introduced to the Hanalei National Wildlife Refuge in April 2000 (U.S. Fish and Wildlife Service 2004). Monthly counts at the Hanalei National Wildlife Refuge ranged between 40 and 211 Hawaiian geese (nēnē) from 2010 to 2015 (State of Hawaiʻi Division of Forestry and Wildlife 2021).

In 2011, an increase to 400 Hawaiian geese (nēnē) at Kauaʻi Lagoons (now Hōkūala Resort) along the southeast coast of Kauaʻi adjacent to Līhuʻe International Airport prompted DOFAW to initiate a translocation plan to reduce risk to aircraft operations (State of Hawaiʻi Division of Forestry and Wildlife 2012). Between 2011 and 2016, 652 birds were translocated to Maui and Hawaiʻi (U.S. Department of Agriculture-Wildlife Services 2019). Since 2016, Hawaiian geese (nēnē) resumed nesting at the resort, and in 2019, over 100 Hawaiian geese (nēnē) were recorded at the facility (David et al. 2019). Even with the translocation of birds to Maui and Hawaiʻi, Hawaiian goose (nēnē) are increasing on Kauaʻi (Figure 8; Nēnē Recovery Action Group 2017, 2022).



*Source:
U.S. Fish and Wildlife Service and Nene Recovery Action Group (2017)

Figure 8. Hawaiian Goose (nēnē) Established Use Areas

3A.8.5 Threats

As with the other Hawaiian waterbirds, the primary causes of the decline of the Hawaiian goose (nēnē) are predation by introduced animals, loss of habitat, over-hunting in the late 19th century and early 20th century, disease, and environmental contaminants (U.S. Fish and Wildlife Service 2011c). During periods of flightlessness (while growing flight feathers and molting; February–May), Hawaiian goose (nēnē) goslings and adults are both extremely vulnerable to predation by invasive mammals. Introduced predators such as dogs, cats, and, on other islands, mongoose pose a serious threat to the Hawaiian goose (nēnē) by taking eggs, young birds, and even adults (U.S. Fish and Wildlife Service 2011c; State of Hawaiʻi Division of Forestry and Wildlife 2012).

Human activities have led to loss of lowland habitat for development of cultivated agriculture, housing developments, hotels, and golf courses. Habitat loss has also resulted from ungulate grazing and browsing, increased frequency of fire, and invasive plant species invasion (U.S. Fish and Wildlife Service 2004, 2019). However, palatable grasses and other plants in some pastureland, golf courses, lawns, and roadsides allow Hawaiian goose (nēnē) to forage and nest where it otherwise could not (Banko et al. 1999). In light of this information and the fact that the Hawaiian goose (nēnē) population in the lowland Kauaʻi sites have been the most successful, managers have expanded efforts to find lowland areas for potential Hawaiian goose (nēnē) reintroduction (U.S. Fish and Wildlife Service 2004). The threat of destruction and modification of habitat, particularly in lowland areas, by urbanization and land use conversion, including agriculture, is ongoing and expected to continue to limit the amount of Hawaiian goose (nēnē) foraging and nesting habitat, which may lead to reduced reproductive success and population declines (U.S. Fish and Wildlife Service 2019).

Increased use of urban, agricultural, and human built environments exposes Hawaiian geese (nēnē) to injury or death from collisions with vehicles, aircraft, construction or agricultural equipment, and golf balls or golf carts (Banko et al. 1999; David et al. 2019; U.S. Fish and Wildlife Service 2004). Although instances exist of ducks, geese, and rails colliding with powerlines (Bevanger 1998; Travers et al. 2019), there is little evidence that collisions with utility structures are having a large impact on Hawaiian geese (nēnē) (or other waterbird species) on Kauaʻi. During one seabird season of powerline monitoring, KESRP reported bird collisions that involved two cattle egrets, one black-crowned night heron (aukuʻu), and one Hawaiian goose (nēnē) (Travers and Raine 2020). During the period from 2007 to 2019, five Hawaiian geese (nēnē) were turned in to the SOS Program, found in the vicinity of powerlines, but the cause of death was not determined (Bache 2020).

Diseases could also render local habitats unsuitable for sustaining life history requirements. Avian botulism type C, introduced by humans, is the most prevalent disease affecting all Hawaiian waterbirds (U.S. Fish and Wildlife Service 2011c). It is caused by a neurotoxin produced by a common bacterium (*Clostridium botulinum*). Normally dormant, avian botulism spores only release toxins when certain conditions occur, including warm temperatures, high pH, low dissolved oxygen, and stagnant waters. By eating invertebrates containing the toxin, birds can be infected. The disease causes flaccid paralysis, the eventual loss of use of legs, and death (U.S. Fish and Wildlife Service 2011c). Since 2013, avian botulism outbreaks have been documented at 10 locations on Kauaʻi (Pratt and Brisbin 2020). Omphalitis, an infection of the umbilical stump, has been found to cause mortality in both wild and captive Hawaiian goose (nēnē) goslings (U.S. Fish and Wildlife Service 2004).

The possibility of West Nile virus or avian influenza reaching the Hawaiian Islands from the U.S. mainland or Asia currently is not a concern, but the potential for the future introduction of this pathogen in the Hawaiian waterbird populations remains a concern.

3A.8.5.1 Climate Change

Threats related to climate change that are discussed in Section A.4.5.1, *Climate Change*, for Hawaiian stilt (aeʻo) are similar for the Hawaiian goose (nēnē), including habitat loss due to flooding and sea level rise, the spread of invasive plant species, and disease. Climate change analyses in the Pacific Islands currently lack sufficient spatial resolution to make specific predictions concerning the effects of climate-related changes on Hawaiian goose (nēnē) on Kauaʻi (University of Hawaiʻi at Mānoa 2014).

3A.9 Central North Pacific Distinct Population Segment of the Green Sea Turtle (honu) (*Chelonia mydas)*

3A.9.1 Listing Status and Taxonomy

The green sea turtle (honu) is the largest marine turtle in the family Cheloniidae, second in maximum size only to the leatherback sea turtle (*Dermochelys coriacea*), and the sole species within the genus *Chelonia*. Green sea turtles (honu) grow to have a carapace length of 4 ft (1.2 m) and to weigh more than 400 pounds (181 kilograms). Its carapace has an olive-to-black color pattern and is composed of five scutes (or plates) running down its center, with four on either side. Other notable morphological distinctions are the species' yellow undersides and the two scales between its eyes. This species and other members of the Cheloniidae inhabit tropical and subtropical seas around the world.

All green sea turtles (honu) were listed under the federal ESA on July 28, 1978 (43 FR 32800). At that time, breeding populations in Florida and along the Pacific Coast of Mexico were listed as endangered and all other populations were listed as threatened. Major factors contributing to its status included human encroachment and associated activities on nesting beaches; commercial harvest of eggs, subadults, and adults; predation; lack of comprehensive and consistent protective regulations; and incidental take in fisheries. The federal recovery of the species is administered jointly between USFWS and NMFS (collectively referred to as "the Services") (U.S. Fish and Wildlife Service and National Marine Fisheries Service 2015).

On February 16, 2012, the Services received a petition from the Association of Hawaiian Civic Clubs to identify the Hawaiian green sea turtle (honu) population as a distinct population segment (DPS) and delist it. On August 1, 2012, NMFS—with USFWS concurrence—determined that the petitioned action might be warranted, on the basis of the substantial information presented (77 FR 45571). After conducting a status review, the Services determined on April 6, 2016, that the Hawaiian population of the green sea turtle (honu) met the definition of threatened and identified it as the Central North Pacific distinct population segment (CNPDPS) (81 FR 20057). The status review analysis determined there were 11 DPSs for the species globally. All other green sea turtle (honu) populations remain federally protected, with three DPSs listed as endangered and eight DPSs listed as threatened, including the CNPDPS. Critical habitat for the CNPDPS of the green sea turtle (honu) has not been designated; however, the Services have agreed to identify and propose critical habitat for the five DPSs (including the CNPDPS) within U.S. jurisdictional lands and waters by 2023.

The CNPDPS of the green sea turtle (honu) is also protected by Chapter 195D of the HRS and Section 13-124 of Hawaiʻi Administrative Rules. Both adopt the same definitions, status designations, and prohibitions as the federal ESA, with the exceptions of some additional critical habitat designations and protections under the federal ESA, and additional penalties for violations at the state government level.

3A.9.2 Life History

Seminoff et al. (2015) published the status review as a NOAA Technical Memorandum entitled *Status Review of the Green Turtle (*Chelonia mydas*) under the U.S. Endangered Species Act*. This work serves as the most contemporary and comprehensive published repository of information for the species globally. As such, it forms the basis for most of the detail in this section.

Green sea turtle (honu) is migratory, and requires shoreline, neritic (nearshore), and oceanic habitats to satisfy different parts of its life cycle. Green sea turtles (honu) become sexually mature at 25–35 years. During the nesting season (April through September), females come ashore to lay eggs within a few weeks of mating. After making their way above the high-tide line, they use their front flippers to dig a large depression called a *body pit*. Females then use their back flippers to dig a smaller hole at the posterior end of the body pit called an *egg chamber*, into which they deposit between 50 and 200 soft-shelled eggs. After refilling and covering their nests with sand, they return to the ocean to forage before returning to shore approximately 14 days later to nest again. The female will nest approximately three to four times in a nesting season. Upon laying the final nest, the female returns to the ocean, taking up to several months to reach marine foraging grounds in the MHI. Females return to these specific, generally neritic feeding areas, to replenish energy stores for the next reproductive season. This typically takes more than a year; while males can mate annually, on average, females mate every 2 to 4 years to accommodate the energetic requirements of reproduction.

After about 2 months, hatchlings break through the eggshell and slowly dig their way to the surface, typically en masse, and head to the ocean. This movement generally occurs at night or in the early predawn hours to avoid detection on the beach or in nearshore waters by predators. Hatchlings initially orient to the brightest horizon, naturally occurring over the moonlit ocean, in areas devoid of artificial lighting (Daniel and Smith 1947; Limpus 1971; Salmon et al. 1992; Witherington and Martin 1996; Witherington 1997). After reaching the water, hatchlings exhibit a multi-day *swimming frenzy*, during which they swim almost continuously, fueled only by leftover egg yolk, to reach deeper water away from shore.

Young turtles are transported by strong currents to oceanic habitats, where they live among flotsam, such as Sargassum (brown algae) and flotsam mats. During this part of the green sea turtle's (honu) life cycle, which can last years to decades, the animals are omnivorous. This period is often referred to as "the lost years." Because it is difficult to study the turtles during this period, relatively little is known about this phase of the turtle's life cycle. Once juvenile turtles reach a certain size and age range, around 10 to 15 years old, the animals return to the highly productive neritic feeding areas to finish growing, a process that can take as little as a few years and as long as a few decades.

Adult turtles also occupy neritic foraging areas while traveling between nesting and breeding locations. After acquiring sufficient resources, adult males and females migrate to breeding areas to mate and, in the case of females, to nest. Females exhibit strong natal homing, meaning that to lay their own eggs, they return to the coastline where they had hatched. The distance between feeding and breeding areas can be hundreds to tens of thousands of miles.

3A.9.3 Habitat Requirements and Ecology

Seminoff et al. (2015) state that most green sea turtles (honu) spend most of their lives in neritic foraging grounds. These areas of shallow waters include both open coastline and protected bays and lagoons. While in these areas, green sea turtles (honu) rely on marine algae and seagrass as their primary food, although some populations also forage heavily on invertebrates during different parts of their life cycle. This is the case for the CNPDPS during its oceanic life stage as detailed below. These coastal habitats are often highly dynamic with annual fluctuation in salinity and air temperature, which can cause the distribution and abundance of potential green sea turtle (honu) food items to vary substantially between seasons and years (Carballo et al. 2002). Conditions at coastal foraging areas have been shown to affect the timing of green sea turtle (honu) reproduction (Limpus and Nicholls 1988; Solow et al. 2002). Therefore, even though foraging areas are usually separated from nesting areas by hundreds to thousands of miles, they have a profound influence on population dynamics. Annual and decadal oscillations in marine climate likely play a large role in these large-scale movements, because winds and currents are affected, but additional research is required to understand how environmental variability triggers or limits green sea turtle (honu) migration and reproduction.

Oceanic habitats are used by juveniles as noted in Section A.9.2, *Life History*, migrating adults, and, on some occasions, by green sea turtles (honu) that reside in the oceanic zone for foraging. Despite these uses of the oceanic zone, much remains unknown about how oceanography affects juvenile survival, adult migration, and prey availability in this species.

On shore, green sea turtles (honu) rely on safe and "healthy" beaches characterized by intact dune structure, native vegetation, lack of artificial lighting, and normal beach temperatures for nesting (Limpus 1971; Salmon et al. 1992; Ackerman 1997; Witherington 1997; Lorne and Salmon 2007). Research has shown that higher sand temperatures result in disproportionate sex ratios in sea turtles (higher temperatures result disproportionately more females produced and vice versa for males), which in turn can lead to lower fecundity rates and ultimately population declines (Blechschmidt et al. 2020). Coastal areas denuded of vegetation or where development is occurring can also affect the quality of nesting habitat by disrupting normal thermal regimes but also lead to the potential for tidal inundation associated with lack of vegetation. Nests laid in these areas are at a higher risk than those on more pristine beaches (Schroeder and Mosier 2000).

As noted above, green sea turtles (honu) have been shown to consume a wide variety of seagrass, marine algae, and invertebrates (Bjorndal 1997). Limited studies of oceanic adults have shown them to be primarily carnivorous (Arthur et al. 2008; Parker et al. 2011). Parker et al. (2011) conducted one of the few diet analyses of oceanic green sea turtles (honu). The authors studied ten animals opportunistically obtained as fisheries bycatch within the CNPDPS. Analysis indicated that green sea turtles (honu) of the CNPDPS during the oceanic life stage were "carnivorous with some omnivorous tendencies, foraging within the first 100 m of the water column." Neritic-stage juvenile and adult green turtles have been found to be generally herbivorous, foraging on seagrasses and marine algae, although some populations appear to forage heavily on invertebrates (Bjorndal 1997; Jones and Seminoff 2013). Additionally, some populations may exhibit one or more ontogenetic dietary shifts (i.e., developmental events that occur during the existence of a living organism) after recruitment to the neritic zone (Arthur et al. 2008; Howell et al. 2013). The CNPDPS of the green sea turtle (honu) is distinct in that this population segment has integrated invasive plant species into its diet (Russell and Balazs 2009). Seminoff et al. (2015) noted a scarcity of detailed diet information among the various life stages for this species globally.

3A.9.4 Distribution and Population Trends

3A.9.4.1 Current and Historic Distribution

The range of the CNPDPS of the green sea turtle (honu) includes the Hawaiian Archipelago and Johnston Atoll. The Hawaiian Archipelago represents the most geographically isolated chain of islands globally and the CNPDPS distribution reflects that isolation. The Hawaiian Archipelago consists of the MHI: Ni‘ihau, Kaua‘i, O‘ahu, Moloka‘i, Maui, Lāna‘i, Kaho‘olawe, and Hawai‘i, and the Northwestern Hawaiian Islands which extend to Kure Atoll and are within Papahānaumokuākea Marine National Monument (Papahānaumokuākea). From 1965 to 2013, 17,536 individuals of the CNPDPS of the green sea turtle (honu) have been tagged, an effort that has involved all post-pelagic size classes from juveniles to adults. With only three exceptions, the 7,360 recaptures of these tagged turtles have been made within the Hawaiian Archipelago. The outliers involved one recovery each in Japan, the Marshall Islands, and the Philippines (Seminoff et al. 2015).

The principal nesting site for the CNPDPS of the green sea turtle (honu) where approximately 95 percent of all nesting occurs is French Frigate Shoals (Lalo), an atoll in Papahānaumokuākea (islands that make up the northwestern portion of the Hawaiian Archipelago) (Figure 9). Based on data collected from 1973 to 2005, East Island is where approximately 50 percent of the nesting occurs within French Frigate Shoals (Lalo) (Balazs and Chaloupka 2004, 2006). Since nesting surveys of the CNPDPS of the green sea turtle (honu) were initiated in 1973, there has been a marked increase in numbers nesting at East Island. The other islands within French Frigate Shoals (Lalo) include Tern, Trig, Gin, and Little Gin, all of which combined, account for the remainder of CNPDPS green sea turtle (honu) nesting at the atoll.

At East Island, the mean annual nesting abundance was 83 females during the first 4 years of monitoring (1973–1977) which increased to 464 females during the monitoring period of 2009–2012 (Seminoff et al. 2015). This trend represents an annual increase of 4.8 percent for the CNPDPS of the green sea turtle (honu) since monitoring began (Seminoff et al. 2015). Information on at-sea abundance trends is consistent with the increase in nesting (Balazs et al. 1996, 2005; Balazs 2000; Seminoff et al. 2015).

In 2018, East Island was dramatically altered by a Category 3 Hurricane, Walaka. The storm shrank the roughly 11-acre island by 94 percent. As sand re-accreted over time, the island moved offshore from its pre-Walaka position. In 2019, the island grew by nearly 600 percent and as of 2020, East Island had returned to nearly 60 percent of its pre-Walaka size (Kane et al. 2020) and appears to have shifted slightly from its pre-Walaka position.

Surveys were conducted in 2019 (National Oceanic and Atmospheric Administration 2019) at both East and Tern Islands. In 2019, 106 females were identified on at East Island (National Oceanic and Atmospheric Administration 2020a) and 251 females were identified at Tern Island (National Oceanic and Atmospheric Administration 2019). Relative to recent years, abundances of nesting females had increased at Tern Island and decreased at East Island in 2019. It is unclear if this increase is due solely to habitat loss and displacement from East and Trig islets or if there were additional factors facilitating increased abundance of nesting females at Tern Island (National Oceanic and Atmospheric Administration 2019). At both islands, additional ecological changes were observed. At Tern Island, the loss of vegetation due to Walaka and increased entrapment of nesters nesting over a larger area within overall suboptimal habitat has been observed. At East Island, surveys found that nests were frequently washed out., including the loss of an important index site that had been used to monitor trends in abundance for CNPDPS of the green sea turtle (honu) over the last 30 years (National Oceanic and Atmospheric Administration 2020a). In 2020, normal survey efforts were interrupted by COVID-19 but opportunistic surveys were able to be completed by Papahānaumokuākea Marine National Monument Co Trustee Agency partner staff already deployed prior to COVID-19 restrictions; these data were not publicly available (National Oceanic and Atmospheric Administration 2020b).

3A.9.4.2 Within the Plan Area

Seminoff et al. (2015) calculated and summarized abundance of nesting individuals across all locations within the CNPDPS of the green sea turtle (honu). Estimated total nester abundance was calculated as [(total counted females / year of monitoring) x remigration interval]. For Kauaʻi, green sea turtle (honu) monitoring data collected from 2010 to 2012 were used to calculate an estimated nester abundance of 16 females. This represents only 0.39 percent of the total estimate of 3,864 breeding females calculated for the CNPDPS of the green sea turtle (honu).

In addition, Parker and Balazs (2015) documented 20 nesting sites[1] from 1976 to 2012 around Kauaʻi. All but two were described as having intermittent or indeterminate use (Figure 9). The two locations regularly used by nesting females are Lāwaʻi Kai and Kīpū Kai on the south side of the island. Average annual nesting density of green sea turtles (honu) at all Kauaʻi sites is very low, ranging from less than one (i.e., one nest every several years) to one to two nests per year between 2015 and 2020 (State of Hawaiʻi Division of Aquatic Resources 2020). Lāwaʻi Kai and Kīpū Kai averaged one to two nests per year during the same time period (State of Hawaiʻi Division of Aquatic Resources 2020). Although nesting density is low, observations of nesting have increased over the past 5 years (State of Hawaiʻi Division of Aquatic Resources 2020).

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[1] Nesting data reported from Kauaʻi are speculative due to the lack of systematic surveys. Estimates may also be skewed toward high-use beaches and beaches that regularly have resting seals (as this is how green sea turtle [honu] nests have been opportunistically found).

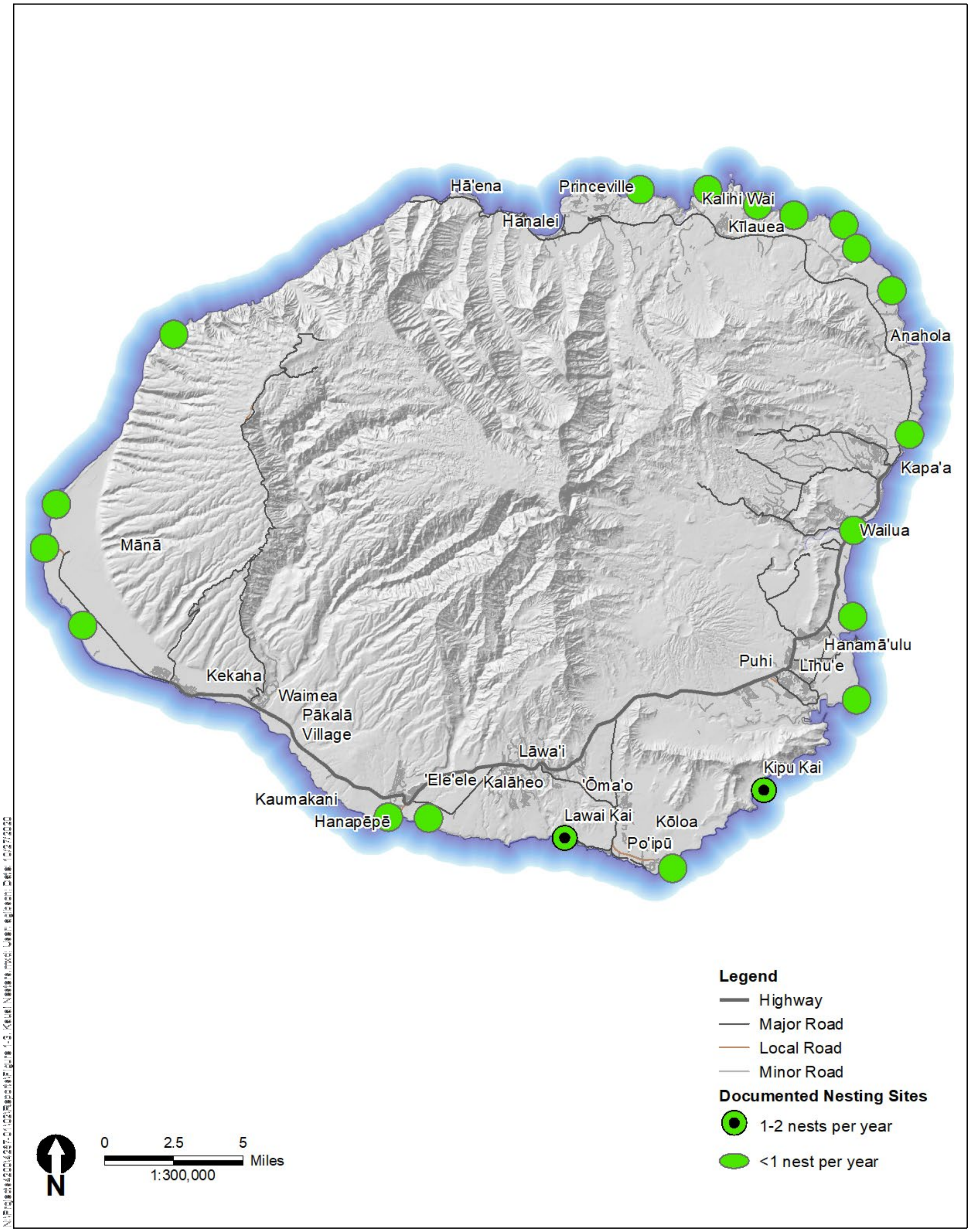

Figure 9. Location and Estimated Abundance of Central North Pacific Distinct Population Segment of the Green Sea Turtle (honu) Nests on Kauaʻi

3A.9.5 Threats

Seminoff et al. (2015) present the status review of the green sea turtle (honu) across the global range and document threats as part of the overall evaluation of each DPS. Consistent with the overall global threats, the primary causes of the decline of the CNPDPS of the green sea turtle (honu) are attributed to a variety of anthropogenic threats. Threats, such as bycatch in fishing gear (the incidental capture of non-target species), pollution, interactions with recreational and commercial vessels, development and public use of beaches, climate change, artificial lighting, predation, disease, beach driving, and major storm events all negatively affect green sea turtles (honu) in this DPS. Three of the most common reasons for sea turtle strandings in Hawaiʻi are entanglement in fishing lines, interactions with fishing hooks, and interaction with marine debris (usually entanglement in nets) (Francke et al. 2013).

Coastal development and construction, artificial lighting, vehicular and pedestrian traffic, beach pollution, tourism, and other human-related activities are increasing threats to the basking and nesting population in the MHI (currently very limited) and negatively affect hatchling and nesting turtles on beaches where these threats are present. Climate change effects, especially sea level rise, is a threat to the terrestrial and neritic-oceanic zones in both the MHI and Papahānaumokuākea ; potential effects on green sea turtle (honu) life stages that rely on other zones are less certain.

3A.9.5.1 Development

Human populations are growing rapidly in many areas of the insular Pacific and this expansion is exerting increased pressure on limited island resources. The most valuable land on most Pacific islands is often located along the coastline, particularly when it is associated with a sandy beach. Construction is occurring at a rapid rate in some areas and is resulting in loss or degradation of green sea turtle nesting habitat (honu). Construction-related threats to the region's nesting beaches include construction of buildings (e.g., hotels, houses, restaurants) and recreational facilities (e.g., golf courses) on or directly adjacent to the beach; clearing of stabilizing beach vegetation, which accelerates erosion; and use of heavy construction equipment on the beach, which can cause sand compaction or beach erosion. Lighting associated with coastal development also degrades nesting habitat (Section A.9.5.4, *Artificial Light Attraction*).

3A.9.5.2 Public Use of Beaches

Increased public use of nesting beaches is a threat to green sea turtle (honu) nesting habitat in Kauaʻi. Public use of beaches includes a variety of recreational activities, such as picnicking (which can include beach camping and fires), swimming, surfing, playing sports, scuba diving, use of watercraft in the nearshore environment, and snorkeling access (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998). Public use of beaches can also increase litter and other refuse on the beach, which can attract destructive non-native animals such as pigs. Although driving on Kauaʻi's beaches is illegal, there is extensive vehicle traffic in suitable green sea turtle (honu) nesting habitat (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998).

3A.9.5.3 Vessel Strikes

Various types of watercraft can strike green sea turtles (honu) when they are at or near the surface. Vessel strikes are a major threat to large juveniles at sea and adults in nearshore areas. High boat traffic areas such as marinas present a high risk to this species, and nesting females are vulnerable to vessel strikes when making reproductive migrations or while they are near shore during the nesting season (National Marine Fisheries Service 2021). Sea turtles can also be struck and seriously injured by boat propellers, hydrofoils and jet skis. From 2005 to 2009, 18.2 percent of all stranded green turtles (695 of 3818) in the U.S. Atlantic (Northeast, Southeast, and Gulf of Mexico) were documented as having sustained some type of propeller or collision injuries (Seminoff et al. 2015).

Green sea turtles (honu) have been documented as occasionally being hit by boats in Kauaʻi. In December 2020, a green sea turtle (honu) was struck by a boat and stranded on the shoreline. The individual had to be euthanized due the extent of its injuries. The turtle is just one of 22 that were injured in the NMFS Pacific Islands Region since March 2020 (Wu 2020).

3A.9.5.4 Climate Change

Global climate change will lead to alterations of green sea turtle (honu) nesting habitat. For example, sea level rise will result in increased erosion of nesting beaches and significant loss of habitat (Baker et al. 2006; Intergovernmental Panel on Climate Change 2007). The extent to which green sea turtles (honu) can adapt to these changes in nesting beach location and quality is unknown. Climate change will likely also cause higher sand temperatures leading to increased feminization of surviving hatchings (i.e., changes in sex ratio); and some beaches will also experience lethal incubation temperatures that will result in complete losses of hatchling cohorts (Glen and Mrosovsky 2004; Fuentes et al. 2010, 2011; Booth et al. 2020). Increased sea surface temperatures may alter the timing of nesting for some stocks (Weishampel et al. 2004), although the implications of changes in nesting timing are unclear. Changes in sea temperatures will also likely alter seagrass, macroalgae, and invertebrate populations in coastal habitats in many regions (Scavia et al. 2002). Climate forecasts are needed in population models to understand the impacts of rising temperatures (e.g., sand temperatures) on hatchling sex ratios and hatching success.

East and Tern islands of French Frigate Shoals (Lalo), the center of the CNPDPS range, are vulnerable to sea level rise (Baker et al. 2006). High-resolution digital elevation data and models are necessary to describe observed sea level rise and its future modeled potential at French Frigate Shoals (Lalo) and other nesting sites to assess green sea turtle (honu) vulnerability.

Changing storm dynamics and intensity because of climate change are emerging concerns for habitat in both the MHI and the Papahānaumokuākea (Baker et al. 2006; Keller et al. 2009). Storms and seasonal changes in current patterns can reduce or eliminate sandy beaches, degrade turtle nesting habitat, and cause barriers to adult and hatchling turtle movements on affected beaches.

One such notable event occurred in early October 2018 when Hurricane Walaka, a category 3 storm, directly affected French Frigate Shoals (Lalo). Satellite imagery documented dramatically altered shoreline habitat on East and Tern islands. East Island was almost completely claimed by the ocean. Unhatched turtle nests were severely affected by the storm at French Frigate Shoals (Lalo) as reported to USFWS by personal observations. One observation reported the runway at Tern Island was littered with turtle eggs destroyed from the storm. Consequently, the impacts of the hurricane affected nesting rates for 2018 and subsequent years following the event (U.S. Fish and Wildlife Service pers. comm.).

Some islands in French Frigate Shoals (Lalo) had already become submerged and were lost prior to Hurricane Walaka. As is common in sand-dominated ecosystems, Whale and Skate Islands were lost to erosion during the 1990s and Trig Island eroded earlier in 2018. Observations have led scientists to believe that, when these events occur, animals adapt by changing breeding locations (Papahānaumokuākea Marine National Monument 2018).

3A.9.5.5 Artificial Light Attraction

The presence of artificial lights on or adjacent to sea turtle nesting beaches alters the behavior of nesting adults (Witherington 1992); it is often fatal to emerging hatchlings, as they are attracted to light sources and drawn away from the water (Witherington and Bjorndal 1991; Nelson Sella et al. 2006). Light pollution has also been shown to affect females by deterring them from coming ashore to nest or drawing them away from the ocean after they are done nesting. These impacts have been well documented along coastal stretches of Florida and MHI. Based on hatchling orientation index surveys at nests located on 23 representative beaches in six Florida counties in 1993 and 1994, Witherington and Martin (1996) found approximately 10–30 percent of all sea turtle nests in each county showed evidence of hatchlings disoriented by artificial lighting.

Despite Seminoff et al. (2015) attempts to provide detailed analysis of all known threats to the species and relevant DPSs, light pollution is absent from the analysis for the CNPDPS. Although there is scant documentation for negative impacts from artificial lighting related to nesting on Kauaʻi, it is well known that artificial lighting affects sea turtles in the MHI. On Kauaʻi, there is recent documentation (2020) of one incident of more than one hatchling from a single nest being run over by vehicles near Kekaha Beach, resulting from disorientation due to artificial lighting emitted by a nearby streetlight adjacent to the main highway (Kauaʻi Hawaiian Monk Seal Conservation Hui pers. comm.). In addition, at least two known disorientation incidents also have occurred at a hotel in Poʻipū and one at Salt Pond County Park (Reiss pers. comm.). There are also numerous examples of hawksbill sea turtle (honuʻea) (*Eretmochelys imbricata*) disorientation of both hatchlings and nesting females from artificial lighting on Maui and the Island of Hawaiʻi. For example, on Maui in 1993 and 1996, two female hawksbills (honuʻea) with eggs and numerous hatchlings were killed by cars while trying to cross North Kīhei Road from the adjacent nesting beach (Hawaiʻi Wildlife Fund 2021).

3A.9.5.6 Disease

Fibropapilloma disease affects green sea turtles (honu) found in the MHI (Francke et al. 2013). This disease results in internal and external tumors (fibropapillomas) that may grow large enough to hamper swimming, vision, feeding, and potential escape from predators. In 2012 alone, 36 green turtle strandings in the MHI involved fibropapilloma tumors (Francke 2013). The exact numbers of animals affected by fibropapilloma is unknown because reported stranding data availability is limited and only represent a fraction of all CNPDPS of the green sea turtle (honu) mortalities. Depending on the area of Hawaiʻi, fibropapilloma disease appears to have peaked, remained the same, or increased (Van Houtan et al. 2010). Environmental factors may be significant in promoting fibropapilloma incidence; eutrophication (increase in nutrients) of coastal marine ecosystems also may promote this disease (Van Houtan et al. 2010). Fibropapilloma remains an important concern, particularly given the continued (and possibly future increasing) human impacts, including eutrophication of coastal marine ecosystems. Spirorchid (blood fluke) infections are reported for the CNPDPS of the green sea turtle (honu) (Greenblatt et al. 2005; Work et al. 2005); however, the extent to which this is a threat to the population is unknown.

3A.9.5.7 Predation

Predation of green sea turtle (honu) hatchlings by native species is normal and is something to which green sea turtles (honu) have adapted. Ghost crabs (*Ocypode* spp.) prey on hatchlings at French Frigate Shoals (Lalo) (Niethammer et al. 1997). The exact number of hatchlings lost is unknown but is estimated at approximately 5 percent (Balazs 1980). Hatchlings may also be eaten by fish when they enter the ocean. Large grouper (*Epinephelus tauvina*) are documented predators of post-hatchling green turtles in Hawaiʻi; however, the extent of grouper depredation is unknown (Balazs 1995). Seabirds, primarily the great frigatebird (ʻiwa) (*Fregatta minor*), an opportunistic predator of other seabird nestlings and known to prey on sea turtle hatchlings elsewhere, may also prey on sea turtle hatchlings at French Frigate Shoals (Lalo) (Balazs and Kubis 2007). Stranding records from Papahānaumokuākea and MHI (e.g., Francke 2013) show shark predation of CNPDPS of the green sea turtle (honu), predominantly adult turtles. The exact numbers of animals taken by sharks is unknown because reported strandings only represent a fraction of all CNPDPS of the green sea turtle (honu) mortalities.

Depredation of green sea turtle (honu) hatchlings by introduced species can exert additional pressure on the population in the cumulative context of additional anthropogenic sources. Mongoose, rats, dogs, feral pigs, and cats—all introduced species—exist on the MHI and are known to prey on eggs and hatchlings, although the exact impact on the current low level of nesting is unclear. If nesting in the MHI increases, it is likely the threat from these predators would increase.

3A.9.5.8 Illegal Harvest

While the harvesting of eggs and turtles was likely the major contributing factor to the historical decline of the population globally, current illegal harvest of green sea turtles (honu) for human consumption is limited. Harvest of CNPDPS of the green sea turtle (honu) has been illegal since it was listed under the federal ESA in 1978; furthermore, federal and state cooperative efforts and existing legislation appear to be minimizing the threat from illegal harvest. It is possible that human take today is underreported: anecdotal information suggests that some degree of illegal take continues to occur throughout the MHI.

3A.9.5.9 Marine Pollution, Fisheries Direct and Fisheries Indirect Interactions

Marine pollution includes the ingestion of, and entanglement in, marine debris, is another anthropogenic threat to CNPDPS of the green sea turtle (honu) throughout their range. Turtles ingest plastic, monofilament fishing line, and other marine debris (Bjorndal et al. 1994). Although direct effects may or may not be lethal, they result in varying side effects that could increase the probability of death (Balazs 1985a; Carr 1987; McCauley and Bjorndal 1999). CNPDPS of the green sea turtle (honu) can also be affected by contamination from herbicides, pesticides, oil spills, and other chemicals; as well as impacts on water quality (e.g., increases in water column sediments) resulting from structural degradation associated with excessive boat anchoring, dredging, and other sources (Francour et al. 1999; Lee Long et al. 2000; Waycott et al. 2005).

Historic military-related activities within the area covered by CNPDPS of green sea turtle (honu) have been a legacy of modification of offshore and onshore habitat at French Frigate Shoals (Lalo), including contamination (e.g., point sources of polychlorinated biphenyls because of former Long Range Navigation stations). Elevated levels of contamination remain in soils and nearshore sediment and biota; and sea and land pollution related to past and present human activities continues to stress the Papahānaumokuākea ecosystem (Wedding et al. 2008). During the 20th century, Johnston Atoll was the location of significant human and military activities such as guano mining, missile launching, airplane operations, nuclear testing, and chemical weapons incineration. The lingering effects of these activities include soil contamination, such as petroleum contamination of turtle foraging habitat (Balazs 1985b). However, the current effects of these activities on the marine environment and sea turtles are unclear.

Marine debris is a known threat for the CNPDPS of the green sea turtle (honu) in both terrestrial and marine environments. In 1996, it was estimated that between 750 and 1,000 tons of marine debris were on reefs and beaches in the Papahānaumokuākea, with fishing nets discarded or lost in the northeastern Pacific Ocean contributing the most (Keller et al. 2009). Keller et al. (2009) explain that even if no new debris were to enter the ocean, existing debris in the ocean will continue to accumulate in the Papahānaumokuākea for years. Such debris poses a major entanglement threat to sea turtles in the Papahānaumokuākea and can result in serious injury or mortality; it also can cause damage to habitat (Wedding et al. 2008). Balazs and Kubis (2007) describe entanglement and ingestion of marine debris as a potential threat to CNPDPS of the green sea turtle (honu), specifying discarded or abandoned fishing gear (nets and lines), as well as plastics (bags, six-pack rings, tar balls, polystyrene or other items that could ensnare or be eaten). Stranding information shows that fishing line and gill net gear entanglement is one of the causes of CNPDPS of the green sea turtle (honu) strandings and mortality in the MHI (Francke 2013, 2014). For example, 36 strandings in 2012 (Francke 2013) and 42 strandings in 2013 were related to entanglement in or ingestion of fishing line (Francke 2014). This number is a subset of the total number of animals possibly affected by this threat.

Interactions between the CNPDPS of green sea turtles (honu) and commercial and recreational fisheries in the Exclusive Economic Zone of the MHI can result in entanglement, injury, and mortality.

In addition, hook-and-line fishing from shore or boats hook and entangle individuals from the CNPDPS of the green sea turtle (honu) (National Marine Fisheries Service 2012; Francke et al. 2013). Interactions with nearshore recreational fisheries are identified in the NMFS stranding database as those turtles that strand as a result of interactions with fishhooks and fishing line. These include turtles that were hooked externally, ingested hooks, became entangled in fishing line, or exhibited intestinal prolapses due to line ingestion. Hook-and-line interactions have increased over time, with more than 60 turtles in 2011 and 46 turtles in 2012 stranded (Francke 2013; Francke et al. 2013; Ikonomopoulou et al. 2013). While current public outreach efforts by NMFS and its partners are attempting to reduce the magnitude of impact on CNPDPS of the green sea turtle (honu) from hook-and-line fishing, injury or mortality from the hooking or from the effects of line remaining on turtles that are cut free or break the line remains an issue (National Oceanic and Atmospheric Administration 2013).

Net and gill net entanglement cases include unidentified nearshore and pelagic nets, including cargo nets, trawl nets, lobster nets, and monofilament gill nets. Each year, individuals from the CNPDPS of the green sea turtle (honu) are incidentally entangled in net gear and some of these result in mortality (e.g., Francke 2013); however, the reported stranding is believed to be a smaller subset of the actual level of interaction with this gear. Henderson et al. (1987) documented sea turtle mortality resulting from entanglement in fishing gear in Hawaiʻi. Chaloupka et al. (2008) reported that between 1982 and 2002 approximately 7 percent of stranding related to gear-induced trauma were attributed to hook-and-line fishing; 5 percent for gill-net fishing. While gill nets are regulated by the State of Hawaiʻi, fishers are only required to inspect them completely every 2 hours, so entanglement and drowning do occur (National Marine Fisheries Service 2012).

Hawaiʻi-based pelagic longline fisheries use baited lines up to several miles long that have thousands of hooks and lures that inadvertently catch turtles, resulting in death by drowning (as they are unable to rise to the surface for air) or digestive debilitation (line and hook gets lodged in the stomach) (Sea Turtle Conservancy 2020). These fisheries are expected to take up to seven individuals from the CNPDPS of the green sea turtle (honu) annually (National Marine Fisheries Service 2005, 2012). Sea turtle bycatch rates in foreign fisheries are estimated to be at least 10 times and perhaps 20 times greater than Hawaiʻi-based fisheries (Bartram and Kaneko 2004; Kaneko and Bartram 2008), given the much greater fishing effort among foreign vessels (National Marine Fisheries Service 2012). While exact numbers are not available, at a minimum, an estimated 100 individuals of the CNPDPS of the green sea turtle (honu) are captured and killed annually as longline bycatch (National Marine Fisheries Service 2012).

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Appendix 4A

Conservation Site Selection

4A.1 Introduction

4A.1.1 Purpose

The purpose of this appendix is to describe the conservation site selection process for the Kauaʻi Island Utility Cooperative (KIUC) Habitat Conservation Plan (HCP). The conservation sites are the locations where Conservation Measure 4, *Manage and Enhance Seabird Breeding Habitat and Colonies at Conservation Sites* (hereafter Conservation Measure 4), will be implemented. Management actions under Conservation Measure 4 include predator control, predator exclusion fencing, social attraction, and invasive plant species control. This appendix describes the conservation site selection background, conservation site selection process, and the conservation sites for the KIUC HCP.

4A.1.2 Conservation Site Selection Background

The HCP conservation strategy includes conservation measures to offset the injury and mortality of Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) from collisions with KIUC powerlines and fallout from KIUC lights. Collisions by band-rumped storm-petrel (ʻakēʻakē) have not been quantified but are thought to be infrequent due to the species' flight behavior (Ainley pers. comm.) and lack of any documented powerline collisions to date (Travers et al. 2020) and, as such, any impacts on this species would be mitigated by the conservation measures for the other two covered seabirds. A critical aspect of the conservation strategy is that the conservation requirements are commensurate with the amount of unavoidable take estimated to be caused by KIUC powerlines to meet the state and federal requirements for an HCP.

The goal of the KIUC HCP conservation strategy for the covered seabird species is to result in a population size, age structure, population growth rate, demography, and distribution that is representative of a viable metapopulation on the Island of Kauaʻi that will provide for the survival of the Kauaʻi metapopulation and contribute to species' recovery. This goal will be achieved, in part, by implementing Conservation Measure 4 at the conservation sites.

4A.2 Conservation Site Selection

4A.2.1 Site Selection Methods

4A.2.1.1 Identification of Potential Conservation Sites

The U.S. Fish and Wildlife Service (USFWS), the State of Hawaiʻi Division of Forestry and Wildlife (DOFAW), KIUC, and other stakeholders and species experts have been working collaboratively since 2002 to identify and evaluate potential conservation sites to contribute to viable metapopulations of the covered seabird species on Kauaʻi (Kauaʻi Island Utility Cooperative 2011). Initially, potential sites were identified through a desktop assessment using selection criteria that were developed in consultation with DOFAW, USFWS, and species experts.

During the evaluation process, DOFAW and USFWS worked with KIUC to narrow the list of potential sites and review new sites as they were proposed. Raine et al. (2020) provided key information on the current status of the covered seabird populations, practicability of implementing the conservation measures, and site constraints, to inform the site selection process. KIUC coordinated with USFWS and DOFAW staff and Dr. Andre Raine along with Lindsay Young of Pacific Rim Conservation for suggestions on appropriate sites and the practicability of implementing conservation measures at those sites. In 2020, Lindsey Young of Pacific Rim Conservation was contracted to conduct a feasibility analysis on potential conservation sites to further inform conservation site selection (Young 2020).

4A.2.1.2 Habitat Suitability Models and Population Estimation

An important determinant of conservation sites is the presence of suitable breeding habitat for the two primary covered seabirds, Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu). Habitat distribution models were used to determine the location of suitable breeding habitat as a starting point to identify possible suitable conservation sites. Troy et al. (2014, 2016, 2017) developed habitat suitability models for both Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) using abiotic and biotic environmental parameters (e.g., elevation, wind speed, slope, vegetation cover) that are key nesting habitat characteristic of these species. These parameters were presented in a digital raster layer representing independent variables to produce the model in a GIS framework at a 164-foot (ft) by 164-ft (50-meter [m] by 50-m) pixel resolution representing categorical values of habitat suitability from 1 to 10. The output of the model is the predicted probability that each pixel supports (or could support) the nesting activities of Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) based on the environmental conditions of the pixel.

In 2018, Raine et al. used the Troy et al. (2014, 2016, 2017) habitat suitability models to estimate population sizes of endangered seabird colonies on Kauaʻi. Pixels valued 8 or higher were extracted from the habitat suitability models and used to identify areas of suitable habitat for each species within each conservation site. Areas of suitable breeding habitat were refined using current seabird activity for each species, as determined from the result of the Kauaʻi Endangered Seabird Recovery Project's auditory surveys. The average minimum area between burrows was then used to calculate an average density (burrow per m). Then, the minimum burrow densities for each species were multiplied by the total area of regions identified as occupied suitable breeding habitat (i.e., area with suitable breeding habitat in an area within constant intensive activity, as determined by auditory surveys) allowing the calculation of a total population estimate for each site (Raine et al. 2018).

4A.2.1.3 Evaluation of Conservation Site Selection Criteria

The conservation site selection criteria listed in the following sections were developed by Raine et al. (2020) as a way of prioritizing known endangered seabird colonies that would be most suitable for long-term conservation under the KIUC HCP. Each conservation site is assessed against 14 criteria, with each criterion given a score from 0 or 1 to 5. Conservation sites are ranked independently for each covered seabird species. However, a criterion for the presence of multiple species is also included to increase the value of a conservation site with more than one covered seabird species.[1]

A description of the relative scores is outlined at the beginning of each criterion for ease of reference. Once each criterion was summed to a total score, the conservation sites with the highest scores were those that were selected as conservation sites for the HCP. A perfect score would total 96 points[2] (Raine et al. 2020).

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[1] The multiple species criterion score only goes from 1 to 3 because there are only 3 covered seabird species.

[2] The perfect score is over 70 because a few criteria are doubled or tripled to increase their significance for conservation site selection.

Covered Species Occupancy

Criterion 1. Presence of a covered seabird breeding colony

Criterion 1 is defined as nesting within a conservation site by the covered seabird species. This criterion requires occurrence data (i.e., auditory surveys and/or burrow monitoring) to determine whether the site is occupied.

The criterion scores for presence of a covered species breeding colony are as follows:

- 0—No colony present
- 1—Species recorded at least once during auditory surveys
- 2—Auditory surveys confirm areas of activity identified as hotspot light (i.e., ‘*localized aerial activity, sporadic calling*’)
- 3—Auditory surveys confirm areas of activity identified as hotspot heavy (i.e., ‘*localized aerial activity, continuous calling*’)
- 4—Auditory surveys confirmed ground calling (highest level of evidence that a breeding colony exists at the site below the discovery of an actual burrow)
- 5—Confirmed breeding colony (through the discovery of active burrows)

The covered species occupancy criterion score is multiplied by a factor of two if a breeding colony is present to increase its weight. Conservation sites that contain a covered species breeding colony should be weighted more heavily than sites where social attraction is required to initiate a breeding colony. The criterion score is multiplied by a factor of three if the density of breeding birds at the site is high (i.e., for Newell’s shearwater [ʻaʻo], the density at the Upper Limahuli Preserve [average nearest neighbor distance 62.7 ft {19.1 m}] and for and Hawaiian petrel [ʻuaʻu] the density at North Bog [average nearest neighbor distance 45.6 ft {13.9 m}]).

Sites with a criterion score of 0 for covered species occupancy were only included as a conservation site in the KIUC HCP if they met Criterion 2 or Criterion 3. If one or both of these criteria are met, then these sites could be considered if social attraction was planned to be used as a management tool to create a new breeding colony within the conservation site.

Criterion 2. Presence of a covered species breeding colony adjacent to the conservation site

Criterion 2 is defined as nesting by one or more of the covered species adjacent to the conservation site (within 0.62 mile [1 kilometer {km}]). This criterion requires occurrence data (i.e., auditory surveys and/or burrow monitoring) to determine whether the adjacent habitat is occupied.

The criterion scores for presence of a breeding colony adjacent to the conservation site are as follows:

- 0—No colony present
- 1—Species recorded at least once during auditory surveys
- 2—Auditory surveys confirm areas of activity identified as hotspot light (i.e., ‘*localized aerial activity, sporadic calling*’)
- 3—Auditory surveys confirm areas of activity identified as hotspot heavy (‘*localized aerial activity, continuous calling*’)

- 4—Auditory surveys confirmed ground calling
- 5—Confirmed nest site

Conservation sites with adjacent breeding colonies would be ranked higher than conservation sites with little to no adjacent covered species activity.

Criterion 3. Presence of covered species transiting over the site

Criterion 3 is defined as presence of one or more of the covered species transiting over the conservation site. Conservation sites that are on a known flyway would be ranked higher than conservation sites that are not. This criterion requires auditory surveys and song meters to determine if the covered species pass over the conservation site.

The criterion scores for covered species occupancy are as follows:

- 0—No seabirds transiting over the site
- 1—Occasional covered seabirds transiting over the site, but not nightly
- 2— Occasional covered seabirds transiting over the site, on a nightly basis
- 3—Small numbers (<30) of covered seabirds transiting over the site during peak movement hours on a nightly basis
- 4—Moderate (31–75) numbers of covered seabirds transiting over the site during peak movement hours on a nightly basis
- 5—High numbers (76+) of covered seabirds transiting over the site during peak movement hours on a nightly basis

Social attraction in the conservation sites that are located within the nocturnal flyway is more likely to successfully attract breeding adults than in conservation sites with little or no covered seabird activity.

Criterion 4. Presence of multiple covered species at the conservation site

Criterion 4 is defined as occupancy of a conservation site by multiple covered species. This criterion requires occurrence data (i.e., auditory surveys and/or burrow monitoring) to determine whether the site is occupied.

The criterion scores for covered species occupancy are as follows (because there are three covered seabird species the maximum score is 3).

- 1—One species present
- 2—Two species present
- 3—Three species present

Conservation sites with multiple covered species increase the cost-benefit of the conservation measures because the same conservation actions can affect multiple covered species. The criterion score is multiplied by a factor of two if multiple species are present to increase its weight. Conservation sites with multiple covered species are of higher value than conservation sites with only one covered species colony.

Habitat Quality

Criterion 5. Presence of Invasive Plant Species

Criterion 5 requires an assessment of the quality of the habitat for breeding seabirds within the conservation site. On Kauaʻi, Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) nest in wet montane forests with a high proportion of native trees (particularly ʻōhiʻa lehua [*Metrosideros polymorpha*] in the canopy and native plants in the understory (particularly false staghorn [uluhe; *Dicranopteris linearis*]) (Raine et al. 2021). Newell's shearwater (ʻaʻo) are also found in the sheer cliffs of the Nā Pali Coast (where band-rumped storm-petrel [ʻakēʻakē]) are also found).

This criterion should, however, be considered with the following proviso in mind: the requirement that plants are native species is less important than the structural composition of the vegetation and the topography of the conservation site. That can be seen in the presence of Newell's shearwater (ʻaʻo) in the coastal habitat present at Kīlauea Point National Wildlife Refuge, which is vastly different from other breeding colonies on the island. Habitat quality should primarily be considered in terms of the presence of invasive plant species that alter habitat structure to impede burrowing and nesting behavior (e.g., strawberry guava [*Psidium littoralei*], Australian tree fern [*Sphaeropteris cooperi*], Himalayan ginger [kāhili ginger] [*Hedychium gardnerianum*]) and the level of ongoing habitat management within the conservation site. Conservation sites with high levels of invasive plants are assigned a low score. If positive habitat modification can occur in the conservation site after the fence enclosure is created (i.e., the terrain is easy to work in), then this was reflected in the scoring system. Good-quality native habitat was assigned the highest possible score.

- 1—Predominantly nonnative invasive plant species with no invasive plant species management
- 2—Native plant species mixed with a higher proportion of nonnative invasive plant species and no invasive plant management
- 3—Native plant species mixed equally with nonnative invasive plant species and sporadic invasive plant species control
- 4—High-quality native habitat with a lower proportion of nonnative invasive species and moderate invasive plant species management
- 5—Predominantly native plant species with intensive invasive plant species management

Predators

Criterion 6. Terrestrial predators

Criterion 6 is defined as the abundance of terrestrial predators in the conservation site and the level of ongoing predator control. Various factors can be used to infer whether or not the conservation site is likely to have high or low densities of terrestrial predators, such as proximity to urban areas, presence of roads or trails leading to the breeding site, degree of human traffic in the area (i.e., more humans leads to more trash and direct feeding), and topography and natural barriers that prevent predator movement.

- 1—High density of terrestrial predators, no ongoing predator control
- 2—High density of terrestrial predators, sporadic predator control
- 3—Moderate density of terrestrial predators, ongoing predator control

- 4—Low density of terrestrial predators, ongoing intensive predator control
- 5—No terrestrial predators (only applicable to areas where eradication has already occurred [e.g., Lehua Islet, fenced social attraction sites])

The greater the abundance of terrestrial predators present within a conservation site, the more difficult it will be to reduce or eradicate them and limit future incursion. While terrestrial predators are found throughout Kauaʻi, they are particularly prevalent in lowland areas near urban centers. Conservation sites with a high abundance of terrestrial predators would be ranked lower than conservation sites where predators are present in lower densities.

Criterion 7. Aerial introduced predators (barn owls [*Tyto alba*])

Criterion 7 is defined as the abundance of barn owls within the conservation site and the level of ongoing barn owl control. Various factors can be used to infer whether or not the conservation site is likely to have high or low densities of barn owls present, including proximity to rural areas and open fields (barn owls occur at higher densities in open areas), topography, and type of habitat in the conservation site.

- 1—High levels of barn owl activity or data deficient, no active barn owl control
- 2—Moderate levels of barn owl activity, no active barn owl control
- 3—Moderate levels of barn owl activity, sporadic barn owl control
- 4—Moderate levels of barn owl activity, regular barn owl control
- 5—Low levels of barn owl activity, intensive barn owl control

Conservation sites where barn owls are present in large numbers (particularly in the lowlands and near agricultural areas) will present significant management challenges. Barn owl control requires year-round targeted control efforts by well-trained professionals. As such, conservation sites with a lower density of barn owls would score higher than conservation sites with a high density of barn owls. For conservation sites where barn owl density is unknown, this criterion will score 3, which assumes that there are likely to be some barn owls within the conservation site given that this species is distributed across Kauaʻi.

Existing Management

Criterion 8. Existing management activities

Criterion 8 is defined as the status of management activities within the conservation site, including infrastructure to support management activities. Scores for this criterion are multiplied by a factor of two because the presence of existing management actions and infrastructure greatly reduce startup costs and reduce the time to realize covered species benefits.

- 0—No existing management
- 1—Very little existing management and infrastructure
- 2—Existing management but limited infrastructure
- 3—Existing management and infrastructure but they are not seabird-directed
- 4—Existing seabird-directed management and infrastructure ongoing for short-time (1–2 years)

- 5—Existing seabird-directed management has been ongoing for many years (3+ years) and infrastructure is present and in good condition

Scores for this criterion consider land ownership (i.e., federal, state, private), which may have relevance for whether or not the conservation site is already managed (e.g., within the Department of Land and Natural Resources System or has a private landowner who is supportive seabird management on their land), the conservation status of the parcel (i.e., if the land is already within a Conservation District or within a protected area such as a Hono O Nā Pali Natural Area Reserve [NAR], State Wilderness Park, or National Park), infrastructure present (e.g., fences, helicopter landing sites, weatherports), and the scope of any existing management activities. This criterion must also evaluate whether the current management regime on the conservation site is compatible with the biological goals and objectives of the KIUC HCP and is sustainable for the life of the permit term (i.e., due to land ownership/status/zoning). Conservation sites with existing covered seabird-directed management activities that are compatible with the biological goals and objectives of the KIUC HCP would score higher than locations without existing management.

Site Practicability

Criterion 9. Predator control operations

Criterion 9 is defined as the factors that limit predator control operations, such as steepness and slope, geographic scale, habitat structure, and substrate that directly affect the practicability of implementing the conservation measures within a conservation site. Sites with steep valleys, dense vegetation, or sites that are very large will all require significantly more effort in terms of predator control and would thus be less practicable than smaller areas or areas with gently undulating terrain and sparser vegetation. In addition, conservation sites where the topography results in fences with open ends (e.g., waterfalls, sheer cliffs) would be ranked lower than sites where fencing can be constructed without open ends (Young 2020).

- 0—Physical site conditions prevent predator control operations
- 1—Low practicability of predator control operations
- 2—Low to moderate practicability of predator control operations
- 3—Moderate practicability of predator control operations
- 4—High practicability of predator control operations
- 5—High practicability of predator control operations and predator eradication practicable if coupled with a predator exclusion fence or if an islet

The predator control operations criterion is multiplied by a factor of two to increase its weight in the total score, given that the physical site conditions can severely affect the feasibility of implementing the conservation measures within a conservation site. If no conservation measures were practicable, this criterion received a score of 0.

Criterion 10. Practicability of terrestrial predator exclusion fence construction

Criterion 10 is defined as the practicability of constructing a terrestrial predator exclusion fence within the conservation site. The factors that determine the practicability of constructing terrestrial predator exclusion fencing is the same as described for predator control operations above (Criterion 9). Installation of terrestrial predator exclusion fencing is challenging because it requires infrastructure (e.g., horizontal mesh skirt) to exclude both small mammals and ungulates. While a site may be practicable to fence, the landowners may not agree to have a predator exclusion fence on their land.

- 0—Terrestrial predator exclusion fence construction is impracticable
- 1—Terrestrial predator exclusion fencing is very difficult to construct in any portion of the site
- 2—Terrestrial predator exclusion fencing construction is practicable over a small portion of the site
- 3—Terrestrial predator exclusion fencing construction is practicable over between a quarter and half of the site
- 4—Terrestrial predator exclusion fencing construction is practicable over majority of site
- 5—Entire site can easily be fenced

The practicability of terrestrial predator exclusion fence construction criterion is multiplied by a factor of two to increase its weight in the total score. Terrestrial predator exclusion fencing will further increase the effectiveness of open management predator control.

Criterion 11. Practicability of ungulate fence construction

Criterion 11 is defined as the practicability of constructing an ungulate exclusion fence within the conservation site.

- 0—Ungulate fencing construction is impracticable
- 1—Ungulate fencing is very difficult to construct in any portion of the site
- 2—Ungulate fencing construction is practicable over a small portion of the site
- 3—Ungulate fencing construction is practicable over between a quarter and half of the site
- 4—Ungulate fencing construction is practicable over majority of site
- 5—Entire site can easily be fenced

The factors that determine the practicability of constructing ungulate fencing include habitat structure, geographic scale, substrate, and topography. Large conservation sites with steep valleys, dense vegetation, drainages, or crumbly substrate would be ranked lower than smaller conservation sites with gently undulating terrain, sparser vegetation, no drainages, and a sturdy substrate. While a site may be practicable to fence, the landowners may not agree to have an ungulate exclusion fence on their land.

Criterion 12. Accessibility

Criterion 12 is defined as the existing site infrastructure (e.g., roads, trails, helicopter landing sites) that determine site accessibility and safety. Transportation to and from the site is a critical consideration, both in terms of the initial setup as well as follow-up monitoring and control efforts once the conservation measure is in place. For example, site infrastructure was reviewed to determine whether a site could be accessed by trails and/or roads not blocked with fencing or gates, or by helicopter.

- 1—Limited accessibility

- 2—Accessible by helicopter or boat, but weather may limit helicopter or boat access at certain times of the year
- 3—Accessible year-round by helicopter
- 4—Accessible by road vehicles, but weather may limit road access at certain time of the year
- 5—Accessible year-round by road vehicles

Conservation sites that are difficult to access, or are not practicable for road vehicles and require special transportation (i.e., helicopters or boats), will result in higher operational costs and may present logistical difficulties (e.g., if access is weather dependent this may result in fewer visits due to flight cancellations). Consequently, remote sites that require helicopters or boats would rank lower than those which can be easily accessed by roads or dirt tracks. Sites that could not be accessed by trails or roads, or by specialized transportation (e.g., no nearby landing site is practicable), were eliminated from further consideration.

Landowner Approval

Criterion 13. Landowner approval

Criterion 13 is defined as the degree of landowner willingness to allow implementation of the conservation measures on their land. For a site to be selected, landowner approval is necessary to implement the conservation measures as planned. The factors to consider under this criterion include: (1) who is the landowner, (2) are there multiple landowners, (3) are there socio-political factors that increase or decrease landowner willingness, and (4) is there political or social opposition to implementation of the conservation measures on the conservation site and if so, is appropriate outreach being conducted?

- 0—Currently no access from landowner
- 1—Low likelihood of landowner approval
- 2—Moderate likelihood of landowner approval
- 3—Initial conversations with landowner have occurred but interest is not known
- 4—Landowner has expressed interest
- 5—Agreement with landowner in place or high likelihood of receiving landowner approval

It is necessary to secure agreements with landowners, whether state or private, for access to a conservation site for at least 30 years so that conservation measures could be implemented for at least the duration of the HCP permit term. Generally, landowner approval is accomplished through coordination and negotiation directly with the landowner. If the landowner is not willing, the conservation site would receive a score of 0 under this criterion.

Anthropogenic Threats

Criterion 14. Anthropogenic threats

Criterion 14 is defined as the presence of powerlines and lights on or adjacent to the site, or on the flyway for which birds would access the site. This criteria also considers if there are: (1) foreseeable development projects in the area (e.g., new housing developments) or (2) impending minimization actions (e.g., the removal of powerlines, use of diverters to reduce strikes, removal or dimming of known problem lights). The site selection process evaluates whether existing and future KIUC infrastructure and surrounding urbanization pose a threat to the covered seabird colony based on the location of the infrastructure and urban development in relation to the colony. This criterion was necessary to avoid compromising the conservation benefits generated by the HCP, especially as the seabird colonies increase in size with implementation of the conservation measures.

- 1—High levels of anthropogenic threats that are unlikely to be minimized
- 2—High level of anthropogenic threats, some of which can be minimized if sufficient funding is available
- 3—Moderate level of anthropogenic threats, some of which can be minimized if sufficient funding is available
- 4—Low level of anthropogenic threats or moderate/high level of anthropogenic threats, most of which can be minimized
- 5—Minimal anthropogenic threats

4A.2.2 Site Selection Scores

A total of 28 sites were evaluated against the 14 criteria listed above. Each criterion was scored separately for Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu), as shown in Tables 4A-1 and 4A-2, respectively. Site selection scores are not included in this appendix for band-rumped storm-petrel (ʻakēʻakē) because, as stated in Section 1.2, *Conservation Site Selection Background*, at present the known impacts on this species are so low they are assumed to be mitigated by the conservation measures for the other two covered seabirds.

Table 4A-1. Conservation Site Selection Scores for Newell's Shearwater (ʻaʻo), Listed by Total Score (Highest to Lowest)

Site Selection Criterion	Criterion 1. Presence of a covered seabird breeding colony	Criterion 2. Presence of a covered seabird breeding colony adjacent to the conservation site	Criterion 3. Presence of a covered species transiting over the site	Criterion 4. Presence of multiple covered species at the conservation site	Criterion 5. Presence of invasive plant species	Criterion 6. Terrestrial predators	Criterion 7. Barn owls	Criterion 8. Existing management activities	Criterion 9. Predator control operations	Criterion 10. Practicability of terrestrial predator exclusion fence construction	Criterion 11. Practicability of ungulate fence construction	Criterion 12. Accessibility	Criterion 13. Landowner approval	Criterion 14. Anthropogenic threats	Total
Max Score	10	5	5	6	5	5	5	10	10	10	10	5	5	5	96
Pōhākea	10	5	5	4	4	4	4	10	8	10	10	3	5	5	87
Upper Limahuli Valley	10	5	5	4	5	4	3	10	8	10	10	3	5	5	87
Honopū—upper valley	10	5	5	4	3	3	3	8	8	10	10	4	3	5	81
Hanakoa	10	5	5	4	3	4	4	10	8	6	10	2	5	5	81
Hanakāpiʻai	10	5	5	4	3	4	4	10	8	6	10	2	5	5	81
North Bog	10	5	4	4	4	4	4	10	8	6	10	2	5	5	81
Upper Mānoa Valley	10	5	5	4	3	3	4	10	8	10	10	3	1	5	81
Pihea	4	5	4	4	4	4	4	10	8	2	10	5	5	5	74
Nuʻalolo Kai	8	5	5	4	3	3	2	8	8	6	8	3	4	5	72
Honopū—lower valley	8	5	5	4	2	3	2	8	8	8	8	3	3	5	72
Nuʻalolo Aina	8	5	5	4	2	3	3	8	8	6	8	3	3	5	71
Lumahaʻi Valley	8	5	5	4	3	1	1	6	8	8	10	3	4	4	70
Hanalei Valley	8	5	5	4	3	1	1	3	8	6	10	4	4	3	65
Waimea Canyon	8	4	5	4	3	1	1	2	8	8	8	5	3	3	63
Awaʻawapuhi	8	5	5	4	2	2	2	6	8	2	8	3	3	5	63

Site Selection Criterion	**Criterion 1. Presence of a covered seabird breeding colony**	**Criterion 2. Presence of a covered seabird breeding colony adjacent to the conservation site**	**Criterion 3. Presence of a covered species transiting over the site**	**Criterion 4. Presence of multiple covered species at the conservation site**	**Criterion 5. Presence of invasive plant species**	**Criterion 6. Terrestrial predators**	**Criterion 7. Barn owls**	**Criterion 8. Existing management activities**	**Criterion 9. Predator control operations**	**Criterion 10. Practicability of terrestrial predator exclusion fence construction**	**Criterion 11. Practicability of ungulate fence construction**	**Criterion 12. Accessibility**	**Criterion 13. Landowner approval**	**Criterion 14. Anthropogenic threats**	**Total**
Waiʻoli	8	5	5	2	2	1	1	10	8	4	8	3	2	3	62
HNP New	6	3	3	4	4	2	2	2	8	6	10	2	4	5	61
Nāmolokama	8	5	5	2	3	2	2	4	8	2	10	1	4	4	60
Lāʻau	8	4	5	4	3	1	2	4	8	2	10	1	3	4	59
Kalalau Valley	8	5	5	4	4	2	1	4	6	4	8	2	1	5	59
Lehua Islet	0	0	2	2	2	5	3	4	10	10	10	2	4	5	59
Miloliʻi	4	2	3	4	2	2	1	2	8	2	6	3	2	5	46
Kāhili	10	3	4	4	2	1	1	4	8	2	4	5	1	1	50
Waipā	0	5	5	2	2	1	1	2	8	4	8	3	2	3	46
Hāʻupu	4	2	3	4	3	1	1	2	8	4	4	3	1	1	41
Koluahonu	2	3	3	2	1	1	1	2	6	6	6	4	1	1	39
Sleeping Giant	4	2	3	2	1	1	1	2	6	2	6	5	1	1	37

Table 4A-2. Conservation Site Selection Scores for Hawaiian Petrel (ʻuaʻu), Listed by Total Score (Highest to Lowest)

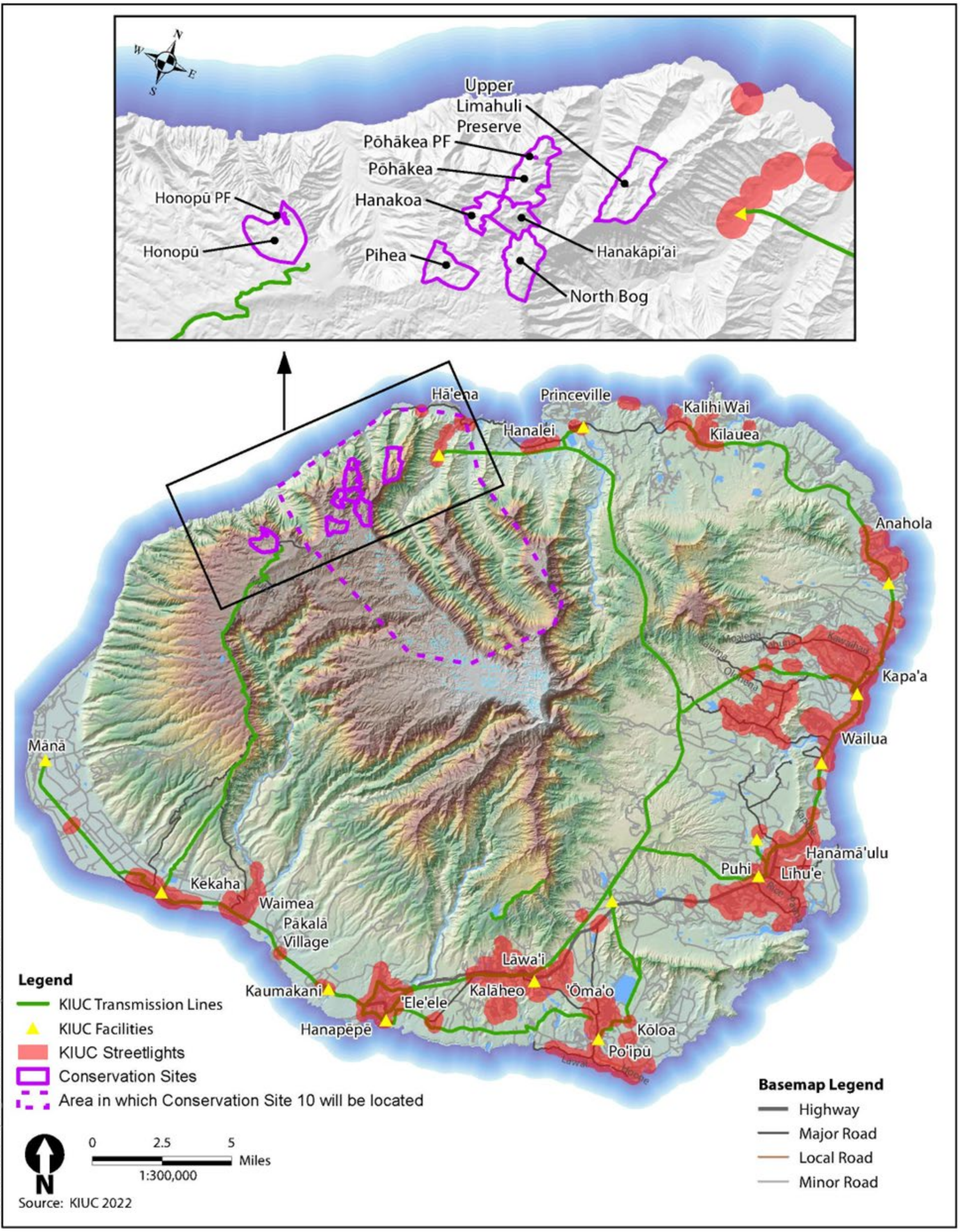
Site Selection Criterion	Criterion 1. Presence of a covered seabird breeding colony	Criterion 2. Presence of a covered seabird breeding colony adjacent to the conservation site	Criterion 3. Presence of a covered species transiting over the site	Criterion 4. Presence of multiple covered species at the conservation site	Criterion 5. Presence of invasive plant species	Criterion 6. Terrestrial predators	Criterion 7. Barn owls	Criterion 8. Existing management activities	Criterion 9. Predator control operations	Criterion 10. Practicability of terrestrial predator exclusion fence construction	Criterion 11. Practicability of ungulate fence construction	Criterion 12. Accessibility	Criterion 13. Landowner approval	Criterion 14. Anthropo-genic threats	Total
Max Score	10	5	5	6	5	5	5	10	10	10	10	5	5	5	96
Pōhākea	10	5	5	4	4	4	4	10	8	10	10	3	5	5	87
Upper Limahuli Preserve	10	5	5	4	5	4	3	10	8	10	10	3	5	5	87
North Bog	10	5	5	4	4	4	4	10	8	6	10	2	5	5	82
Pihea	10	5	5	4	4	4	4	10	8	2	10	5	5	5	81
Hanakoa	10	5	5	4	3	4	4	10	8	6	10	2	5	5	81
Hanakāpiʻai	10	5	5	4	3	4	4	10	8	6	10	2	5	5	81
Upper Mānoa Valley	0	5	5	4	3	3	4	10	8	10	10	3	1	5	71
Lumahaʻi Valley	8	4	5	4	3	1	1	6	8	8	10	3	4	4	69
Hanalei Valley	8	4	5	4	3	1	1	4	8	6	10	4	4	3	65
Lehua Islet	0	0	1	2	1	5	3	10	10	10	10	2	5	5	64
HNP New	6	3	3	4	4	2	2	4	8	6	10	2	4	5	63
Honopū—upper valley	0	0	1	4	3	3	3	8	8	10	8	4	3	5	60
Lāʻau	8	4	5	4	3	1	2	2	8	2	10	1	3	4	57
Nuʻalolo Kai	0	0	1	4	4	3	1	8	8	6	8	3	4	5	55
Honopū—lower valley	0	0	1	4	2	3	2	8	8	8	8	3	3	5	55

Site Selection Criterion	Criterion 1. Presence of a covered seabird breeding colony	Criterion 2. Presence of a covered seabird breeding colony adjacent to the conservation site	Criterion 3. Presence of a covered species transiting over the site	Criterion 4. Presence of multiple covered species at the conservation site	Criterion 5. Presence of invasive plant species	Criterion 6. Terrestrial predators	Criterion 7. Barn owls	Criterion 8. Existing management activities	Criterion 9. Predator control operations	Criterion 10. Practicability of terrestrial predator exclusion fence construction	Criterion 11. Practicability of ungulate fence construction	Criterion 12. Accessibility	Criterion 13. Landowner approval	Criterion 14. Anthropo-genic threats	Total
Waipā	8	5	5	2	2	1	1	2	8	4	8	3	2	3	54
Nuʻalolo Aina	0	0	1	4	2	3	3	6	8	6	8	3	3	3	50
Nāmolokama	0	4	5	2	3	2	2	2	8	2	10	1	4	4	49
Kalalau Valley	0	5	5	4	4	2	1	2	6	4	8	2	1	5	49
Waimea Canyon	0	0	2	4	3	1	1	4	8	8	8	5	2	3	49
Waiʻoli	0	4	5	2	2	1	1	2	8	4	8	3	2	3	45
Awaʻawapuhi	0	0	1	4	2	2	2	4	8	2	8	3	3	5	44
Miloliʻi	0	0	1	4	2	2	1	4	8	2	6	3	2	5	40
Kāhili	4	2	3	4	2	1	1	2	8	2	4	5	1	1	40
Hāʻupu	0	0	2	4	3	1	1	2	8	4	4	3	1	1	34
Koluahonu	0	1	2	2	1	1	1	2	6	6	6	4	1	1	34
Sleeping Giant	0	0	2	2	1	1	1	2	6	2	6	5	1	1	30

4A.2.3 KIUC HCP Conservation Sites

A total of nine conservation sites with the highest site selection scores have been selected for the KIUC HCP. A tenth site is still being evaluated, as described below. All of the selected conservation sites are located within the "no light conservation area" identified by the USFWS on the north shore of Kauaʻi. The majority of the conservation sites that were selected for the KIUC HCP are the same sites where KIUC has been funding predator control and seabird monitoring (and invasive plant species control at two sites) annually since 2011 for the Short-Term HCP and in the interim period between the Short-Term HCP and commencement of this KIUC HCP. This provided KIUC, USFWS, and DOFAW with a large amount of data that was used to determine if management at these sites would continue to benefit the covered seabird species during HCP implementation. Because management had been occurring at these sites for such a long time, it also led to the decision to include these sites as conservation sites for the KIUC HCP rather than replace them with new sites. Other significant factors for selection of the conservation sites in the KIUC HCP included site adjacency and presence of existing fences. The location of all selected conservation sites is shown in Figure 4A-1. Table 4-4 in Chapter 4, *Conservation Strategy*, identifies the total size of each selected conservation site and the estimated number of Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) breeding pairs, and Table 4-5 in Chapter 4, identifies the management action that will be implemented in each conservation site.

KIUC will select a tenth conservation site but the final location of this site is still under evaluation. The final site is identified temporarily as "Conservation Site 10" and will be located at one of four potential sites in the area shown as a dashed purple line on Figure 4A-1 in the northwest corner of Kauaʻi. KIUC is currently evaluating four candidate locations for Conservation Site 10 against the selection criteria listed above. Specifically, Conservation Site 10 will be selected based on the presence of Newell's shearwater (ʻaʻo) colonies and the feasibility of establishing a predator exclusion fence and initiating social attraction. KIUC will select and commit to a specific location and configuration for Conservation Site 10 no later than the end of 2023 and before permit issuance.



Source: KIUC 2022

Figure 4A-1. KIUC HCP Conservation Sites

4A.2.3.1 Upper Limahuli Preserve

The Upper Limahuli Preserve (Preserve) is a 378-acre (ac) (153-hectare [ht]) conservation site ranging in elevation between 1,600 and 3,200 ft (488 and 975 m). The Preserve is owned and managed in perpetuity as a conservation area by the National Tropical Botanical Garden, who have agreed to include the Preserve as a conservation site in the HCP. The Preserve contains numerous steep ridgelines and cliffs that can only be accessed by helicopter.

Based on currently available data, 167 Newell's shearwater (ʻaʻo), 49 Hawaiian petrel (ʻuaʻu), and 38 unidentified burrows have been located at the Preserve (Raine et al. 2022) and the population estimate for the species within the site is between 498 and 617 Newell's shearwater (ʻaʻo) breeding pairs and between 112 and 135 Hawaiian petrel (ʻuaʻu) breeding pairs (Raine 2022). Tracking of nesting adults indicates that most birds arrive and depart from the colony over the closely adjacent ocean, with only a few tracks showing birds flying high over existing powerlines (Raine et al. 2017). In 2009, work was completed on an ungulate exclusion fence that now protects the entire Preserve from ungulates. Other infrastructure includes several helicopter landing zones, two weatherports to support personnel and operations, and an extensive network of trails.

KIUC has funded predator control and monitoring efforts at this location since 2011, with predator control operations increasing in scope and personnel in recent years. Ongoing management activities at this site include invasive plant removal, maintenance of ungulate fencing, monitoring to keep the site ungulate-free, predator control (rats, cats, pigs, and barn owl), acoustic assessment of seabird activity, auditory surveys, and estimation of annual seabird reproductive success through nest monitoring.

The Preserve was included as a conservation site because it had a willing landowner and significant populations of both covered seabirds (particularly Newell's shearwater [ʻaʻo]). The large size of the site also suggests that the populations of both species can be expanded into new portions of the Preserve using social attraction techniques. The conservation site was also selected because of the substantial existing infrastructure, including the extensive ungulate exclusion fence that has been maintained successfully since 2009.

4A.2.3.2 North Bog

North Bog is part of the Hono O Nā Pali NAR, managed by DOFAW. DOFAW has approved inclusion of North Bog as a conservation site in the HCP. The North Bog conservation site, encompassing 348 ac (141 ht), is a site where seabird management has been ongoing. Site access for fence construction, predator control, and monitoring activities is by helicopter only, although in emergencies there is a trail to hike out. Given the site's remote location on the edge of Wainiha Valley, powerline collisions and light attraction are a lower risk to breeding birds. Site infrastructure consists of a helicopter landing zone, a weatherport to support personnel and operations, and an approximately 2-ac (0.8-ht) ungulate exclusion fence installed to protect rare native plants. A new ungulate exclusion fence was constructed by DOFAW in 2014 to protect the Hono O Nā Pali NAR. This fence extends from the Pihea lookout to the Kilohana lookout, preventing ingress by pigs from the Alakaʻi Swamp. A second ungulate exclusion fence was constructed in 2017 extending northward from the Pihea lookout, preventing ingress by pigs from the Kalalau Valley and further wing fences have been built on the Nā Pali Coast for the same reason.

Based on currently available data, a total of 2 Newell's shearwater (ʻaʻo), 235 Hawaiian petrel (ʻuaʻu), and 39 unidentified burrows have been located (Raine et al. 2022). The population estimate for the two species within the site is between 66 and 80 Newell's shearwater (ʻaʻo) breeding pairs and between 880 and 1,261 Hawaiian petrel (ʻuaʻu) breeding pairs (Raine 2022).

Current seabird management actions include nest site monitoring, predator control (rats, cats, pigs, and barn owl), acoustic assessment of seabird activity, and estimation of annual seabird reproductive success. KIUC has funded predator control and monitoring efforts at this location since 2015.

4A.2.3.3 Pōhākea

Pōhākea is part of the Hono O Nā Pali NAR, managed by DOFAW. DOFAW has approved inclusion of Pōhākea as a conservation site in the HCP. Located in the northeastern corner of the Hono O Nā Pali NAR, Pōhākea is a 363-ac (147-ht) site bordered to the east by the Hanakāpiʻai drainage and to the south by the Hanakāpiʻai conservation site (Figure 4A-1). The Pōhākea site is on the Nā Pali Coast and as such is at low risk from existing powerlines and coastal lights. Site access for predator control and monitoring activities is by helicopter only.

Pōhākea is considered an important conservation site for seabirds. Based on currently available data, a total of 58 Newell's shearwater (ʻaʻo), 67 Hawaiian petrel (ʻuaʻu), and 33 unidentified burrows have been located (Raine et al. 2022). The population estimate for the two species within the site is between 290 and 464 Newell's shearwater (ʻaʻo) breeding pairs and between 161 and 611 Hawaiian petrel (ʻuaʻu) breeding pairs (Raine 2022). Current seabird conservation activities include nest monitoring, predator control (rats, cats, pigs, and barn owls), acoustic assessment of seabird activity, and estimation of annual seabird reproductive success. All the Pōhākea conservation site (i.e., all 363 ac [146.9 ht]) supports potential habitat for one or both of the covered seabirds (Troy et al. 2014, 2017). Construction of ungulate fencing associated with this conservation area has already been completed by the Hono O Nā Pali NAR program. KIUC has funded predator control and monitoring efforts at this location in recent years.

4A.2.3.4 Pōhākea PF

Pōhākea PF (which stands for predator exclusion fence) is a small 0.34-ac (0.14-ht) area located within the northern portion of the larger Pōhākea conservation site, described above in Section 2.3.4, *Pōhākea*. A 0.34-ac (0.14-ht) in length predator exclusion fence was created by DOFAW and DOFAW partners around the site in 2021, and 50 artificial burrows and a sound system will be deployed inside the fence area in early 2022 (prior to the start of the breeding season) to attract Newell's shearwater (ʻaʻo) to the fully protected area. The site was chosen for several reasons—(i) close proximity to a large breeding cluster of Newell's shearwater (ʻaʻo), (ii) located on a flyway for Newell's shearwater (ʻaʻo) transiting overhead to colonies in the back of Wainiha Valley, (iii) a steep bowl topography to allow nesting shearwaters to take off from without colliding with the fence and (iv) a high proportion of invasive vegetation (especially Himalayan ginger [kāhili ginger]), meaning that burrows could be dug into the site without disturbing significant amounts of native vegetation and no rare plant species. KIUC will take control of the predator exclusion fenced area in 2022 and maintain and manage it as a conservation site in accordance with this HCP.

4A.2.3.5 Honopū (and Honopū PF)

The Honopū conservation site is part of the Nā Pali Coast State Wilderness Park managed by the Division of State Parks. Approval from State Parks and DOFAW is pending for inclusion of this conservation site in the HCP. Development of this site involves a large ungulate fence and a smaller predator exclusion fence located within the ungulate fence, the establishment of predator control in both fenced areas and the establishment of social attraction in the predator exclusion fence. It can be accessed via several trails from the main Kokeʻe Road and has a scattered trail system and two helicopter landing zones. No weatherports or other infrastructure are currently present. Site access for fence maintenance, predator control, and covered species monitoring is predominantly on foot. The conservation site is located along the edge of the Kalalau Valley and the risk from powerlines and coastal lights is minimal.[3]

A 2.7-mile (4.4-km) ungulate fence was constructed by the State of Hawaiʻi and partners which tied off at the steep, impassable cliffs of Honopū Valley, resulting in a conservation site of 239 ac (97 ht). Within the Honopū conservation site a total of four Newell's shearwater (ʻaʻo) burrows have been located (Raine pers. comm.), two of which were active in 2020. While the conservation site contains suitable breeding habitat for Newell's shearwater (ʻaʻo), decades of predation from cats, rats, pigs, and barn owl have restricted the breeding population predominantly to the inaccessible Nā Pali cliffs. Therefore, while the current breeding population of Newell's shearwater (ʻaʻo) within the ungulate fenced area is 90 to 92 breeding pairs, the potential population estimate for the site is 396 to 487 pairs. Hawaiian petrels (ʻuaʻu) are not known to breed in this area, although small numbers transit over. Band-rumped storm-petrels (ʻakēʻakē) breed in good numbers on the cliffs adjacent to the conservation site, and this species is also often seen flying over the area. KIUC began funding and implementing predator control and seabird monitoring at Honopū in 2022.

In addition, a 3.3-ac (1.3-ht) predator exclusion fence and social attraction site (i.e., Honopū PF) is currently being developed by the State and partners inside the ungulate fence area, covering the northern edge of the conservation site overlooking the cliffs of Honopū Valley. In April 2021, 35 artificial burrows were installed in one section of the site for band-rumped storm-petrel (ʻakēʻakē) and 29 artificial burrows for both Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) in another section. The proximity of this conservation site to large breeding colonies of both Newell's shearwater (ʻaʻo) and band-rumped storm-petrel (ʻakēʻakē) in the cliffs of Honopū Valley make this an ideal social attraction site for these two species.

4A.2.3.6 Pihea

Pihea is a 515-ac (208-ht) site that is part of the Nā Pali Coast State Wilderness Park managed by the Division of State Parks. State Parks has approved inclusion of this conservation site in the HCP. The Pihea conservation site can be accessed from the Pihea trail from Puʻu O Kila lookout, a scattered trail system, and there are two helicopter landing zones. No weatherports or other infrastructure are currently present. Several sections of strategic ungulate fence spanning 1.2 miles (1.9 km) have been installed by the Hono O Nā Pali NAR since 2014, resulting in regional conservation benefits that extend to the Pihea conservation site. The site is located along the edge of the Kalalau Valley and the risk from powerlines and coastal lights is minimal.[4] Site access for fence construction, maintenance, and predator control and monitoring is predominantly by helicopter.

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[3] The site sits below the Kokeʻe Air Force Station, where a large fallout event of Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) occurred in 2015. The Air Force Station has since changed its lights and—as long as this lighting protocol is maintained—presents minimal fallout risk to birds breeding in this area.

[4] The site does point towards the Kōkeʻe Air Force Station, where a large fallout event of Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) occurred in 2015. The Air Force Station has since changed its lights and—as long as this lighting protocol is maintained—now presents minimal fallout risk to birds breeding in this area.

Based on currently available data, a total of 144 Hawaiian petrel (ʻuaʻu) burrows and 27 unidentified burrows have been located (Raine et al. 2022) and the population estimate for this species within the site is between 645 and 815 Hawaiian petrel (ʻuaʻu) breeding pairs (Raine 2022). The lack of a robust Newell's shearwater (ʻaʻo) population at Pihea is likely because most Newell's shearwaters (ʻaʻo) nest along the edge of Kalalau Valley, which cannot be accessed safely for monitoring because of the steepness of the terrain.

4A.2.3.7 Hanakoa

Hanakoa is part of the Hono O Nā Pali NAR managed by DOFAW. DOFAW has approved inclusion of Hanakoa as a conservation site in the HCP. The Hanakoa conservation site encompasses 186 ac (75 ht) within the Hono O Nā Pali NAR and is situated immediately adjacent and to the west of the Pōhākea and Hanakāpiʻai conservation areas (Figure 4A-1). The Hanakoa conservation site is in the interior mountainous region and thus at limited risk from existing powerlines and coastal lights. Site access for predator control and monitoring activities is by helicopter only.

Hanakoa is considered an important conservation site for seabirds. To date a total of 2 Newell's shearwater (ʻaʻo), 176 Hawaiian petrel (ʻuaʻu), and 36 unidentified burrows have been located (Raine et al. 2022). The population estimate for the two species within this site is between 45 and 74 Newell's shearwater (ʻaʻo) breeding pairs and between 171 and 455 Hawaiian petrel (ʻuaʻu) breeding pairs (Raine 2022).

Construction of ungulate fence associated with this conservation area was completed by the Hono O Nā Pali NAR program. Funding for predator control efforts, between 2016 and 2019 was secured through the National Fish and Wildlife Foundation (via American Bird Conservancy) by D. E. Shaw Renewable Investments, LLC in partial fulfillment of Hawaiian petrel (ʻuaʻu) mitigation obligations under the HCP for Kawailoa Wind. KIUC began funding predator control and seabird monitoring at Hanakoa in 2021.

4A.2.3.8 Hanakāpiʻai

Hanakāpiʻai is part of the Hono O Nā Pali NAR managed by DOFAW. DOFAW approved inclusion of Hanakāpiʻai as a conservation site in the HCP. Bordered by North Bog to the east, Pōhākea to the west, and Hanakoa to the south (Figure 4A-1), Hanakāpiʻai is considered an important conservation site for seabirds, especially Hawaiian petrel (ʻuaʻu). The conservation site contains numerous steep ridgelines and cliffs that can only be accessed by helicopter. The Hanakāpiʻai site has three landing zones for helicopters and a scattered trail system. The conservation site is in the interior of the Hono O Nā Pali NAR and thus at limited risk from artificial lights and powerlines.

The Hanakāpiʻai conservation site encompasses 187 ac (76 ht) of potential habitat. To date a total of 19 Newell's shearwater (ʻaʻo), 316 Hawaiian petrel (ʻuaʻu), and 65 unidentified burrows have been located (Raine et al. 2022). The population estimate for the two species within this site is between 76 and 85 Newell's shearwater (ʻaʻo) breeding pairs and between 289 and 398 Hawaiian petrel (ʻuaʻu) breeding pairs (Raine 2022).

Construction of ungulate fencing associated with this conservation area was completed by the Hono O Nā Pali NAR program and funding for predator control efforts was initially undertaken through funding from the National Fish and Wildlife Foundation (via American Bird Conservancy) between 2016 and 2019 and via D. E. Shaw Renewable Investments, LLC in partial fulfillment of Hawaiian petrel (ʻuaʻu) mitigation obligations under the HCP for Kawailoa Wind, in 2020. KIUC began funding and implementing predator control and seabird monitoring at Hanakāpiʻai in 2021.

4A.3 References

4A.3.1 Published Sources

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4A.3.2 Personal Communication

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Appendix 4B

KIUC Minimization Projects

Span Number	Span Name	Distance (miles)	Minimization Type	Year
1	Mana Substation to WKEP	0.0526	69kV removal	2022
1	Mana Substation to WKEP	0.0526	Static wire removal	2022
2	Mana Substation to WKEP	0.0734	69kV removal	2022
2	Mana Substation to WKEP	0.0734	Static wire removal	2022
3	Mana Substation to WKEP	0.0757	69kV removal	2022
3	Mana Substation to WKEP	0.0757	Static wire removal	2022
4	Mana Substation to WKEP	0.0834	69kV removal	2022
4	Mana Substation to WKEP	0.0834	Static wire removal	2022
5	Mana Substation to WKEP	0.0807	69kV removal	2022
5	Mana Substation to WKEP	0.0807	Static wire removal	2022
6	Mana Substation to WKEP	0.0771	69kV removal	2022
6	Mana Substation to WKEP	0.0771	Static wire removal	2022
7	Mana Substation to WKEP	0.0754	69kV removal	2022
7	Mana Substation to WKEP	0.0754	Static wire removal	2022
8	Mana Substation to WKEP	0.0477	69kV removal	2022
8	Mana Substation to WKEP	0.0477	Static wire removal	2022
9	Mana Substation to WKEP	0.0459	69kV removal	2022
9	Mana Substation to WKEP	0.0459	Static wire removal	2022
10	Mana Substation to WKEP	0.0462	69kV removal	2022
10	Mana Substation to WKEP	0.0462	Static wire removal	2022
11	Mana Substation to WKEP	0.0477	69kV removal	2022
11	Mana Substation to WKEP	0.0477	Static wire removal	2022
12	Mana Substation to WKEP	0.0468	69kV removal	2022
12	Mana Substation to WKEP	0.0468	Static wire removal	2022
13	Mana Substation to WKEP	0.0375	69kV removal	2022
13	Mana Substation to WKEP	0.0375	Static wire removal	2022
14	Mana Substation to WKEP	0.0505	69kV removal	2022
14	Mana Substation to WKEP	0.0505	Static wire removal	2022
15	Mana Substation to WKEP	0.0513	69kV removal	2022
15	Mana Substation to WKEP	0.0513	Static wire removal	2022
16	Mana Substation to WKEP	0.0505	69kV removal	2022
16	Mana Substation to WKEP	0.0505	Static wire removal	2022
17	Mana Substation to WKEP	0.0666	69kV removal	2022
17	Mana Substation to WKEP	0.0666	Static wire removal	2022

18	Mana Substation to WKEP	0.0522	69kV removal	2022
18	Mana Substation to WKEP	0.0522	Static wire removal	2022
19	Mana Substation to WKEP	0.0339	69kV removal	2022
19	Mana Substation to WKEP	0.0339	Static wire removal	2022
20	Mana Substation to WKEP	0.0680	69kV removal	2022
20	Mana Substation to WKEP	0.0680	Static wire removal	2022
21	Mana Substation to WKEP	0.0725	69kV removal	2022
21	Mana Substation to WKEP	0.0725	Static wire removal	2022
22	Mana Substation to WKEP	0.0394	69kV removal	2022
22	Mana Substation to WKEP	0.0394	Static wire removal	2022
23	Mana Substation to WKEP	0.0718	69kV removal	2022
23	Mana Substation to WKEP	0.0718	Static wire removal	2022
24	Mana Substation to WKEP	0.0724	69kV removal	2022
24	Mana Substation to WKEP	0.0724	Static wire removal	2022
25	Mana Substation to WKEP	0.0738	69kV removal	2022
25	Mana Substation to WKEP	0.0738	Static wire removal	2022
26	Mana Substation to WKEP	0.0730	69kV removal	2022
26	Mana Substation to WKEP	0.0730	Static wire removal	2022
27	Mana Substation to WKEP	0.0691	69kV removal	2022
27	Mana Substation to WKEP	0.0691	Static wire removal	2022
28	Mana Substation to WKEP	0.0799	69kV removal	2022
28	Mana Substation to WKEP	0.0799	Static wire removal	2022
29	Mana Substation to WKEP	0.0759	69kV removal	2022
29	Mana Substation to WKEP	0.0759	Static wire removal	2022
30	WKEP to Kekaha Substation	0.0450	Diverter installation (Reflective)	2021
31	WKEP to Kekaha Substation	0.0482	Diverter installation (Reflective)	2021
32	WKEP to Kekaha Substation	0.0741	Diverter installation (Reflective)	2021
33	WKEP to Kekaha Substation	0.0397	Diverter installation (Reflective)	2021
34	WKEP to Kekaha Substation	0.0551	Diverter installation (Reflective)	2021
35	WKEP to Kekaha Substation	0.0545	Diverter installation (Reflective)	2021
36	WKEP to Kekaha Substation	0.0545	Diverter installation (Reflective)	2021
37	WKEP to Kekaha Substation	0.0572	Diverter installation (Reflective)	2021
38	WKEP to Kekaha Substation	0.0748	Diverter installation (Reflective)	2021
39	WKEP to Kekaha Substation	0.0732	Diverter installation (Reflective)	2021
40	WKEP to Kekaha Substation	0.0733	Diverter installation (Reflective)	2021

41	WKEP to Kekaha Substation	0.0731	Diverter installation (Reflective)	2021
42	WKEP to Kekaha Substation	0.0738	Diverter installation (Reflective)	2021
43	WKEP to Kekaha Substation	0.0744	Diverter installation (Reflective)	2021
44	WKEP to Kekaha Substation	0.0361	Diverter installation (Reflective)	2021
45	WKEP to Kekaha Substation	0.0682	Diverter installation (Reflective)	2021
46	WKEP to Kekaha Substation	0.0775	Diverter installation (Reflective)	2021
47	WKEP to Kekaha Substation	0.0793	Diverter installation (Reflective)	2021
48	WKEP to Kekaha Substation	0.0795	Diverter installation (Reflective)	2021
49	WKEP to Kekaha Substation	0.0792	Diverter installation (Reflective)	2021
50	WKEP to Kekaha Substation	0.0811	Diverter installation (Reflective)	2021
51	WKEP to Kekaha Substation	0.0366	Diverter installation (Reflective)	2021
52	WKEP to Kekaha Substation	0.0750	Diverter installation (Reflective)	2021
53	WKEP to Kekaha Substation	0.0742	Diverter installation (Reflective)	2021
54	WKEP to Kekaha Substation	0.0728	Diverter installation (Reflective)	2021
55	WKEP to Kekaha Substation	0.0744	Diverter installation (Reflective)	2021
56	WKEP to Kekaha Substation	0.0723	Diverter installation (Reflective)	2021
57	WKEP to Kekaha Substation	0.0750	Diverter installation (Reflective)	2021
58	WKEP to Kekaha Substation	0.0383	Diverter installation (Reflective)	2021
59	WKEP to Kekaha Substation	0.0758	Diverter installation (Reflective)	2021
60	WKEP to Kekaha Substation	0.0759	Diverter installation (Reflective)	2021
61	WKEP to Kekaha Substation	0.0577	Diverter installation (Reflective)	2021
62	WKEP to Kekaha Substation	0.0545	Diverter installation (Reflective)	2021
63	WKEP to Kekaha Substation	0.0660	Diverter installation (Reflective)	2021
64	WKEP to Kekaha Substation	0.0652	Diverter installation (Reflective)	2021
65	WKEP to Kekaha Substation	0.0655	Diverter installation (Reflective)	2021
66	WKEP to Kekaha Substation	0.0647	Diverter installation (Reflective)	2021
67	WKEP to Kekaha Substation	0.0371	Diverter installation (Reflective)	2021
68	WKEP to Kekaha Substation	0.0769	Diverter installation (Reflective)	2021
69	WKEP to Kekaha Substation	0.0751	Diverter installation (Reflective)	2021
70	WKEP to Kekaha Substation	0.0744	Diverter installation (Reflective)	2021
71	WKEP to Kekaha Substation	0.0734	Diverter installation (Reflective)	2021
72	WKEP to Kekaha Substation	0.0758	Diverter installation (Reflective)	2021
73	WKEP to Kekaha Substation	0.0368	Diverter installation (Reflective)	2021
74	WKEP to Kekaha Substation	0.0764	Diverter installation (Reflective)	2021
75	WKEP to Kekaha Substation	0.0732	Diverter installation (Reflective)	2021

76	WKEP to Kekaha Substation	0.0731	Diverter installation (Reflective)	2021
77	WKEP to Kekaha Substation	0.0753	Diverter installation (Reflective)	2021
78	WKEP to Kekaha Substation	0.1202	Diverter installation (Reflective)	2021
79	WKEP to Kekaha Substation	0.0625	Diverter installation (Reflective)	2021
80	WKEP to Kekaha Substation	0.0755	Diverter installation (Reflective)	2021
81	WKEP to Kekaha Substation	0.0656	Diverter installation (Reflective)	2021
82	WKEP to Kekaha Substation	0.0421	Diverter installation (Reflective)	2021
83	WKEP to Kekaha Substation	0.0539	Diverter installation (Reflective)	2021
84	WKEP to Kekaha Substation	0.0423	Diverter installation (Reflective)	2021
85	WKEP to Kekaha Substation	0.0413	Diverter installation (Reflective)	2021
86	WKEP to Kekaha Substation	0.0801	Diverter installation (Reflective)	2021
87	WKEP to Kekaha Substation	0.0589	Diverter installation (Reflective)	2021
88	WKEP to Kekaha Substation	0.0685	Diverter installation (Reflective)	2021
89	WKEP to Kekaha Substation	0.0659	Diverter installation (Reflective)	2021
90	WKEP to Kekaha Substation	0.0630	Diverter installation (Reflective)	2021
91	WKEP to Kekaha Substation	0.0665	Diverter installation (Reflective)	2021
92	WKEP to Kekaha Substation	0.0654	Diverter installation (Reflective)	2021
93	WKEP to Kekaha Substation	0.0388	Diverter installation (Reflective)	2021
94	WKEP to Kekaha Substation	0.0393	Diverter installation (Reflective)	2021
95	WKEP to Kekaha Substation	0.0264	Diverter installation (Reflective)	2021
96	WKEP to Kekaha Substation	0.0616	Diverter installation (Reflective)	2021
97	WKEP to Kekaha Substation	0.0547	Diverter installation (Reflective)	2021
98	WKEP to Kekaha Substation	0.0636	Diverter installation (Reflective)	2021
99	WKEP to Kekaha Substation	0.0310	Diverter installation (Reflective)	2021
100	WKEP to Kekaha Substation	0.0539	Diverter installation (Reflective)	2021
101	WKEP to Kekaha Substation	0.0769	Diverter installation (Reflective)	2021
102	WKEP to Kekaha Substation	0.0655	Diverter installation (Reflective)	2021
103	WKEP to Kekaha Substation	0.0750	Diverter installation (Reflective)	2021
104	WKEP to Kekaha Substation	0.0727	Diverter installation (Reflective)	2022
105	WKEP to Kekaha Substation	0.0432	Diverter installation (Reflective)	2021
106	WKEP to Kekaha Substation	0.0367	Diverter installation (Reflective)	2021
107	WKEP to Kekaha Substation	0.0542	Diverter installation (Reflective)	2021
108	WKEP to Kekaha Substation	0.0596	Diverter installation (Reflective)	2021
109	WKEP to Kekaha Substation	0.0553	Diverter installation (Reflective)	2021
110	WKEP to Kekaha Substation	0.0592	Diverter installation (Reflective)	2021

111	WKEP to Kekaha Substation	0.0567	Diverter installation (Reflective)	2021
112	WKEP to Kekaha Substation	0.0505	Diverter installation (Reflective)	2021
113	WKEP to Kekaha Substation	0.0259	Diverter installation (Reflective)	2021
116	Kekaha Substation to Waimea Bridge	0.0788	Diverter installation (Reflective)	2022
116	Kekaha Substation to Waimea Bridge	0.0788	Static wire removal	2022
117	Kekaha Substation to Waimea Bridge	0.0670	Diverter installation (Reflective)	2021
117	Kekaha Substation to Waimea Bridge	0.0670	Static wire removal	2021
118	Kekaha Substation to Waimea Bridge	0.0543	Diverter installation (Reflective)	2021
118	Kekaha Substation to Waimea Bridge	0.0543	Static wire removal	2021
119	Kekaha Substation to Waimea Bridge	0.0533	Diverter installation (Reflective)	2022
119	Kekaha Substation to Waimea Bridge	0.0533	Static wire removal	2021
120	Kekaha Substation to Waimea Bridge	0.0584	Diverter installation (Reflective)	2022
120	Kekaha Substation to Waimea Bridge	0.0584	Static wire removal	2021
121	Kekaha Substation to Waimea Bridge	0.0335	Diverter installation (Reflective)	2022
121	Kekaha Substation to Waimea Bridge	0.0335	Static wire removal	2021
122	Kekaha Substation to Waimea Bridge	0.0387	Diverter installation (Reflective)	2022
122	Kekaha Substation to Waimea Bridge	0.0387	Static wire removal	2021
123	Kekaha Substation to Waimea Bridge	0.0388	Diverter installation (Reflective)	2022
123	Kekaha Substation to Waimea Bridge	0.0388	Static wire removal	2021
124	Kekaha Substation to Waimea Bridge	0.0439	Diverter installation (Reflective)	2022
124	Kekaha Substation to Waimea Bridge	0.0439	Static wire removal	2021
125	Kekaha Substation to Waimea Bridge	0.0331	Diverter installation (Reflective)	2022
125	Kekaha Substation to Waimea Bridge	0.0331	Static wire removal	2021
126	Kekaha Substation to Waimea Bridge	0.0490	Diverter installation (Reflective)	2022
126	Kekaha Substation to Waimea Bridge	0.0490	Static wire removal	2021
127	Kekaha Substation to Waimea Bridge	0.0531	Diverter installation (Reflective)	2022
127	Kekaha Substation to Waimea Bridge	0.0531	Static wire removal	2021
128	Kekaha Substation to Waimea Bridge	0.0237	Diverter installation (Reflective)	2022
128	Kekaha Substation to Waimea Bridge	0.0237	Static wire removal	2021
129	Kekaha Substation to Waimea Bridge	0.0236	Diverter installation (Reflective)	2022
129	Kekaha Substation to Waimea Bridge	0.0236	Static wire removal	2021
130	Kekaha Substation to Waimea Bridge	0.0281	Diverter installation (Reflective)	2022
130	Kekaha Substation to Waimea Bridge	0.0281	Static wire removal	2021
131	Kekaha Substation to Waimea Bridge	0.0312	Diverter installation (Reflective)	2022
131	Kekaha Substation to Waimea Bridge	0.0312	Static wire removal	2021

132	Kekaha Substation to Waimea Bridge	0.0546	Diverter installation (Reflective)	2022
132	Kekaha Substation to Waimea Bridge	0.0546	Static wire removal	2021
133	Kekaha Substation to Waimea Bridge	0.0609	Diverter installation (Reflective)	2022
133	Kekaha Substation to Waimea Bridge	0.0609	Static wire removal	2021
134	Kekaha Substation to Waimea Bridge	0.0729	Diverter installation (Reflective)	2022
134	Kekaha Substation to Waimea Bridge	0.0729	Static wire removal	2021
135	Kekaha Substation to Waimea Bridge	0.0788	Diverter installation (Reflective)	2022
135	Kekaha Substation to Waimea Bridge	0.0788	Static wire removal	2021
136	Kekaha Substation to Waimea Bridge	0.0741	Diverter installation (Reflective)	2022
136	Kekaha Substation to Waimea Bridge	0.0741	Static wire removal	2021
137	Kekaha Substation to Waimea Bridge	0.0757	Diverter installation (Reflective)	2022
137	Kekaha Substation to Waimea Bridge	0.0757	Static wire removal	2021
138	Kekaha Substation to Waimea Bridge	0.0760	Diverter installation (Reflective)	2022
138	Kekaha Substation to Waimea Bridge	0.0760	Static wire removal	2021
139	Kekaha Substation to Waimea Bridge	0.0738	Diverter installation (Reflective)	2022
139	Kekaha Substation to Waimea Bridge	0.0738	Static wire removal	2021
140	Kekaha Substation to Waimea Bridge	0.0775	Diverter installation (Reflective)	2022
140	Kekaha Substation to Waimea Bridge	0.0775	Static wire removal	2021
141	Kekaha Substation to Waimea Bridge	0.0748	Diverter installation (Reflective)	2022
141	Kekaha Substation to Waimea Bridge	0.0748	Static wire removal	2021
142	Kekaha Substation to Waimea Bridge	0.0766	Diverter installation (Reflective)	2022
142	Kekaha Substation to Waimea Bridge	0.0766	Static wire removal	2021
143	Kekaha Substation to Waimea Bridge	0.0817	Diverter installation (Reflective)	2022
143	Kekaha Substation to Waimea Bridge	0.0817	Static wire removal	2021
144	Kekaha Substation to Waimea Bridge	0.0692	Diverter installation (Reflective)	2022
144	Kekaha Substation to Waimea Bridge	0.0692	Static wire removal	2021
145	Kekaha Substation to Waimea Bridge	0.0760	Diverter installation (Reflective)	2022
145	Kekaha Substation to Waimea Bridge	0.0760	Static wire removal	2021
146	Kekaha Substation to Waimea Bridge	0.0766	Diverter installation (Reflective)	2022
146	Kekaha Substation to Waimea Bridge	0.0766	Static wire removal	2021
147	Kekaha Substation to Waimea Bridge	0.0731	Diverter installation (Reflective)	2022
147	Kekaha Substation to Waimea Bridge	0.0731	Static wire removal	2021
148	Kekaha Substation to Waimea Bridge	0.0725	Diverter installation (Reflective)	2022
148	Kekaha Substation to Waimea Bridge	0.0725	Static wire removal	2021
149	Kekaha Substation to Waimea Bridge	0.0817	Diverter installation (Reflective)	2022

149	Kekaha Substation to Waimea Bridge	0.0817	Static wire removal	2021
150	Kekaha Substation to Waimea Bridge	0.0846	Diverter installation (Reflective)	2022
150	Kekaha Substation to Waimea Bridge	0.0846	Static wire removal	2021
151	Kekaha Substation to Waimea Bridge	0.0703	Diverter installation (Reflective)	2022
151	Kekaha Substation to Waimea Bridge	0.0703	Static wire removal	2021
152	Kekaha Substation to Waimea Bridge	0.0762	Diverter installation (Reflective)	2022
152	Kekaha Substation to Waimea Bridge	0.0762	Static wire removal	2021
153	Kekaha Substation to Waimea Bridge	0.0757	Diverter installation (Reflective)	2022
153	Kekaha Substation to Waimea Bridge	0.0757	Static wire removal	2021
154	Kekaha Substation to Waimea Bridge	0.0735	Diverter installation (Reflective)	2022
154	Kekaha Substation to Waimea Bridge	0.0735	Static wire removal	2021
155	Kekaha Substation to Waimea Bridge	0.0585	Diverter installation (Reflective)	2022
155	Kekaha Substation to Waimea Bridge	0.0585	Static wire removal	2021
156	Kekaha Substation to Waimea Bridge	0.0587	Diverter installation (Reflective)	2022
156	Kekaha Substation to Waimea Bridge	0.0587	Static wire removal	2021
157	Kekaha Substation to Waimea Bridge	0.0423	Diverter installation (Reflective)	2022
157	Kekaha Substation to Waimea Bridge	0.0423	Static wire removal	2021
158	Kekaha Substation to Waimea Bridge	0.0565	Diverter installation (Reflective)	2022
158	Kekaha Substation to Waimea Bridge	0.0565	Static wire removal	2021
159	Kekaha Substation to Waimea Bridge	0.0579	Diverter installation (Reflective)	2022
159	Kekaha Substation to Waimea Bridge	0.0579	Static wire removal	2021
160	Kekaha Substation to Waimea Bridge	0.0528	Diverter installation (Reflective)	2022
160	Kekaha Substation to Waimea Bridge	0.0528	Static wire removal	2021
161	Kekaha Substation to Waimea Bridge	0.0557	Static wire removal	2021
162	Kekaha Substation to Waimea Bridge	0.0245	Diverter installation (Reflective)	2022
162	Kekaha Substation to Waimea Bridge	0.0245	Static wire removal	2021
163	Kekaha Substation to Waimea Bridge	0.0285	Diverter installation (Reflective)	2022
163	Kekaha Substation to Waimea Bridge	0.0285	Static wire removal	2021
164	Kekaha Substation to Waimea Bridge	0.0558	Diverter installation (Reflective)	2022
164	Kekaha Substation to Waimea Bridge	0.0558	Static wire removal	2021
165	Kekaha Substation to Waimea Bridge	0.0608	Diverter installation (Reflective)	2022
165	Kekaha Substation to Waimea Bridge	0.0608	Static wire removal	2021
166	Kekaha Substation to Waimea Bridge	0.0383	Diverter installation (Reflective)	2022
166	Kekaha Substation to Waimea Bridge	0.0383	Static wire removal	2021
167	Kekaha Substation to Waimea Bridge	0.0329	Diverter installation (Reflective)	2022

167	Kekaha Substation to Waimea Bridge	0.0329	Static wire removal	2021
168	Kekaha Substation to Waimea Bridge	0.0342	Diverter installation (Reflective)	2022
168	Kekaha Substation to Waimea Bridge	0.0342	Static wire removal	2021
169	Kekaha Substation to Waimea Bridge	0.0292	Diverter installation (Reflective)	2022
169	Kekaha Substation to Waimea Bridge	0.0292	Static wire removal	2021
170	Kekaha Substation to Waimea Bridge	0.0333	Diverter installation (Reflective)	2022
170	Kekaha Substation to Waimea Bridge	0.0333	Static wire removal	2021
171	Kekaha Substation to Waimea Bridge	0.0582	Diverter installation (Reflective)	2022
171	Kekaha Substation to Waimea Bridge	0.0582	Static wire removal	2021
172	Kekaha Substation to Waimea Bridge	0.0461	Diverter installation (Reflective)	2022
172	Kekaha Substation to Waimea Bridge	0.0461	Static wire removal	2021
173	Kekaha Substation to Waimea Bridge	0.0919	Diverter installation (Reflective)	2022
173	Kekaha Substation to Waimea Bridge	0.0919	Static wire removal	2021
174	Waimea Bridge to Kaumakani	0.0781	Diverter installation (Reflective)	2022
174	Waimea Bridge to Kaumakani	0.0781	Static wire removal	2021
175	Waimea Bridge to Kaumakani	0.0728	Diverter installation (Reflective)	2022
175	Waimea Bridge to Kaumakani	0.0728	Static wire removal	2021
176	Waimea Bridge to Kaumakani	0.0753	Diverter installation (Reflective)	2022
176	Waimea Bridge to Kaumakani	0.0753	Static wire removal	2021
177	Waimea Bridge to Kaumakani	0.0778	Diverter installation (Reflective)	2022
177	Waimea Bridge to Kaumakani	0.0778	Static wire removal	2021
178	Waimea Bridge to Kaumakani	0.0753	Diverter installation (Reflective)	2022
178	Waimea Bridge to Kaumakani	0.0753	Static wire removal	2021
179	Waimea Bridge to Kaumakani	0.0524	Diverter installation (Reflective)	2022
179	Waimea Bridge to Kaumakani	0.0524	Static wire removal	2021
180	Waimea Bridge to Kaumakani	0.0694	Diverter installation (Reflective)	2022
180	Waimea Bridge to Kaumakani	0.0694	Static wire removal	2021
181	Waimea Bridge to Kaumakani	0.0756	Diverter installation (Reflective)	2022
181	Waimea Bridge to Kaumakani	0.0756	Static wire removal	2021
182	Waimea Bridge to Kaumakani	0.0747	Diverter installation (Reflective)	2022
182	Waimea Bridge to Kaumakani	0.0747	Static wire removal	2021
183	Waimea Bridge to Kaumakani	0.0751	Diverter installation (Reflective)	2022
183	Waimea Bridge to Kaumakani	0.0751	Static wire removal	2021
184	Waimea Bridge to Kaumakani	0.0829	Diverter installation (Reflective)	2022
184	Waimea Bridge to Kaumakani	0.0829	Static wire removal	2021

185	Waimea Bridge to Kaumakani	0.0749	Diverter installation (Reflective)	2022
185	Waimea Bridge to Kaumakani	0.0749	Static wire removal	2021
186	Waimea Bridge to Kaumakani	0.0391	Diverter installation (Reflective)	2022
186	Waimea Bridge to Kaumakani	0.0391	Static wire removal	2021
187	Waimea Bridge to Kaumakani	0.0363	Diverter installation (Reflective)	2022
187	Waimea Bridge to Kaumakani	0.0363	Static wire removal	2021
188	Waimea Bridge to Kaumakani	0.0387	Diverter installation (Reflective)	2022
188	Waimea Bridge to Kaumakani	0.0387	Static wire removal	2021
189	Waimea Bridge to Kaumakani	0.0369	Diverter installation (Reflective)	2022
189	Waimea Bridge to Kaumakani	0.0369	Static wire removal	2021
190	Waimea Bridge to Kaumakani	0.0390	Diverter installation (Reflective)	2022
190	Waimea Bridge to Kaumakani	0.0390	Static wire removal	2021
191	Waimea Bridge to Kaumakani	0.0390	Diverter installation (Reflective)	2022
191	Waimea Bridge to Kaumakani	0.0390	Static wire removal	2021
192	Waimea Bridge to Kaumakani	0.0335	Diverter installation (Reflective)	2022
192	Waimea Bridge to Kaumakani	0.0335	Static wire removal	2021
193	Waimea Bridge to Kaumakani	0.0402	Diverter installation (Reflective)	2022
193	Waimea Bridge to Kaumakani	0.0402	Static wire removal	2021
194	Waimea Bridge to Kaumakani	0.0336	Diverter installation (Reflective)	2022
194	Waimea Bridge to Kaumakani	0.0336	Static wire removal	2021
195	Waimea Bridge to Kaumakani	0.0810	Diverter installation (Reflective)	2022
195	Waimea Bridge to Kaumakani	0.0810	Static wire removal	2021
196	Waimea Bridge to Kaumakani	0.0731	Diverter installation (Reflective)	2022
196	Waimea Bridge to Kaumakani	0.0731	Static wire removal	2021
197	Waimea Bridge to Kaumakani	0.0767	Diverter installation (Reflective)	2022
197	Waimea Bridge to Kaumakani	0.0767	Static wire removal	2021
198	Waimea Bridge to Kaumakani	0.0768	Diverter installation (Reflective)	2022
198	Waimea Bridge to Kaumakani	0.0768	Static wire removal	2021
199	Waimea Bridge to Kaumakani	0.0745	Diverter installation (Reflective)	2022
199	Waimea Bridge to Kaumakani	0.0745	Static wire removal	2021
200	Waimea Bridge to Kaumakani	0.0780	Diverter installation (Reflective)	2022
200	Waimea Bridge to Kaumakani	0.0780	Static wire removal	2021
201	Waimea Bridge to Kaumakani	0.0749	Diverter installation (Reflective)	2022
201	Waimea Bridge to Kaumakani	0.0749	Static wire removal	2021
202	Waimea Bridge to Kaumakani	0.0759	Diverter installation (Reflective)	2022

202	Waimea Bridge to Kaumakani	0.0759	Static wire removal	2021
203	Waimea Bridge to Kaumakani	0.0542	Diverter installation (Reflective)	2022
203	Waimea Bridge to Kaumakani	0.0542	Static wire removal	2021
204	Waimea Bridge to Kaumakani	0.0501	Diverter installation (Reflective)	2022
204	Waimea Bridge to Kaumakani	0.0501	Static wire removal	2021
205	Waimea Bridge to Kaumakani	0.0624	Diverter installation (Reflective)	2022
205	Waimea Bridge to Kaumakani	0.0624	Static wire removal	2021
206	Waimea Bridge to Kaumakani	0.0629	Diverter installation (Reflective)	2022
206	Waimea Bridge to Kaumakani	0.0629	Static wire removal	2021
207	Waimea Bridge to Kaumakani	0.0688	Diverter installation (Reflective)	2022
207	Waimea Bridge to Kaumakani	0.0688	Static wire removal	2021
208	Waimea Bridge to Kaumakani	0.0430	Diverter installation (Reflective)	2022
208	Waimea Bridge to Kaumakani	0.0430	Static wire removal	2021
209	Waimea Bridge to Kaumakani	0.0587	Diverter installation (Reflective)	2022
209	Waimea Bridge to Kaumakani	0.0587	Static wire removal	2021
210	Waimea Bridge to Kaumakani	0.0740	Diverter installation (Reflective)	2022
210	Waimea Bridge to Kaumakani	0.0740	Static wire removal	2021
211	Waimea Bridge to Kaumakani	0.0724	Diverter installation (Reflective)	2022
211	Waimea Bridge to Kaumakani	0.0724	Static wire removal	2021
212	Waimea Bridge to Kaumakani	0.0896	Diverter installation (Reflective)	2022
212	Waimea Bridge to Kaumakani	0.0896	Static wire removal	2021
213	Waimea Bridge to Kaumakani	0.0740	Diverter installation (Reflective)	2022
213	Waimea Bridge to Kaumakani	0.0740	Static wire removal	2021
214	Waimea Bridge to Kaumakani	0.0802	Diverter installation (Reflective)	2022
214	Waimea Bridge to Kaumakani	0.0802	Static wire removal	2021
215	Waimea Bridge to Kaumakani	0.0791	Diverter installation (Reflective)	2022
215	Waimea Bridge to Kaumakani	0.0791	Static wire removal	2021
216	Waimea Bridge to Kaumakani	0.0654	Diverter installation (Reflective)	2022
216	Waimea Bridge to Kaumakani	0.0654	Static wire removal	2021
217	Waimea Bridge to Kaumakani	0.0781	Diverter installation (Reflective)	2022
217	Waimea Bridge to Kaumakani	0.0781	Static wire removal	2021
218	Waimea Bridge to Kaumakani	0.0943	Diverter installation (Reflective)	2022
218	Waimea Bridge to Kaumakani	0.0943	Static wire removal	2021
219	Waimea Bridge to Kaumakani	0.0919	Diverter installation (Reflective)	2022
219	Waimea Bridge to Kaumakani	0.0919	Static wire removal	2021

220	Waimea Bridge to Kaumakani	0.0799	Diverter installation (Reflective)	2022
220	Waimea Bridge to Kaumakani	0.0799	Static wire removal	2021
221	Waimea Bridge to Kaumakani	0.0701	Diverter installation (Reflective)	2022
221	Waimea Bridge to Kaumakani	0.0701	Static wire removal	2021
222	Waimea Bridge to Kaumakani	0.0663	Diverter installation (Reflective)	2022
222	Waimea Bridge to Kaumakani	0.0663	Static wire removal	2021
223	Waimea Bridge to Kaumakani	0.0752	Diverter installation (Reflective)	2022
223	Waimea Bridge to Kaumakani	0.0752	Static wire removal	2021
224	Waimea Bridge to Kaumakani	0.0777	Diverter installation (Reflective)	2022
224	Waimea Bridge to Kaumakani	0.0777	Static wire removal	2021
225	Waimea Bridge to Kaumakani	0.0401	Diverter installation (Reflective)	2022
225	Waimea Bridge to Kaumakani	0.0401	Static wire removal	2021
226	Waimea Bridge to Kaumakani	0.0406	Diverter installation (Reflective)	2022
226	Waimea Bridge to Kaumakani	0.0406	Static wire removal	2021
227	Waimea Bridge to Kaumakani	0.0590	Diverter installation (Reflective)	2022
227	Waimea Bridge to Kaumakani	0.0590	Static wire removal	2021
228	Waimea Bridge to Kaumakani	0.0611	Diverter installation (Reflective)	2022
228	Waimea Bridge to Kaumakani	0.0611	Static wire removal	2021
229	Waimea Bridge to Kaumakani	0.0532	Diverter installation (Reflective)	2022
229	Waimea Bridge to Kaumakani	0.0532	Static wire removal	2021
230	Waimea Bridge to Kaumakani	0.0774	Diverter installation (Reflective)	2022
230	Waimea Bridge to Kaumakani	0.0774	Static wire removal	2021
231	Waimea Bridge to Kaumakani	0.0801	Diverter installation (Reflective)	2022
231	Waimea Bridge to Kaumakani	0.0801	Static wire removal	2021
232	Waimea Bridge to Kaumakani	0.0401	Diverter installation (Reflective)	2022
232	Waimea Bridge to Kaumakani	0.0401	Static wire removal	2021
233	Waimea Bridge to Kaumakani	0.0735	Diverter installation (Reflective)	2022
233	Waimea Bridge to Kaumakani	0.0735	Static wire removal	2021
234	Waimea Bridge to Kaumakani	0.0590	Diverter installation (Reflective)	2022
234	Waimea Bridge to Kaumakani	0.0590	Static wire removal	2021
235	Waimea Bridge to Kaumakani	0.0474	Diverter installation (Reflective)	2022
235	Waimea Bridge to Kaumakani	0.0474	Static wire removal	2021
236	Waimea Bridge to Kaumakani	0.1019	Diverter installation (Reflective)	2022
236	Waimea Bridge to Kaumakani	0.1019	Static wire removal	2021
237	Waimea Bridge to Kaumakani	0.1036	Diverter installation (Reflective)	2022

237	Waimea Bridge to Kaumakani	0.1036	Static wire removal	2021
238	Waimea Bridge to Kaumakani	0.0469	Diverter installation (Reflective)	2022
238	Waimea Bridge to Kaumakani	0.0469	Static wire removal	2021
239	Waimea Bridge to Kaumakani	0.0473	Diverter installation (Reflective)	2022
239	Waimea Bridge to Kaumakani	0.0473	Static wire removal	2021
240	Waimea Bridge to Kaumakani	0.0386	Diverter installation (Reflective)	2022
240	Waimea Bridge to Kaumakani	0.0386	Static wire removal	2021
241	Waimea Bridge to Kaumakani	0.0391	Diverter installation (Reflective)	2022
241	Waimea Bridge to Kaumakani	0.0391	Static wire removal	2021
242	Waimea Bridge to Kaumakani	0.0376	Diverter installation (Reflective)	2022
242	Waimea Bridge to Kaumakani	0.0376	Static wire removal	2021
243	Waimea Bridge to Kaumakani	0.0376	Diverter installation (Reflective)	2022
243	Waimea Bridge to Kaumakani	0.0376	Static wire removal	2021
244	Waimea Bridge to Kaumakani	0.0769	Diverter installation (Reflective)	2015
244	Waimea Bridge to Kaumakani	0.0769	Static wire removal	2021
245	Waimea Bridge to Kaumakani	0.0716	Diverter installation (Reflective)	2015
245	Waimea Bridge to Kaumakani	0.0716	Static wire removal	2021
246	Waimea Bridge to Kaumakani	0.0766	Diverter installation (Reflective)	2015
246	Waimea Bridge to Kaumakani	0.0766	Static wire removal	2021
247	Waimea Bridge to Kaumakani	0.0741	Diverter installation (Reflective)	2015
247	Waimea Bridge to Kaumakani	0.0741	Static wire removal	2021
248	Waimea Bridge to Kaumakani	0.0361	Diverter installation (Reflective)	2022
248	Waimea Bridge to Kaumakani	0.0361	Static wire removal	2021
249	Waimea Bridge to Kaumakani	0.0391	Diverter installation (Reflective)	2022
249	Waimea Bridge to Kaumakani	0.0391	Static wire removal	2021
250	Waimea Bridge to Kaumakani	0.0412	Diverter installation (Reflective)	2022
250	Waimea Bridge to Kaumakani	0.0412	Static wire removal	2021
251	Waimea Bridge to Kaumakani	0.0333	Diverter installation (Reflective)	2022
251	Waimea Bridge to Kaumakani	0.0333	Static wire removal	2021
252	Waimea Bridge to Kaumakani	0.0365	Diverter installation (Reflective)	2022
252	Waimea Bridge to Kaumakani	0.0365	Static wire removal	2021
253	Waimea Bridge to Kaumakani	0.0385	Diverter installation (Reflective)	2015
253	Waimea Bridge to Kaumakani	0.0385	Static wire removal	2021
254	Waimea Bridge to Kaumakani	0.0720	Diverter installation (Reflective)	2015
254	Waimea Bridge to Kaumakani	0.0720	Static wire removal	2021

255	Waimea Bridge to Kaumakani	0.0778	Diverter installation (Reflective)	2022
255	Waimea Bridge to Kaumakani	0.0778	Static wire removal	2021
256	Waimea Bridge to Kaumakani	0.0757	Diverter installation (Reflective)	2022
256	Waimea Bridge to Kaumakani	0.0757	Static wire removal	2021
257	Waimea Bridge to Kaumakani	0.0790	Diverter installation (Reflective)	2022
257	Waimea Bridge to Kaumakani	0.0790	Static wire removal	2021
258	Waimea Bridge to Kaumakani	0.0452	Diverter installation (Reflective)	2022
258	Waimea Bridge to Kaumakani	0.0452	Static wire removal	2021
259	Waimea Bridge to Kaumakani	0.0499	Diverter installation (Reflective)	2022
259	Waimea Bridge to Kaumakani	0.0499	Static wire removal	2021
260	Kaumakani to Port Allen	0.0263	Diverter installation (Reflective)	2022
260	Kaumakani to Port Allen	0.0263	Static wire removal	2021
261	Kaumakani to Port Allen	0.0476	Diverter installation (Reflective)	2022
261	Kaumakani to Port Allen	0.0476	Static wire removal	2021
262	Kaumakani to Port Allen	0.0754	Diverter installation (Reflective)	2022
262	Kaumakani to Port Allen	0.0754	Static wire removal	2021
263	Kaumakani to Port Allen	0.0719	Diverter installation (Reflective)	2022
263	Kaumakani to Port Allen	0.0719	Static wire removal	2021
264	Kaumakani to Port Allen	0.0773	Diverter installation (Reflective)	2022
264	Kaumakani to Port Allen	0.0773	Static wire removal	2021
265	Kaumakani to Port Allen	0.0364	Diverter installation (Reflective)	2022
265	Kaumakani to Port Allen	0.0364	Static wire removal	2021
266	Kaumakani to Port Allen	0.0486	Diverter installation (Reflective)	2022
266	Kaumakani to Port Allen	0.0486	Static wire removal	2021
267	Kaumakani to Port Allen	0.0513	Diverter installation (Reflective)	2021
267	Kaumakani to Port Allen	0.0513	Static wire removal	2021
268	Kaumakani to Port Allen	0.0832	Diverter installation (Reflective)	2022
268	Kaumakani to Port Allen	0.0832	Static wire removal	2021
269	Kaumakani to Port Allen	0.0496	Diverter installation (Reflective)	2021
269	Kaumakani to Port Allen	0.0496	Static wire removal	2021
270	Kaumakani to Port Allen	0.0567	Diverter installation (Reflective)	2021
270	Kaumakani to Port Allen	0.0567	Static wire removal	2021
271	Kaumakani to Port Allen	0.0792	Diverter installation (Reflective)	2021
271	Kaumakani to Port Allen	0.0792	Static wire removal	2021
272	Kaumakani to Port Allen	0.0153	Diverter installation (Reflective)	2021

272	Kaumakani to Port Allen	0.0153	Static wire removal	2021
273	Kaumakani to Port Allen	0.0208	Diverter installation (Reflective)	2021
273	Kaumakani to Port Allen	0.0208	Static wire removal	2021
274	Kaumakani to Port Allen	0.0120	Diverter installation (Reflective)	2021
274	Kaumakani to Port Allen	0.0120	Static wire removal	2021
275	Kaumakani to Port Allen	0.0500	Diverter installation (Reflective)	2021
275	Kaumakani to Port Allen	0.0500	Static wire removal	2021
276	Kaumakani to Port Allen	0.0831	Diverter installation (Reflective)	2021
276	Kaumakani to Port Allen	0.0831	Static wire removal	2021
277	Kaumakani to Port Allen	0.0693	Diverter installation (Reflective)	2021
277	Kaumakani to Port Allen	0.0693	Static wire removal	2021
277	Kaumakani to Port Allen	0.0693	Static wire removal	2021
278	Kaumakani to Port Allen	0.0581	Diverter installation (Reflective)	2021
278	Kaumakani to Port Allen	0.0581	Static wire removal	2021
279	Kaumakani to Port Allen	0.0229	Diverter installation (Reflective)	2021
279	Kaumakani to Port Allen	0.0229	Static wire removal	2021
280	Kaumakani to Port Allen	0.0642	Diverter installation (Reflective)	2021
280	Kaumakani to Port Allen	0.0642	Static wire removal	2021
281	Kaumakani to Port Allen	0.0660	Diverter installation (Reflective)	2021
281	Kaumakani to Port Allen	0.0660	Static wire removal	2021
282	Kaumakani to Port Allen	0.0211	Diverter installation (Reflective)	2021
282	Kaumakani to Port Allen	0.0211	Static wire removal	2021
283	Kaumakani to Port Allen	0.0341	Diverter installation (Reflective)	2021
283	Kaumakani to Port Allen	0.0341	Static wire removal	2021
284	Kaumakani to Port Allen	0.0386	Diverter installation (Reflective)	2021
284	Kaumakani to Port Allen	0.0386	Static wire removal	2021
285	Kaumakani to Port Allen	0.0260	Diverter installation (Reflective)	2021
285	Kaumakani to Port Allen	0.0260	Static wire removal	2021
286	Kaumakani to Port Allen	0.0498	Diverter installation (Reflective)	2021
286	Kaumakani to Port Allen	0.0498	Static wire removal	2021
287	Kaumakani to Port Allen	0.0461	Diverter installation (Reflective)	2021
287	Kaumakani to Port Allen	0.0461	Static wire removal	2022
289	Kaumakani to Port Allen	0.0364	Diverter installation (Reflective)	2022
289	Kaumakani to Port Allen	0.0364	Static wire removal	2022
290	PAGS to Waialo Rd/Hwy intersection	0.0337	Diverter installation (Reflective)	2021

290	PAGS to Waialo Rd/Hwy intersection	0.0337	Static wire removal	2021
291	PAGS to Waialo Rd/Hwy intersection	0.0379	Diverter installation (Reflective)	2021
291	PAGS to Waialo Rd/Hwy intersection	0.0379	Static wire removal	2021
292	PAGS to Waialo Rd/Hwy intersection	0.0374	Diverter installation (Reflective)	2021
292	PAGS to Waialo Rd/Hwy intersection	0.0374	Static wire removal	2021
293	PAGS to Waialo Rd/Hwy intersection	0.0411	Diverter installation (Reflective)	2021
293	PAGS to Waialo Rd/Hwy intersection	0.0411	Static wire removal	2021
294	PAGS to Waialo Rd/Hwy intersection	0.0367	Diverter installation (Reflective)	2021
294	PAGS to Waialo Rd/Hwy intersection	0.0367	Static wire removal	2021
295	PAGS to Waialo Rd/Hwy intersection	0.0406	Diverter installation (Reflective)	2021
295	PAGS to Waialo Rd/Hwy intersection	0.0406	Static wire removal	2021
296	PAGS to Waialo Rd/Hwy intersection	0.0437	Diverter installation (Reflective)	2021
296	PAGS to Waialo Rd/Hwy intersection	0.0437	Static wire removal	2021
297	PAGS to Waialo Rd/Hwy intersection	0.0210	Diverter installation (Reflective)	2021
297	PAGS to Waialo Rd/Hwy intersection	0.0210	Static wire removal	2021
298	Waialo Rd/Hwy intersection to Brydsewood	0.0278	Diverter installation (Reflective)	2021
298	Waialo Rd/Hwy intersection to Brydsewood	0.0278	Static wire removal	2019
299	Waialo Rd/Hwy intersection to Brydsewood	0.0254	Diverter installation (Reflective)	2021
299	Waialo Rd/Hwy intersection to Brydsewood	0.0254	Static wire removal	2019
300	Waialo Rd/Hwy intersection to Brydsewood	0.0282	Diverter installation (Reflective)	2021
300	Waialo Rd/Hwy intersection to Brydsewood	0.0282	Static wire removal	2019
301	Waialo Rd/Hwy intersection to Brydsewood	0.0282	Diverter installation (Reflective)	2021
301	Waialo Rd/Hwy intersection to Brydsewood	0.0282	Static wire removal	2019
302	Waialo Rd/Hwy intersection to Brydsewood	0.0282	Diverter installation (Reflective)	2021
302	Waialo Rd/Hwy intersection to Brydsewood	0.0282	Static wire removal	2019
303	Waialo Rd/Hwy intersection to Brydsewood	0.0377	Diverter installation (Reflective)	2022
303	Waialo Rd/Hwy intersection to Brydsewood	0.0377	Static wire removal	2019
304	Waialo Rd/Hwy intersection to Brydsewood	0.0336	Diverter installation (Reflective)	2022
304	Waialo Rd/Hwy intersection to Brydsewood	0.0336	Static wire removal	2019
305	Waialo Rd/Hwy intersection to Brydsewood	0.0663	Diverter installation (Reflective)	2022
305	Waialo Rd/Hwy intersection to Brydsewood	0.0663	Static wire removal	2019
306	Waialo Rd/Hwy intersection to Brydsewood	0.0653	Diverter installation (Reflective)	2022
306	Waialo Rd/Hwy intersection to Brydsewood	0.0653	Static wire removal	2019
307	Waialo Rd/Hwy intersection to Brydsewood	0.0625	Diverter installation (Reflective)	2022
307	Waialo Rd/Hwy intersection to Brydsewood	0.0625	Static wire removal	2019

308	Waialo Rd/Hwy intersection to Brydsewood	0.0423	Diverter installation (Reflective)	2021
308	Waialo Rd/Hwy intersection to Brydsewood	0.0423	Static wire removal	2019
309	Waialo Rd/Hwy intersection to Brydsewood	0.0312	Diverter installation (Reflective)	2021
309	Waialo Rd/Hwy intersection to Brydsewood	0.0312	Static wire removal	2019
310	Waialo Rd/Hwy intersection to Brydsewood	0.0721	Diverter installation (Reflective)	2021
310	Waialo Rd/Hwy intersection to Brydsewood	0.0721	Static wire removal	2019
311	Waialo Rd/Hwy intersection to Brydsewood	0.0626	Diverter installation (Reflective)	2021
311	Waialo Rd/Hwy intersection to Brydsewood	0.0626	Static wire removal	2019
312	Waialo Rd/Hwy intersection to Brydsewood	0.0371	Diverter installation (Reflective)	2021
312	Waialo Rd/Hwy intersection to Brydsewood	0.0371	Static wire removal	2019
313	Waialo Rd/Hwy intersection to Brydsewood	0.0310	Diverter installation (Reflective)	2022
313	Waialo Rd/Hwy intersection to Brydsewood	0.0310	Static wire removal	2019
314	Waialo Rd/Hwy intersection to Brydsewood	0.0709	Diverter installation (Reflective)	2022
314	Waialo Rd/Hwy intersection to Brydsewood	0.0709	Static wire removal	2019
315	Waialo Rd/Hwy intersection to Brydsewood	0.0741	Diverter installation (LED)	2022
315	Waialo Rd/Hwy intersection to Brydsewood	0.0741	Static wire removal	2019
316	Waialo Rd/Hwy intersection to Brydsewood	0.0750	Diverter installation (Reflective)	2022
316	Waialo Rd/Hwy intersection to Brydsewood	0.0750	Static wire removal	2019
317	Waialo Rd/Hwy intersection to Brydsewood	0.0781	Diverter installation (Reflective)	2021
317	Waialo Rd/Hwy intersection to Brydsewood	0.0781	Static wire removal	2019
318	Waialo Rd/Hwy intersection to Brydsewood	0.0299	Diverter installation (Reflective)	2021
318	Waialo Rd/Hwy intersection to Brydsewood	0.0299	Static wire removal	2019
319	Waialo Rd/Hwy intersection to Brydsewood	0.0537	Diverter installation (Reflective)	2021
319	Waialo Rd/Hwy intersection to Brydsewood	0.0537	Static wire removal	2019
320	Waialo Rd/Hwy intersection to Brydsewood	0.0590	Diverter installation (Reflective)	2021
320	Waialo Rd/Hwy intersection to Brydsewood	0.0590	Static wire removal	2019
321	Waialo Rd/Hwy intersection to Brydsewood	0.0554	Diverter installation (Reflective)	2021
321	Waialo Rd/Hwy intersection to Brydsewood	0.0554	Static wire removal	2019
322	Waialo Rd/Hwy intersection to Brydsewood	0.0436	Diverter installation (Reflective)	2021
322	Waialo Rd/Hwy intersection to Brydsewood	0.0436	Static wire removal	2019
323	Waialo Rd/Hwy intersection to Brydsewood	0.0723	Diverter installation (Reflective)	2021
323	Waialo Rd/Hwy intersection to Brydsewood	0.0723	Static wire removal	2019
324	Waialo Rd/Hwy intersection to Brydsewood	0.0751	Diverter installation (Reflective)	2021
324	Waialo Rd/Hwy intersection to Brydsewood	0.0751	Static wire removal	2019
325	Waialo Rd/Hwy intersection to Brydsewood	0.0466	Diverter installation (Reflective)	2021

325	Waialo Rd/Hwy intersection to Brydsewood	0.0466	Static wire removal	2019
326	Waialo Rd/Hwy intersection to Brydsewood	0.0468	Diverter installation (Reflective)	2021
326	Waialo Rd/Hwy intersection to Brydsewood	0.0468	Static wire removal	2019
327	Waialo Rd/Hwy intersection to Brydsewood	0.0074	Static wire removal	2022
328	Waialo Rd/Hwy intersection to Brydsewood	0.1601	Static wire removal	2016
329	Waialo Rd/Hwy intersection to Brydsewood	0.1170	Static wire removal	2016
330	Waialo Rd/Hwy intersection to Brydsewood	0.1922	Diverter installation (Reflective)	2021
330	Waialo Rd/Hwy intersection to Brydsewood	0.1922	Static wire removal	2016
331	Waialo Rd/Hwy intersection to Brydsewood	0.1533	Diverter installation (Reflective)	2021
331	Waialo Rd/Hwy intersection to Brydsewood	0.1533	Static wire removal	2016
332	Waialo Rd/Hwy intersection to Brydsewood	0.1064	Diverter installation (Reflective)	2021
332	Waialo Rd/Hwy intersection to Brydsewood	0.1064	Static wire removal	2016
333	Waialo Rd/Hwy intersection to Brydsewood	0.1330	Diverter installation (Reflective)	2021
333	Waialo Rd/Hwy intersection to Brydsewood	0.1330	Static wire removal	2016
334	Waialo Rd/Hwy intersection to Brydsewood	0.3177	Static wire removal	2016
335	Waialo Rd/Hwy intersection to Brydsewood	0.1156	Diverter installation (Reflective)	2021
335	Waialo Rd/Hwy intersection to Brydsewood	0.1156	Static wire removal	2016
336	Waialo Rd/Hwy intersection to Brydsewood	0.1161	Diverter installation (Reflective)	2021
336	Waialo Rd/Hwy intersection to Brydsewood	0.1161	Static wire removal	2016
337	Waialo Rd/Hwy intersection to Brydsewood	0.1174	Static wire removal	2016
338	Waialo Rd/Hwy intersection to Brydsewood	0.1456	Static wire removal	2016
339	Waialo Rd/Hwy intersection to Brydsewood	0.1353	Diverter installation (Reflective)	2021
339	Waialo Rd/Hwy intersection to Brydsewood	0.1353	Static wire removal	2016
340	Waialo Rd/Hwy intersection to Brydsewood	0.1378	Diverter installation (Reflective)	2021
340	Waialo Rd/Hwy intersection to Brydsewood	0.1378	Static wire removal	2016
341	Waialo Rd/Hwy intersection to Brydsewood	0.0961	Diverter installation (Reflective)	2021
341	Waialo Rd/Hwy intersection to Brydsewood	0.0961	Static wire removal	2016
342	Waialo Rd/Hwy intersection to Brydsewood	0.1582	Static wire removal	2016
343	Fujita Tap	0.2674	Diverter installation (Reflective)	2022
343	Fujita Tap	0.2674	Static wire removal	2022
344	Fujita Tap	0.1144	Diverter installation (Reflective)	2022
344	Fujita Tap	0.1144	Static wire removal	2022
346	Fujita Tap	0.1209	Diverter installation (Reflective)	2022
346	Fujita Tap	0.1209	Static wire removal	2022
347	Fujita Tap	0.1405	Diverter installation (Reflective)	2022

347	Fujita Tap	0.1405	Static wire removal	2022
348	Fujita Tap	0.1188	Diverter installation (Reflective)	2022
348	Fujita Tap	0.1188	Static wire removal	2022
349	Fujita Tap	0.2632	Diverter installation (Reflective)	2022
349	Fujita Tap	0.2632	Static wire removal	2022
350	Fujita Tap	0.1798	Diverter installation (Reflective)	2022
351	Fujita Tap	0.1673	Diverter installation (Reflective)	2022
352	Fujita Tap	0.4467	Diverter installation (Reflective)	2022
352	Fujita Tap	0.4467	Static wire removal	2016
353	Fujita Tap	0.0274	Diverter installation (Reflective)	2022
354	Fujita Tap	0.1845	Diverter installation (Reflective)	2022
354	Fujita Tap	0.1845	Static wire removal	2022
355	Fujita Tap	0.1461	Diverter installation (Reflective)	2022
355	Fujita Tap	0.1461	Static wire removal	2022
356	Fujita Tap	0.1156	Diverter installation (Reflective)	2022
356	Fujita Tap	0.1156	Static wire removal	2022
357	Fujita Tap	0.1226	Diverter installation (Reflective)	2022
357	Fujita Tap	0.1226	Static wire removal	2022
358	Fujita Tap	0.1965	Diverter installation (Reflective)	2022
358	Fujita Tap	0.1965	Static wire removal	2022
359	Fujita Tap	0.5587	Diverter installation (Reflective)	2022
359	Fujita Tap	0.5587	Static wire removal	2022
361	Fujita Tap	0.2174	Diverter installation (Reflective)	2021
361	Fujita Tap	0.2174	Static wire removal	2022
362	Fujita Tap	0.1666	Diverter installation (Reflective)	2021
362	Fujita Tap	0.1666	Static wire removal	2022
363	Fujita Tap	0.1442	Diverter installation (Reflective)	2021
363	Fujita Tap	0.1442	Static wire removal	2022
364	Fujita Tap	0.1487	Diverter installation (Reflective)	2021
364	Fujita Tap	0.1487	Static wire removal	2022
365	Fujita Tap	0.1400	Diverter installation (Reflective)	2021
365	Fujita Tap	0.1400	Static wire removal	2021
365	Fujita Tap	0.1400	Static wire removal	2021
366	Fujita Tap	0.1312	Diverter installation (Reflective)	2021
366	Fujita Tap	0.1312	Static wire removal	2021

366	Fujita Tap	0.1312	Static wire removal	2021
367	Fujita Tap	0.1278	Diverter installation (Reflective)	2021
367	Fujita Tap	0.1278	Static wire removal	2021
367	Fujita Tap	0.1278	Static wire removal	2021
368	Fujita Tap	0.1461	Diverter installation (Reflective)	2022
368	Fujita Tap	0.1461	Static wire removal	2022
369	Fujita Tap	0.1861	Diverter installation (Reflective)	2022
369	Fujita Tap	0.1861	Static wire removal	2022
370	Fujita Tap	0.1610	Diverter installation (Reflective)	2022
370	Fujita Tap	0.1610	Static wire removal	2022
371	Fujita Tap	0.1603	Diverter installation (Reflective)	2021
371	Fujita Tap	0.1603	Static wire removal	2021
372	Fujita Tap	0.1322	Diverter installation (Reflective)	2021
372	Fujita Tap	0.1322	Static wire removal	2021
373	Fujita Tap	0.1376	Diverter installation (Reflective)	2021
373	Fujita Tap	0.1376	Static wire removal	2021
374	Fujita Tap	0.1526	Diverter installation (Reflective)	2021
374	Fujita Tap	0.1526	Static wire removal	2021
375	Fujita Tap	0.1377	Diverter installation (Reflective)	2021
375	Fujita Tap	0.1377	Static wire removal	2021
376	Fujita Tap	0.1498	Diverter installation (Reflective)	2021
376	Fujita Tap	0.1498	Static wire removal	2021
377	Fujita Tap	0.1467	Diverter installation (Reflective)	2021
377	Fujita Tap	0.1467	Static wire removal	2022
378	Fujita Tap to Kilohana Tap	0.1582	Diverter installation (Reflective)	2022
378	Fujita Tap to Kilohana Tap	0.1582	Static wire removal	2022
379	Fujita Tap to Kilohana Tap	0.1840	Diverter installation (Reflective)	2022
379	Fujita Tap to Kilohana Tap	0.1840	Static wire removal	2022
380	Fujita Tap to Kilohana Tap	0.1811	Diverter installation (Reflective)	2021
380	Fujita Tap to Kilohana Tap	0.1811	Static wire removal	2022
381	Fujita Tap to Kilohana Tap	0.1987	Diverter installation (Reflective)	2021
381	Fujita Tap to Kilohana Tap	0.1987	Static wire removal	2022
382	Fujita Tap to Kilohana Tap	0.1025	Diverter installation (Reflective)	2022
382	Fujita Tap to Kilohana Tap	0.1025	Static wire removal	2022
383	Fujita Tap to Kilohana Tap	0.2119	Diverter installation (Reflective)	2022

383	Fujita Tap to Kilohana Tap	0.2119	Static wire removal	2022
384	Fujita Tap to Kilohana Tap	0.1521	Diverter installation (Reflective)	2022
384	Fujita Tap to Kilohana Tap	0.1521	Static wire removal	2022
385	Fujita Tap to Kilohana Tap	0.1747	Diverter installation (Reflective)	2022
385	Fujita Tap to Kilohana Tap	0.1747	Static wire removal	2022
386	Fujita Tap to Kilohana Tap	0.1371	Diverter installation (Reflective)	2021
386	Fujita Tap to Kilohana Tap	0.1371	Static wire removal	2022
387	Fujita Tap to Kilohana Tap	0.1789	Diverter installation (Reflective)	2021
387	Fujita Tap to Kilohana Tap	0.1789	Static wire removal	2022
388	Fujita Tap to Kilohana Tap	0.1902	Diverter installation (Reflective)	2021
388	Fujita Tap to Kilohana Tap	0.1902	Static wire removal	2022
389	Kilohana to Hanahanapuni (CP1 and CP2)	0.1543	Diverter installation (Reflective)	2021
389	Kilohana to Hanahanapuni (CP1 and CP2)	0.1543	Reconfiguration	2020
389	Kilohana to Hanahanapuni (CP1 and CP2)	0.1543	Static wire removal	2020
390	Kilohana to Hanahanapuni (CP1 and CP2)	0.2215	Diverter installation (Reflective)	2021
390	Kilohana to Hanahanapuni (CP1 and CP2)	0.2215	Reconfiguration	2020
390	Kilohana to Hanahanapuni (CP1 and CP2)	0.2215	Static wire removal	2020
391	Kilohana to Hanahanapuni (CP1 and CP2)	0.1737	Diverter installation (Reflective)	2021
391	Kilohana to Hanahanapuni (CP1 and CP2)	0.1737	Reconfiguration	2020
391	Kilohana to Hanahanapuni (CP1 and CP2)	0.1737	Static wire removal	2020
392	Kilohana to Hanahanapuni (CP1 and CP2)	0.1475	Diverter installation (Reflective)	2021
392	Kilohana to Hanahanapuni (CP1 and CP2)	0.1475	Reconfiguration	2020
392	Kilohana to Hanahanapuni (CP1 and CP2)	0.1475	Static wire removal	2020
393	Kilohana to Hanahanapuni (CP1 and CP2)	0.1522	Diverter installation (Reflective)	2021
393	Kilohana to Hanahanapuni (CP1 and CP2)	0.1522	Reconfiguration	2020
393	Kilohana to Hanahanapuni (CP1 and CP2)	0.1522	Static wire removal	2020
394	Kilohana to Hanahanapuni (CP1 and CP2)	0.3866	Diverter installation (Reflective)	2021
394	Kilohana to Hanahanapuni (CP1 and CP2)	0.3866	Reconfiguration	2020
394	Kilohana to Hanahanapuni (CP1 and CP2)	0.3866	Static wire removal	2020
395	Kilohana to Hanahanapuni (CP1 and CP2)	0.3567	Diverter installation (Reflective)	2021
395	Kilohana to Hanahanapuni (CP1 and CP2)	0.3567	Reconfiguration	2020
395	Kilohana to Hanahanapuni (CP1 and CP2)	0.3567	Static wire removal	2020
396	Kilohana to Hanahanapuni (CP1 and CP2)	0.2601	Diverter installation (Reflective)	2021
396	Kilohana to Hanahanapuni (CP1 and CP2)	0.2601	Reconfiguration	2020
396	Kilohana to Hanahanapuni (CP1 and CP2)	0.2601	Static wire removal	2020

397	Kilohana to Hanahanapuni (CP1 and CP2)	0.1472	Diverter installation (Reflective)	2021
397	Kilohana to Hanahanapuni (CP1 and CP2)	0.1472	Reconfiguration	2020
397	Kilohana to Hanahanapuni (CP1 and CP2)	0.1472	Static wire removal	2020
398	Kilohana to Hanahanapuni (CP1 and CP2)	0.1618	Diverter installation (Reflective)	2021
398	Kilohana to Hanahanapuni (CP1 and CP2)	0.1618	Reconfiguration	2020
398	Kilohana to Hanahanapuni (CP1 and CP2)	0.1618	Static wire removal	2020
399	Kilohana to Hanahanapuni (CP1 and CP2)	0.2034	Diverter installation (Reflective)	2021
399	Kilohana to Hanahanapuni (CP1 and CP2)	0.2034	Reconfiguration	2020
399	Kilohana to Hanahanapuni (CP1 and CP2)	0.2034	Static wire removal	2020
400	Kilohana to Hanahanapuni (CP1 and CP2)	0.2107	Diverter installation (Reflective)	2021
400	Kilohana to Hanahanapuni (CP1 and CP2)	0.2107	Reconfiguration	2020
400	Kilohana to Hanahanapuni (CP1 and CP2)	0.2107	Static wire removal	2020
401	Kilohana to Hanahanapuni (CP1 and CP2)	0.2422	Diverter installation (Reflective)	2021
401	Kilohana to Hanahanapuni (CP1 and CP2)	0.2422	Reconfiguration	2020
401	Kilohana to Hanahanapuni (CP1 and CP2)	0.2422	Static wire removal	2020
402	Kilohana to Hanahanapuni (CP1 and CP2)	0.2233	Diverter installation (Reflective)	2021
402	Kilohana to Hanahanapuni (CP1 and CP2)	0.2233	Reconfiguration	2020
402	Kilohana to Hanahanapuni (CP1 and CP2)	0.2233	Static wire removal	2020
403	Kilohana to Hanahanapuni (CP1 and CP2)	0.1316	Diverter installation (Reflective)	2021
403	Kilohana to Hanahanapuni (CP1 and CP2)	0.1316	Reconfiguration	2020
403	Kilohana to Hanahanapuni (CP1 and CP2)	0.1316	Static wire removal	2020
404	Kilohana to Hanahanapuni (CP1 and CP2)	0.2498	Diverter installation (Reflective)	2021
404	Kilohana to Hanahanapuni (CP1 and CP2)	0.2498	Reconfiguration	2020
404	Kilohana to Hanahanapuni (CP1 and CP2)	0.2498	Static wire removal	2020
405	Kilohana to Hanahanapuni (CP1 and CP2)	0.1358	Diverter installation (Reflective)	2021
405	Kilohana to Hanahanapuni (CP1 and CP2)	0.1358	Reconfiguration	2020
405	Kilohana to Hanahanapuni (CP1 and CP2)	0.1358	Static wire removal	2020
406	Kilohana to Hanahanapuni (CP1 and CP2)	0.1803	Diverter installation (Reflective)	2021
406	Kilohana to Hanahanapuni (CP1 and CP2)	0.1803	Reconfiguration	2020
406	Kilohana to Hanahanapuni (CP1 and CP2)	0.1803	Static wire removal	2020
407	Kilohana to Hanahanapuni (CP1 and CP2)	0.1440	Diverter installation (Reflective)	2021
407	Kilohana to Hanahanapuni (CP1 and CP2)	0.1440	Reconfiguration	2020
407	Kilohana to Hanahanapuni (CP1 and CP2)	0.1440	Static wire removal	2020
408	Kilohana to Hanahanapuni (CP1 and CP2)	0.1251	Diverter installation (Reflective)	2021
408	Kilohana to Hanahanapuni (CP1 and CP2)	0.1251	Reconfiguration	2020

408	Kilohana to Hanahanapuni (CP1 and CP2)	0.1251	Static wire removal	2020
409	Kilohana to Hanahanapuni (CP1 and CP2)	0.0943	Diverter installation (Reflective)	2021
409	Kilohana to Hanahanapuni (CP1 and CP2)	0.0943	Reconfiguration	2020
409	Kilohana to Hanahanapuni (CP1 and CP2)	0.0943	Static wire removal	2020
410	Kilohana to Hanahanapuni (CP1 and CP2)	0.1997	Diverter installation (Reflective)	2021
410	Kilohana to Hanahanapuni (CP1 and CP2)	0.1997	Reconfiguration	2020
410	Kilohana to Hanahanapuni (CP1 and CP2)	0.1997	Static wire removal	2020
411	Kilohana to Hanahanapuni (CP1 and CP2)	0.1941	Diverter installation (Reflective)	2021
411	Kilohana to Hanahanapuni (CP1 and CP2)	0.1941	Reconfiguration	2020
411	Kilohana to Hanahanapuni (CP1 and CP2)	0.1941	Static wire removal	2020
412	Kilohana to Hanahanapuni (CP1 and CP2)	0.1766	Diverter installation (Reflective)	2021
412	Kilohana to Hanahanapuni (CP1 and CP2)	0.1766	Reconfiguration	2020
412	Kilohana to Hanahanapuni (CP1 and CP2)	0.1766	Static wire removal	2020
413	Kilohana to Hanahanapuni (CP1 and CP2)	0.2763	Diverter installation (Reflective)	2021
413	Kilohana to Hanahanapuni (CP1 and CP2)	0.2763	Reconfiguration	2020
413	Kilohana to Hanahanapuni (CP1 and CP2)	0.2763	Static wire removal	2020
414	Kilohana to Hanahanapuni (CP1 and CP2)	0.1573	Diverter installation (Reflective)	2021
414	Kilohana to Hanahanapuni (CP1 and CP2)	0.1573	Reconfiguration	2020
414	Kilohana to Hanahanapuni (CP1 and CP2)	0.1573	Static wire removal	2020
415	Kilohana to Hanahanapuni (CP1 and CP2)	0.1627	Diverter installation (Reflective)	2021
415	Kilohana to Hanahanapuni (CP1 and CP2)	0.1627	Reconfiguration	2020
415	Kilohana to Hanahanapuni (CP1 and CP2)	0.1627	Static wire removal	2020
416	Kilohana to Hanahanapuni (CP1 and CP2)	0.1751	Diverter installation (Reflective)	2021
416	Kilohana to Hanahanapuni (CP1 and CP2)	0.1751	Reconfiguration	2020
416	Kilohana to Hanahanapuni (CP1 and CP2)	0.1751	Static wire removal	2020
417	Kilohana to Hanahanapuni (CP1 and CP2)	0.1372	Diverter installation (Reflective)	2021
417	Kilohana to Hanahanapuni (CP1 and CP2)	0.1372	Reconfiguration	2020
417	Kilohana to Hanahanapuni (CP1 and CP2)	0.1372	Static wire removal	2020
418	Hanahanapuni towards PLT	0.3180	Diverter installation (LED)	2021
419	Hanahanapuni towards PLT	0.4932	Diverter installation (LED)	2021
420	PLT entrance Wailua	0.1481	Diverter installation (LED)	2022
421	PLT entrance Wailua	0.2231	Diverter installation (LED)	2022
422	PLT entrance Wailua	0.2233	Diverter installation (LED)	2022
423	PLT entrance Wailua	0.3024	Diverter installation (LED)	2022
424	Powerline Trail S2	0.3072	Diverter installation (LED)	2022

425	Powerline Trail S2	0.3509	Diverter installation (LED)	2022
426	Powerline Trail S2	0.5663	Diverter installation (LED)	2022
427	Powerline Trail S2	0.2916	Diverter installation (LED)	2022
428	Powerline Trail S2	0.2752	Diverter installation (LED)	2022
429	Powerline Trail S2	0.2018	Diverter installation (LED)	2022
430	Powerline Trail S2	0.1391	Diverter installation (LED)	2021
431	Powerline Trail S2	0.0939	Diverter installation (LED)	2021
432	Powerline Trail S2	0.1595	Diverter installation (LED)	2022
433	Powerline Trail S2	0.1666	Diverter installation (LED)	2022
434	Powerline Trail N1	0.2799	Diverter installation (LED)	2022
435	Powerline Trail N1	0.1477	Diverter installation (LED)	2022
436	Powerline Trail N1	0.3084	Diverter installation (LED)	2022
437	Powerline Trail N1	0.1244	Diverter installation (LED)	2022
438	Powerline Trail N1	0.2152	Diverter installation (LED)	2021
439	Powerline Trail N1	0.1341	Diverter installation (LED)	2021
440	Powerline Trail N1	0.1106	Diverter installation (LED)	2022
441	Powerline Trail N1	0.2110	Diverter installation (LED)	2022
442	Powerline Trail N1	0.2128	Diverter installation (LED)	2021
443	Powerline Trail N1	0.1448	Diverter installation (LED)	2021
444	Powerline Trail N1	0.1405	Diverter installation (LED)	2022
445	Powerline Trail N1	0.1717	Diverter installation (LED)	2022
446	Powerline Trail N1	0.1995	Diverter installation (LED)	2021
447	Powerline Trail N1	0.1454	Diverter installation (LED)	2021
448	Powerline Trail N1	0.1167	Diverter installation (LED)	2022
449	Powerline Trail N1	0.1213	Diverter installation (LED)	2022
450	Powerline Trail N1	0.1961	Diverter installation (LED)	2021
451	Powerline Trail N1	0.2230	Diverter installation (LED)	2021
452	Powerline Trail N1	0.1729	Diverter installation (LED)	2022
453	Powerline Trail N1	0.1309	Diverter installation (LED)	2022
454	Powerline Trail N1	0.2701	Diverter installation (LED)	2022
455	Powerline Trail unminimized	0.1656	Diverter installation (LED)	2022
456	Powerline Trail unminimized	0.1799	Diverter installation (LED)	2022
457	Powerline Trail unminimized	0.1864	Diverter installation (LED)	2022
458	Powerline Trail unminimized	0.2883	Diverter installation (LED)	2022
459	Powerline Trail unminimized	0.2129	Diverter installation (LED)	2022

460	Powerline Trail unminimized	0.1549	Diverter installation (LED)	2022
461	Powerline Trail unminimized	0.1769	Diverter installation (LED)	2022
462	PLT to Hanalei Tap double circuit Transmission	0.3974	Diverter installation (LED)	2022
463	PLT to Hanalei Tap double circuit Transmission	0.2953	Diverter installation (LED)	2022
464	PLT to Hanalei Tap double circuit Transmission	0.3573	Diverter installation (Reflective)	2022
466	PLT to Hanalei Tap double circuit Transmission	0.3200	Diverter installation (Reflective)	2022
467	PLT to Hanalei Tap double circuit Transmission	0.5252	Diverter installation (Reflective)	2022
468	Hanalei Tap to Hanalei Taro Fields	0.1790	Diverter installation (Reflective)	2022
469	Hanalei Tap to Hanalei Taro Fields	0.1778	Diverter installation (Reflective)	2022
470	Hanalei Tap to Hanalei Taro Fields	0.1133	Diverter installation (Reflective)	2022
471	Hanalei Tap to Hanalei Taro Fields	0.0689	Diverter installation (Reflective)	2022
472	Hanalei Tap to Hanalei Taro Fields	0.0887	Diverter installation (Reflective)	2022
473	Hanalei Tap to Hanalei Taro Fields	0.0431	Diverter installation (Reflective)	2022
474	Hanalei Tap to Hanalei Taro Fields	0.0396	Diverter installation (Reflective)	2022
475	Hanalei Tap to Hanalei Taro Fields	0.0920	Diverter installation (Reflective)	2022
476	Hanalei Tap to Hanalei Taro Fields	0.1718	Diverter installation (Reflective)	2022
477	Hanalei Tap to Hanalei Taro Fields	0.0981	Diverter installation (Reflective)	2022
478	Hanalei Taro Fields to Wainiha Substation	0.5152	Diverter installation (Reflective)	2022
479	Hanalei Taro Fields to Wainiha Substation	0.4034	Diverter installation (Reflective)	2022
480	Hanalei Taro Fields to Wainiha Substation	0.4278	Diverter installation (Reflective)	2022
481	Hanalei Taro Fields to Wainiha Substation	0.4559	Diverter installation (Reflective)	2022
482	Hanalei Taro Fields to Wainiha Substation	0.7410	Diverter installation (Reflective)	2022
483	Hanalei Taro Fields to Wainiha Substation	0.4473	Diverter installation (Reflective)	2022
485	Hanalei Taro Fields to Wainiha Substation	0.2582	Diverter installation (Reflective)	2022
486	Port Allen to Halewili Positron	0.0780	Diverter installation (Reflective)	2022
486	Port Allen to Halewili Positron	0.0780	Static wire removal	2021
487	Port Allen to Halewili Positron	0.0810	Diverter installation (Reflective)	2021
487	Port Allen to Halewili Positron	0.0810	Static wire removal	2021
487	Port Allen to Halewili Positron	0.0810	Static wire removal	2021
488	Port Allen to Halewili Positron	0.0684	Diverter installation (Reflective)	2021
488	Port Allen to Halewili Positron	0.0684	Static wire removal	2021
488	Port Allen to Halewili Positron	0.0684	Static wire removal	2021
489	Port Allen to Halewili Positron	0.0663	Diverter installation (Reflective)	2021
489	Port Allen to Halewili Positron	0.0663	Static wire removal	2021
489	Port Allen to Halewili Positron	0.0663	Static wire removal	2021

490	Port Allen to Halewili Positron	0.0715	Diverter installation (Reflective)	2021
490	Port Allen to Halewili Positron	0.0715	Static wire removal	2021
490	Port Allen to Halewili Positron	0.0715	Static wire removal	2021
491	Port Allen to Halewili Positron	0.0687	Diverter installation (Reflective)	2021
491	Port Allen to Halewili Positron	0.0687	Static wire removal	2021
491	Port Allen to Halewili Positron	0.0687	Static wire removal	2021
492	Port Allen to Halewili Positron	0.0688	Diverter installation (Reflective)	2021
492	Port Allen to Halewili Positron	0.0688	Static wire removal	2021
492	Port Allen to Halewili Positron	0.0688	Static wire removal	2021
493	Port Allen to Halewili Positron	0.0697	Diverter installation (Reflective)	2021
493	Port Allen to Halewili Positron	0.0697	Static wire removal	2021
493	Port Allen to Halewili Positron	0.0697	Static wire removal	2021
494	Port Allen to Halewili Positron	0.0687	Diverter installation (Reflective)	2021
494	Port Allen to Halewili Positron	0.0687	Static wire removal	2021
494	Port Allen to Halewili Positron	0.0687	Static wire removal	2021
495	Port Allen to Halewili Positron	0.0755	Diverter installation (Reflective)	2021
495	Port Allen to Halewili Positron	0.0755	Static wire removal	2021
495	Port Allen to Halewili Positron	0.0755	Static wire removal	2021
496	Port Allen to Halewili Positron	0.0312	Diverter installation (Reflective)	2021
496	Port Allen to Halewili Positron	0.0312	Static wire removal	2021
496	Port Allen to Halewili Positron	0.0312	Static wire removal	2021
497	Port Allen to Halewili Positron	0.0574	Diverter installation (Reflective)	2021
497	Port Allen to Halewili Positron	0.0574	Static wire removal	2021
497	Port Allen to Halewili Positron	0.0574	Static wire removal	2021
498	Port Allen to Halewili Positron	0.0642	Diverter installation (Reflective)	2021
498	Port Allen to Halewili Positron	0.0642	Static wire removal	2021
498	Port Allen to Halewili Positron	0.0642	Static wire removal	2021
499	Port Allen to Halewili Positron	0.0607	Diverter installation (Reflective)	2021
499	Port Allen to Halewili Positron	0.0607	Static wire removal	2021
499	Port Allen to Halewili Positron	0.0607	Static wire removal	2021
500	Halewili Positron to Aepo Substation	0.0658	Diverter installation (Reflective)	2021
500	Halewili Positron to Aepo Substation	0.0658	Static wire removal	2022
501	Halewili Positron to Aepo Substation	0.0644	Diverter installation (Reflective)	2021
501	Halewili Positron to Aepo Substation	0.0644	Static wire removal	2022
502	Halewili Positron to Aepo Substation	0.0654	Diverter installation (Reflective)	2021

502	Halewili Positron to Aepo Substation	0.0654	Static wire removal	2022
503	Halewili Positron to Aepo Substation	0.0647	Diverter installation (Reflective)	2021
503	Halewili Positron to Aepo Substation	0.0647	Static wire removal	2022
504	Halewili Positron to Aepo Substation	0.0646	Diverter installation (Reflective)	2021
504	Halewili Positron to Aepo Substation	0.0646	Static wire removal	2022
505	Halewili Positron to Aepo Substation	0.0847	Diverter installation (Reflective)	2021
505	Halewili Positron to Aepo Substation	0.0847	Static wire removal	2022
506	Halewili Positron to Aepo Substation	0.0612	Diverter installation (Reflective)	2021
506	Halewili Positron to Aepo Substation	0.0612	Static wire removal	2022
507	Halewili Positron to Aepo Substation	0.0337	Diverter installation (Reflective)	2021
507	Halewili Positron to Aepo Substation	0.0337	Static wire removal	2022
508	Halewili Positron to Aepo Substation	0.0645	Diverter installation (Reflective)	2021
508	Halewili Positron to Aepo Substation	0.0645	Static wire removal	2022
509	Halewili Positron to Aepo Substation	0.0680	Diverter installation (Reflective)	2021
509	Halewili Positron to Aepo Substation	0.0680	Static wire removal	2022
510	Halewili Positron to Aepo Substation	0.0646	Diverter installation (Reflective)	2021
510	Halewili Positron to Aepo Substation	0.0646	Static wire removal	2022
511	Halewili Positron to Aepo Substation	0.0689	Diverter installation (Reflective)	2021
511	Halewili Positron to Aepo Substation	0.0689	Static wire removal	2022
512	Halewili Positron to Aepo Substation	0.0623	Diverter installation (Reflective)	2021
512	Halewili Positron to Aepo Substation	0.0623	Static wire removal	2022
513	Halewili Positron to Aepo Substation	0.0681	Diverter installation (Reflective)	2021
513	Halewili Positron to Aepo Substation	0.0681	Static wire removal	2022
514	Halewili Positron to Aepo Substation	0.0658	Diverter installation (Reflective)	2021
514	Halewili Positron to Aepo Substation	0.0658	Static wire removal	2022
515	Halewili Positron to Aepo Substation	0.0335	Diverter installation (Reflective)	2021
515	Halewili Positron to Aepo Substation	0.0335	Static wire removal	2022
516	Halewili Positron to Aepo Substation	0.0250	Diverter installation (Reflective)	2021
516	Halewili Positron to Aepo Substation	0.0250	Static wire removal	2022
517	Halewili Positron to Aepo Substation	0.0618	Diverter installation (Reflective)	2021
517	Halewili Positron to Aepo Substation	0.0618	Static wire removal	2022
518	Halewili Positron to Aepo Substation	0.0649	Diverter installation (Reflective)	2021
518	Halewili Positron to Aepo Substation	0.0649	Static wire removal	2022
519	Halewili Positron to Aepo Substation	0.0565	Diverter installation (Reflective)	2021
519	Halewili Positron to Aepo Substation	0.0565	Static wire removal	2022

520	Halewili Positron to Aepo Substation	0.0585	Diverter installation (Reflective)	2021
520	Halewili Positron to Aepo Substation	0.0585	Static wire removal	2022
521	Halewili Positron to Aepo Substation	0.0697	Diverter installation (Reflective)	2021
521	Halewili Positron to Aepo Substation	0.0697	Static wire removal	2022
522	Halewili Positron to Aepo Substation	0.0408	Diverter installation (Reflective)	2021
522	Halewili Positron to Aepo Substation	0.0408	Static wire removal	2022
523	Halewili Positron to Aepo Substation	0.0760	Diverter installation (Reflective)	2021
523	Halewili Positron to Aepo Substation	0.0760	Static wire removal	2022
524	Halewili Positron to Aepo Substation	0.0607	Diverter installation (Reflective)	2021
524	Halewili Positron to Aepo Substation	0.0607	Static wire removal	2022
525	Halewili Positron to Aepo Substation	0.0653	Diverter installation (Reflective)	2021
525	Halewili Positron to Aepo Substation	0.0653	Static wire removal	2022
526	Halewili Positron to Aepo Substation	0.0599	Diverter installation (Reflective)	2021
526	Halewili Positron to Aepo Substation	0.0599	Static wire removal	2022
527	Halewili Positron to Aepo Substation	0.0627	Diverter installation (Reflective)	2021
527	Halewili Positron to Aepo Substation	0.0627	Static wire removal	2022
528	Halewili Positron to Aepo Substation	0.0616	Diverter installation (Reflective)	2021
528	Halewili Positron to Aepo Substation	0.0616	Static wire removal	2022
529	Halewili Positron to Aepo Substation	0.0686	Diverter installation (Reflective)	2021
529	Halewili Positron to Aepo Substation	0.0686	Static wire removal	2022
530	Halewili Positron to Aepo Substation	0.0567	Diverter installation (Reflective)	2021
530	Halewili Positron to Aepo Substation	0.0567	Static wire removal	2022
531	Halewili Positron to Aepo Substation	0.0567	Diverter installation (Reflective)	2021
531	Halewili Positron to Aepo Substation	0.0567	Static wire removal	2022
532	Halewili Positron to Aepo Substation	0.0731	Diverter installation (Reflective)	2021
532	Halewili Positron to Aepo Substation	0.0731	Static wire removal	2022
533	Halewili Positron to Aepo Substation	0.0737	Diverter installation (Reflective)	2021
533	Halewili Positron to Aepo Substation	0.0737	Static wire removal	2022
534	Halewili Positron to Aepo Substation	0.0726	Diverter installation (Reflective)	2021
534	Halewili Positron to Aepo Substation	0.0726	Static wire removal	2022
535	Halewili Positron to Aepo Substation	0.0779	Diverter installation (Reflective)	2021
535	Halewili Positron to Aepo Substation	0.0779	Static wire removal	2022
536	Halewili Positron to Aepo Substation	0.0635	Diverter installation (Reflective)	2021
536	Halewili Positron to Aepo Substation	0.0635	Static wire removal	2022
537	Halewili Positron to Aepo Substation	0.0615	Diverter installation (Reflective)	2021

537	Halewili Positron to Aepo Substation	0.0615	Static wire removal	2022
538	Halewili Positron to Aepo Substation	0.0642	Diverter installation (Reflective)	2021
538	Halewili Positron to Aepo Substation	0.0642	Static wire removal	2022
539	Halewili Positron to Aepo Substation	0.0675	Diverter installation (Reflective)	2021
539	Halewili Positron to Aepo Substation	0.0675	Static wire removal	2022
540	Halewili Positron to Aepo Substation	0.0705	Diverter installation (Reflective)	2021
540	Halewili Positron to Aepo Substation	0.0705	Static wire removal	2022
541	Halewili Positron to Aepo Substation	0.0659	Diverter installation (Reflective)	2021
541	Halewili Positron to Aepo Substation	0.0659	Static wire removal	2022
542	Halewili Positron to Aepo Substation	0.0714	Diverter installation (Reflective)	2021
542	Halewili Positron to Aepo Substation	0.0714	Static wire removal	2022
543	Halewili Positron to Aepo Substation	0.0641	Diverter installation (Reflective)	2021
543	Halewili Positron to Aepo Substation	0.0641	Static wire removal	2022
544	Halewili Positron to Aepo Substation	0.0694	Diverter installation (Reflective)	2021
544	Halewili Positron to Aepo Substation	0.0694	Static wire removal	2022
545	Halewili Positron to Aepo Substation	0.0644	Diverter installation (Reflective)	2021
545	Halewili Positron to Aepo Substation	0.0644	Static wire removal	2022
546	Halewili Positron to Aepo Substation	0.0633	Diverter installation (Reflective)	2021
546	Halewili Positron to Aepo Substation	0.0633	Static wire removal	2022
547	Halewili Positron to Aepo Substation	0.0712	Diverter installation (Reflective)	2021
547	Halewili Positron to Aepo Substation	0.0712	Static wire removal	2022
548	Halewili Positron to Aepo Substation	0.0703	Diverter installation (Reflective)	2021
548	Halewili Positron to Aepo Substation	0.0703	Static wire removal	2022
549	Halewili Positron to Aepo Substation	0.0712	Diverter installation (Reflective)	2021
549	Halewili Positron to Aepo Substation	0.0712	Static wire removal	2022
550	Halewili Positron to Aepo Substation	0.0711	Diverter installation (Reflective)	2021
550	Halewili Positron to Aepo Substation	0.0711	Static wire removal	2022
551	Halewili Positron to Aepo Substation	0.0672	Diverter installation (Reflective)	2021
551	Halewili Positron to Aepo Substation	0.0672	Static wire removal	2022
552	Halewili Positron to Aepo Substation	0.0673	Diverter installation (Reflective)	2021
552	Halewili Positron to Aepo Substation	0.0673	Static wire removal	2022
553	Halewili Positron to Aepo Substation	0.0675	Diverter installation (Reflective)	2021
553	Halewili Positron to Aepo Substation	0.0675	Static wire removal	2022
554	Halewili Positron to Aepo Substation	0.0706	Diverter installation (Reflective)	2021
554	Halewili Positron to Aepo Substation	0.0706	Static wire removal	2022

555	Halewili Positron to Aepo Substation	0.0640	Diverter installation (Reflective)	2021
555	Halewili Positron to Aepo Substation	0.0640	Static wire removal	2022
556	Halewili Positron to Aepo Substation	0.0671	Diverter installation (Reflective)	2021
556	Halewili Positron to Aepo Substation	0.0671	Static wire removal	2022
557	Halewili Positron to Aepo Substation	0.0669	Diverter installation (Reflective)	2021
557	Halewili Positron to Aepo Substation	0.0669	Static wire removal	2022
558	Halewili Positron to Aepo Substation	0.0633	Diverter installation (Reflective)	2021
558	Halewili Positron to Aepo Substation	0.0633	Static wire removal	2022
559	Halewili Positron to Aepo Substation	0.0635	Diverter installation (Reflective)	2021
559	Halewili Positron to Aepo Substation	0.0635	Static wire removal	2022
560	Halewili Positron to Aepo Substation	0.0708	Diverter installation (Reflective)	2021
560	Halewili Positron to Aepo Substation	0.0708	Static wire removal	2022
561	Halewili Positron to Aepo Substation	0.0686	Diverter installation (Reflective)	2021
561	Halewili Positron to Aepo Substation	0.0686	Static wire removal	2022
562	Halewili Positron to Aepo Substation	0.0698	Diverter installation (Reflective)	2021
562	Halewili Positron to Aepo Substation	0.0698	Static wire removal	2022
563	Halewili Positron to Aepo Substation	0.0678	Diverter installation (Reflective)	2021
563	Halewili Positron to Aepo Substation	0.0678	Static wire removal	2022
564	Halewili Positron to Aepo Substation	0.0695	Diverter installation (Reflective)	2021
564	Halewili Positron to Aepo Substation	0.0695	Static wire removal	2022
565	Halewili Positron to Aepo Substation	0.0710	Diverter installation (Reflective)	2021
565	Halewili Positron to Aepo Substation	0.0710	Static wire removal	2022
566	Halewili Positron to Aepo Substation	0.0665	Diverter installation (Reflective)	2021
566	Halewili Positron to Aepo Substation	0.0665	Static wire removal	2022
567	Halewili Positron to Aepo Substation	0.0705	Diverter installation (Reflective)	2021
567	Halewili Positron to Aepo Substation	0.0705	Static wire removal	2022
568	Halewili Positron to Aepo Substation	0.0690	Diverter installation (Reflective)	2021
568	Halewili Positron to Aepo Substation	0.0690	Static wire removal	2022
569	Halewili Positron to Aepo Substation	0.0691	Diverter installation (Reflective)	2021
569	Halewili Positron to Aepo Substation	0.0691	Static wire removal	2022
570	Halewili Positron to Aepo Substation	0.0681	Diverter installation (Reflective)	2021
570	Halewili Positron to Aepo Substation	0.0681	Static wire removal	2022
571	Halewili Positron to Aepo Substation	0.0689	Diverter installation (Reflective)	2021
571	Halewili Positron to Aepo Substation	0.0689	Static wire removal	2022
572	Halewili Positron to Aepo Substation	0.0709	Diverter installation (Reflective)	2021

572	Halewili Positron to Aepo Substation	0.0709	Static wire removal	2022
573	Halewili Positron to Aepo Substation	0.0681	Diverter installation (Reflective)	2021
573	Halewili Positron to Aepo Substation	0.0681	Static wire removal	2022
574	Halewili Positron to Aepo Substation	0.0178	Diverter installation (Reflective)	2021
574	Halewili Positron to Aepo Substation	0.0178	Static wire removal	2022
575	Halewili Positron to Aepo Substation	0.0185	Diverter installation (Reflective)	2021
575	Halewili Positron to Aepo Substation	0.0185	Static wire removal	2022
576	Halewili Positron to Aepo Substation	0.0328	Diverter installation (Reflective)	2021
576	Halewili Positron to Aepo Substation	0.0328	Static wire removal	2022
577	Halewili Positron to Aepo Substation	0.0497	Diverter installation (Reflective)	2021
577	Halewili Positron to Aepo Substation	0.0497	Static wire removal	2022
578	Halewili Positron to Aepo Substation	0.0424	Diverter installation (Reflective)	2021
578	Halewili Positron to Aepo Substation	0.0424	Static wire removal	2022
579	Halewili Positron to Aepo Substation	0.0604	Diverter installation (Reflective)	2021
579	Halewili Positron to Aepo Substation	0.0604	Static wire removal	2022
580	Halewili Positron to Aepo Substation	0.0773	Diverter installation (Reflective)	2021
580	Halewili Positron to Aepo Substation	0.0773	Static wire removal	2022
581	Halewili Positron to Aepo Substation	0.2436	Static wire removal	2016
582	Halewili Positron to Aepo Substation	0.0785	Diverter installation (Reflective)	2022
582	Halewili Positron to Aepo Substation	0.0785	Static wire removal	2022
583	Halewili Positron to Aepo Substation	0.0789	Diverter installation (Reflective)	2021
583	Halewili Positron to Aepo Substation	0.0789	Static wire removal	2022
584	Halewili Positron to Aepo Substation	0.0679	Diverter installation (LED)	2021
584	Halewili Positron to Aepo Substation	0.0679	Static wire removal	2022
585	Halewili Positron to Aepo Substation	0.0579	Diverter installation (LED)	2021
585	Halewili Positron to Aepo Substation	0.0579	Static wire removal	2022
586	Halewili Positron to Aepo Substation	0.0744	Diverter installation (LED)	2021
586	Halewili Positron to Aepo Substation	0.0744	Static wire removal	2022
587	Halewili Positron to Aepo Substation	0.0626	Diverter installation (LED)	2021
587	Halewili Positron to Aepo Substation	0.0626	Static wire removal	2022
588	Halewili Positron to Aepo Substation	0.0430	Diverter installation (LED)	2021
588	Halewili Positron to Aepo Substation	0.0430	Static wire removal	2022
589	Halewili Positron to Aepo Substation	0.0527	Diverter installation (LED)	2021
589	Halewili Positron to Aepo Substation	0.0527	Static wire removal	2022
590	Halewili Positron to Aepo Substation	0.0791	Diverter installation (LED)	2021

590	Halewili Positron to Aepo Substation	0.0791	Static wire removal	2022
591	Halewili Positron to Aepo Substation	0.0523	Diverter installation (LED)	2021
591	Halewili Positron to Aepo Substation	0.0523	Static wire removal	2022
592	Halewili Positron to Aepo Substation	0.0572	Diverter installation (LED)	2021
592	Halewili Positron to Aepo Substation	0.0572	Static wire removal	2022
593	Halewili Positron to Aepo Substation	0.0668	Diverter installation (LED)	2021
593	Halewili Positron to Aepo Substation	0.0668	Static wire removal	2022
594	Halewili Positron to Aepo Substation	0.0550	Diverter installation (LED)	2021
594	Halewili Positron to Aepo Substation	0.0550	Static wire removal	2022
595	Halewili Positron to Aepo Substation	0.0804	Diverter installation (Reflective)	2021
595	Halewili Positron to Aepo Substation	0.0804	Static wire removal	2022
597	Aepo Substation to Kukuiula Riser	0.0686	Diverter installation (Reflective)	2021
597	Aepo Substation to Kukuiula Riser	0.0686	Static wire removal	2022
598	Aepo Substation to Kukuiula Riser	0.0979	Diverter installation (Reflective)	2021
598	Aepo Substation to Kukuiula Riser	0.0979	Static wire removal	2022
599	Aepo Substation to Kukuiula Riser	0.0643	Static wire removal	2022
600	Aepo Substation to Kukuiula Riser	0.0774	Static wire removal	2022
601	Aepo Substation to Kukuiula Riser	0.1030	Diverter installation (Reflective)	2022
601	Aepo Substation to Kukuiula Riser	0.1030	Static wire removal	2022
602.1	Aepo Substation to Kukuiula Riser	0.1324	Diverter installation (Reflective)	2021
602.1	Aepo Substation to Kukuiula Riser	0.1324	Static wire removal	2022
602.2	Aepo Substation to Kukuiula Riser	0.1324	Diverter installation (Reflective)	2021
602.2	Aepo Substation to Kukuiula Riser	0.1324	Static wire removal	2022
603	Aepo Substation to Kukuiula Riser	0.0885	Diverter installation (Reflective)	2021
603	Aepo Substation to Kukuiula Riser	0.0885	Static wire removal	2022
604	Aepo Substation to Kukuiula Riser	0.0468	Diverter installation (Reflective)	2021
604	Aepo Substation to Kukuiula Riser	0.0468	Static wire removal	2022
605	Aepo Substation to Kukuiula Riser	0.0502	Diverter installation (Reflective)	2021
605	Aepo Substation to Kukuiula Riser	0.0502	Static wire removal	2022
606	Aepo Substation to Kukuiula Riser	0.0792	Diverter installation (Reflective)	2021
606	Aepo Substation to Kukuiula Riser	0.0792	Static wire removal	2022
607	Aepo Substation to Kukuiula Riser	0.0678	Static wire removal	2022
608	Aepo Substation to Kukuiula Riser	0.0612	Static wire removal	2022
609	Aepo Substation to Kukuiula Riser	0.0691	Static wire removal	2022
610	Aepo Substation to Kukuiula Riser	0.0773	Static wire removal	2022

611	Aepo Substation to Kukuiula Riser	0.0712	Static wire removal	2022
612	Aepo Substation to Kukuiula Riser	0.0615	Diverter installation (Reflective)	2021
612	Aepo Substation to Kukuiula Riser	0.0615	Static wire removal	2022
613	Aepo Substation to Kukuiula Riser	0.0713	Diverter installation (Reflective)	2021
613	Aepo Substation to Kukuiula Riser	0.0713	Static wire removal	2022
614	Aepo Substation to Kukuiula Riser	0.0987	Diverter installation (Reflective)	2021
614	Aepo Substation to Kukuiula Riser	0.0987	Static wire removal	2022
615	Aepo Substation to Kukuiula Riser	0.0856	Static wire removal	2022
616	Aepo Substation to Kukuiula Riser	0.0637	Static wire removal	2022
617	Ko'ae Housing Project	0.0595	Underground	2022
618	Ko'ae Housing Project	0.0612	Underground	2022
619	Kiahuna Golf to Koloa Substation	0.0646	Static wire removal	2022
620	Kiahuna Golf to Koloa Substation	0.0693	Static wire removal	2022
621	Kiahuna Golf to Koloa Substation	0.0654	Static wire removal	2022
622	Kiahuna Golf to Koloa Substation	0.0745	Static wire removal	2022
623	Kiahuna Golf to Koloa Substation	0.0708	Static wire removal	2022
624	Kiahuna Golf to Koloa Substation	0.0713	Diverter installation (Reflective)	2021
624	Kiahuna Golf to Koloa Substation	0.0713	Static wire removal	2022
625	Kiahuna Golf to Koloa Substation	0.0706	Static wire removal	2022
626	Kiahuna Golf to Koloa Substation	0.0622	Static wire removal	2022
627	Kiahuna Golf to Koloa Substation	0.0710	Diverter installation (Reflective)	2021
627	Kiahuna Golf to Koloa Substation	0.0710	Static wire removal	2022
628	Kiahuna Golf to Koloa Substation	0.0638	Static wire removal	2022
629	Kiahuna Golf to Koloa Substation	0.0696	Diverter installation (Reflective)	2021
629	Kiahuna Golf to Koloa Substation	0.0696	Static wire removal	2022
630	Kiahuna Golf to Koloa Substation	0.0697	Diverter installation (Reflective)	2021
630	Kiahuna Golf to Koloa Substation	0.0697	Static wire removal	2022
631	Kiahuna Golf to Koloa Substation	0.0651	Diverter installation (Reflective)	2021
631	Kiahuna Golf to Koloa Substation	0.0651	Static wire removal	2022
632	Kiahuna Golf to Koloa Substation	0.0647	Diverter installation (Reflective)	2021
632	Kiahuna Golf to Koloa Substation	0.0647	Static wire removal	2022
633	Kiahuna Golf to Koloa Substation	0.0577	Diverter installation (Reflective)	2021
633	Kiahuna Golf to Koloa Substation	0.0577	Static wire removal	2022
634	Kiahuna Golf to Koloa Substation	0.0571	Diverter installation (Reflective)	2021
634	Kiahuna Golf to Koloa Substation	0.0571	Static wire removal	2022

635	Kiahuna Golf to Koloa Substation	0.0561	Diverter installation (Reflective)	2021
635	Kiahuna Golf to Koloa Substation	0.0561	Static wire removal	2022
636	Kiahuna Golf to Koloa Substation	0.0573	Diverter installation (Reflective)	2021
636	Kiahuna Golf to Koloa Substation	0.0573	Static wire removal	2022
637	Kiahuna Golf to Koloa Substation	0.0564	Diverter installation (Reflective)	2021
637	Kiahuna Golf to Koloa Substation	0.0564	Static wire removal	2022
638	Kiahuna Golf to Koloa Substation	0.0562	Diverter installation (Reflective)	2021
638	Kiahuna Golf to Koloa Substation	0.0562	Static wire removal	2022
639	Kiahuna Golf to Koloa Substation	0.0565	Diverter installation (Reflective)	2021
639	Kiahuna Golf to Koloa Substation	0.0565	Static wire removal	2022
640	Kiahuna Golf to Koloa Substation	0.0579	Diverter installation (Reflective)	2021
640	Kiahuna Golf to Koloa Substation	0.0579	Static wire removal	2022
641	Kiahuna Golf to Koloa Substation	0.0600	Diverter installation (Reflective)	2021
641	Kiahuna Golf to Koloa Substation	0.0600	Static wire removal	2022
642	Kiahuna Golf to Koloa Substation	0.0304	Diverter installation (Reflective)	2022
642	Kiahuna Golf to Koloa Substation	0.0304	Static wire removal	2022
643	Kiahuna Golf to Koloa Substation	0.0368	Diverter installation (Reflective)	2022
643	Kiahuna Golf to Koloa Substation	0.0368	Static wire removal	2022
644	Kiahuna Golf to Koloa Substation		Diverter installation (Reflective)	2021
645	Koloa Sub to Waita Reservoir	0.0558	Diverter installation (Reflective)	2021
645	Koloa Sub to Waita Reservoir	0.0558	Static wire removal	2021
646	Koloa Sub to Waita Reservoir	0.0649	Diverter installation (Reflective)	2021
646	Koloa Sub to Waita Reservoir	0.0649	Static wire removal	2021
647	Koloa Sub to Waita Reservoir	0.0724	Diverter installation (Reflective)	2021
647	Koloa Sub to Waita Reservoir	0.0724	Static wire removal	2021
648	Koloa Sub to Waita Reservoir	0.0708	Diverter installation (Reflective)	2021
648	Koloa Sub to Waita Reservoir	0.0708	Static wire removal	2021
649	Koloa Sub to Waita Reservoir	0.0713	Diverter installation (Reflective)	2021
649	Koloa Sub to Waita Reservoir	0.0713	Static wire removal	2021
650	Koloa Sub to Waita Reservoir	0.0700	Diverter installation (Reflective)	2021
650	Koloa Sub to Waita Reservoir	0.0700	Static wire removal	2021
651	Koloa Sub to Waita Reservoir	0.0928	Diverter installation (Reflective)	2021
651	Koloa Sub to Waita Reservoir	0.0928	Static wire removal	2021
652	Koloa Sub to Waita Reservoir	0.0980	Diverter installation (Reflective)	2021
652	Koloa Sub to Waita Reservoir	0.0980	Static wire removal	2021

653	Koloa Sub to Waita Reservoir	0.1253	Diverter installation (Reflective)	2021
653	Koloa Sub to Waita Reservoir	0.1253	Static wire removal	2021
654	Koloa Sub to Waita Reservoir	0.1114	Diverter installation (Reflective)	2021
654	Koloa Sub to Waita Reservoir	0.1114	Static wire removal	2021
655	Koloa Sub to Waita Reservoir	0.0938	Diverter installation (Reflective)	2021
655	Koloa Sub to Waita Reservoir	0.0938	Static wire removal	2021
656	Koloa Sub to Waita Reservoir	0.1049	Diverter installation (Reflective)	2021
656	Koloa Sub to Waita Reservoir	0.1049	Static wire removal	2021
657	Koloa Sub to Waita Reservoir	0.0916	Diverter installation (Reflective)	2021
657	Koloa Sub to Waita Reservoir	0.0916	Static wire removal	2021
658	Koloa Sub to Waita Reservoir	0.1013	Diverter installation (Reflective)	2021
658	Koloa Sub to Waita Reservoir	0.1013	Static wire removal	2021
659	Koloa Sub to Waita Reservoir	0.0858	Diverter installation (Reflective)	2021
659	Koloa Sub to Waita Reservoir	0.0858	Static wire removal	2021
660	Koloa Sub to Waita Reservoir	0.0911	Diverter installation (Reflective)	2021
660	Koloa Sub to Waita Reservoir	0.0911	Static wire removal	2021
661	Koloa Sub to Waita Reservoir	0.1104	Diverter installation (Reflective)	2021
661	Koloa Sub to Waita Reservoir	0.1104	Static wire removal	2021
662	Koloa Sub to Waita Reservoir	0.1923	Diverter installation (Reflective)	2021
662	Koloa Sub to Waita Reservoir	0.1923	Static wire removal	2021
663	Waita Reservoir to Radio Tower	0.0135	Diverter installation (Reflective)	2022
663	Waita Reservoir to Radio Tower	0.0135	Static wire removal	2022
664	Waita Reservoir to Radio Tower	0.3061	Diverter installation (LED)	2022
665	Waita Reservoir to Radio Tower	0.1862	Diverter installation (LED)	2022
666	Waita Reservoir to Radio Tower	0.1575	Diverter installation (LED)	2022
667	Waita Reservoir to Knudsen Gap (Hwy)	0.3960	Diverter installation (Reflective)	2021
667	Waita Reservoir to Knudsen Gap (Hwy)	0.3960	Static wire removal	2021
668	Waita Reservoir to Knudsen Gap (Hwy)	0.3524	Diverter installation (LED)	2021
668	Waita Reservoir to Knudsen Gap (Hwy)	0.3524	Static wire removal	2021
669	Waita Reservoir to Knudsen Gap (Hwy)	0.1474	Static wire removal	2021
670	Waita Reservoir to Knudsen Gap (Hwy)	0.1446	Diverter installation (LED)	2021
670	Waita Reservoir to Knudsen Gap (Hwy)	0.1446	Static wire removal	2021
671	Waita Reservoir to Knudsen Gap (Hwy)	0.2597	Diverter installation (LED)	2021
671	Waita Reservoir to Knudsen Gap (Hwy)	0.2597	Static wire removal	2021
672	Waita Reservoir to Knudsen Gap (Hwy)	0.2404	Diverter installation (LED)	2021

672	Waita Reservoir to Knudsen Gap (Hwy)	0.2404	Static wire removal	2021
673	Waita Reservoir to Knudsen Gap (Hwy)	0.2536	Diverter installation (LED)	2022
674	Waita Reservoir to Knudsen Gap (Hwy)	0.1797	Diverter installation (Reflective)	2022
674	Waita Reservoir to Knudsen Gap (Hwy)	0.1797	Static wire removal	2021
675	Waita Reservoir to Knudsen Gap (Hwy)	0.4354	Diverter installation (Reflective)	2022
675	Waita Reservoir to Knudsen Gap (Hwy)	0.4354	Static wire removal	2021
676	Waita Reservoir to Knudsen Gap (Hwy)	0.2852	Diverter installation (Reflective)	2022
676	Waita Reservoir to Knudsen Gap (Hwy)	0.2852	Static wire removal	2021
677	Knudsen Gap (Hwy) to Green Energy Substation	0.1025	Diverter installation (Reflective)	2022
677	Knudsen Gap (Hwy) to Green Energy Substation	0.1025	Static wire removal	2021
678	Knudsen Gap (Hwy) to Green Energy Substation	0.1063	Diverter installation (Reflective)	2021
678	Knudsen Gap (Hwy) to Green Energy Substation	0.1063	Static wire removal	2021
679	Knudsen Gap (Hwy) to Green Energy Substation	0.0964	Diverter installation (Reflective)	2021
679	Knudsen Gap (Hwy) to Green Energy Substation	0.0964	Static wire removal	2022
680	Green Energy Substation to Fujita Tap	0.0754	Diverter installation (Reflective)	2021
681	Green Energy Substation to Fujita Tap	0.0567	Diverter installation (LED)	2022
682	Green Energy Substation to Fujita Tap	0.0753	Diverter installation (LED)	2022
683	Green Energy Substation to Fujita Tap	0.1076	Diverter installation (LED)	2022
684	Green Energy Substation to Fujita Tap	0.1073	Diverter installation (LED)	2022
686	Fujita Tap to Kilohana Tap	0.1793	Diverter installation (LED)	2022
687	Fujita Tap to Kilohana Tap	0.1350	Diverter installation (LED)	2022
688	Fujita Tap to Kilohana Tap	0.1690	Diverter installation (LED)	2022
689	Fujita Tap to Kilohana Tap	0.2173	Diverter installation (LED)	2022
690	Fujita Tap to Kilohana Tap	0.0980	Diverter installation (LED)	2022
691	Fujita Tap to Kilohana Tap	0.2095	Diverter installation (LED)	2022
692	Fujita Tap to Kilohana Tap	0.1052	Diverter installation (LED)	2022
693	Fujita Tap to Kilohana Tap	0.0798	Diverter installation (LED)	2022
694	Fujita Tap to Kilohana Tap	0.1408	Diverter installation (LED)	2022
695	Fujita Tap to Kilohana Tap	0.0815	Diverter installation (LED)	2022
696	Fujita Tap to Kilohana Tap	0.0822	Diverter installation (LED)	2022
697	Fujita Tap to Kilohana Tap	0.0800	Diverter installation (LED)	2022
698	Fujita Tap to Kilohana Tap	0.0774	Diverter installation (LED)	2022
699	Fujita Tap to Kilohana Tap	0.1060	Diverter installation (Reflective)	2021
700	Fujita Tap to Kilohana Tap	0.0892	Diverter installation (Reflective)	2021
702	Kilohana Tap to Lihue Substation(a) (LC1)	0.0728	Diverter installation (Reflective)	2021

702	Kilohana Tap to Lihue Substation(a) (LC1)	0.0728	Reconfiguration	2020
702	Kilohana Tap to Lihue Substation(a) (LC1)	0.0728	Static wire removal	2020
703	Kilohana Tap to Lihue Substation(a) (LC1)	0.0895	Diverter installation (Reflective)	2021
703	Kilohana Tap to Lihue Substation(a) (LC1)	0.0895	Reconfiguration	2020
703	Kilohana Tap to Lihue Substation(a) (LC1)	0.0895	Static wire removal	2020
704	Kilohana Tap to Lihue Substation(a) (LC1)	0.0854	Diverter installation (Reflective)	2021
704	Kilohana Tap to Lihue Substation(a) (LC1)	0.0854	Reconfiguration	2020
704	Kilohana Tap to Lihue Substation(a) (LC1)	0.0854	Static wire removal	2020
705	Kilohana Tap to Lihue Substation(a) (LC1)	0.0859	Diverter installation (Reflective)	2021
705	Kilohana Tap to Lihue Substation(a) (LC1)	0.0859	Reconfiguration	2020
705	Kilohana Tap to Lihue Substation(a) (LC1)	0.0859	Static wire removal	2020
706	Kilohana Tap to Lihue Substation(a) (LC1)	0.0834	Diverter installation (Reflective)	2021
706	Kilohana Tap to Lihue Substation(a) (LC1)	0.0834	Reconfiguration	2020
706	Kilohana Tap to Lihue Substation(a) (LC1)	0.0834	Static wire removal	2020
707	Kilohana Tap to Lihue Substation(a) (LC1)	0.1774	Diverter installation (Reflective)	2021
707	Kilohana Tap to Lihue Substation(a) (LC1)	0.1774	Reconfiguration	2020
707	Kilohana Tap to Lihue Substation(a) (LC1)	0.1774	Static wire removal	2020
708	Kilohana Tap to Lihue Substation(a) (LC1)	0.1450	Diverter installation (Reflective)	2021
708	Kilohana Tap to Lihue Substation(a) (LC1)	0.1450	Reconfiguration	2020
708	Kilohana Tap to Lihue Substation(a) (LC1)	0.1450	Static wire removal	2020
709	Kilohana Tap to Lihue Substation(a) (LC1)	0.0935	Diverter installation (Reflective)	2021
709	Kilohana Tap to Lihue Substation(a) (LC1)	0.0935	Reconfiguration	2020
709	Kilohana Tap to Lihue Substation(a) (LC1)	0.0935	Static wire removal	2020
710	Kilohana Tap to Lihue Substation(a) (LC1)	0.0916	Diverter installation (Reflective)	2022
710	Kilohana Tap to Lihue Substation(a) (LC1)	0.0916	Reconfiguration	2020
710	Kilohana Tap to Lihue Substation(a) (LC1)	0.0916	Static wire removal	2020
711	Kilohana Tap to Lihue Substation(a) (LC1)	0.1607	Diverter installation (Reflective)	2021
711	Kilohana Tap to Lihue Substation(a) (LC1)	0.1607	Reconfiguration	2020
711	Kilohana Tap to Lihue Substation(a) (LC1)	0.1607	Static wire removal	2020
712	Kilohana Tap to Lihue Substation(a) (LC1)	0.1244	Diverter installation (Reflective)	2021
712	Kilohana Tap to Lihue Substation(a) (LC1)	0.1244	Reconfiguration	2020
712	Kilohana Tap to Lihue Substation(a) (LC1)	0.1244	Static wire removal	2020
713	Kilohana Tap to Lihue Substation(a) (LC1)	0.1135	Diverter installation (Reflective)	2021
713	Kilohana Tap to Lihue Substation(a) (LC1)	0.1135	Reconfiguration	2020
713	Kilohana Tap to Lihue Substation(a) (LC1)	0.1135	Static wire removal	2020

714	Kilohana Tap to Lihue Substation(a) (LC1)	0.0964	Diverter installation (Reflective)	2021
714	Kilohana Tap to Lihue Substation(a) (LC1)	0.0964	Reconfiguration	2020
714	Kilohana Tap to Lihue Substation(a) (LC1)	0.0964	Static wire removal	2020
715	Kilohana Tap to Lihue Substation(a) (LC1)	0.2038	Diverter installation (Reflective)	2022
715	Kilohana Tap to Lihue Substation(a) (LC1)	0.2038	Reconfiguration	2020
715	Kilohana Tap to Lihue Substation(a) (LC1)	0.2038	Static wire removal	2020
716	Kilohana Tap to Lihue Substation(a) (LC1)	0.3558	Diverter installation (Reflective)	2022
716	Kilohana Tap to Lihue Substation(a) (LC1)	0.3558	Reconfiguration	2020
716	Kilohana Tap to Lihue Substation(a) (LC1)	0.3558	Static wire removal	2020
717	Kilohana Tap to Lihue Substation(a) (LC1)	0.1917	Diverter installation (Reflective)	2022
717	Kilohana Tap to Lihue Substation(a) (LC1)	0.1917	Reconfiguration	2020
717	Kilohana Tap to Lihue Substation(a) (LC1)	0.1917	Static wire removal	2020
718	Kilohana Tap to Lihue Substation(a) (LC1)	0.3056	Diverter installation (LED)	2022
718	Kilohana Tap to Lihue Substation(a) (LC1)	0.3056	Static wire removal	2020
719	Kilohana Tap to Lihue Substation(b)	0.1462	Diverter installation (LED)	2022
719	Kilohana Tap to Lihue Substation(b)	0.1462	Static wire removal	2020
720	Kilohana Tap to Lihue Substation(b)	0.1221	Diverter installation (LED)	2022
720	Kilohana Tap to Lihue Substation(b)	0.1221	Static wire removal	2020
721	Kilohana Tap to Lihue Substation(b)	0.1834	Diverter installation (LED)	2022
721	Kilohana Tap to Lihue Substation(b)	0.1834	Static wire removal	2020
722	Kilohana Tap to Lihue Substation(b)	0.1344	Diverter installation (Reflective)	2022
722	Kilohana Tap to Lihue Substation(b)	0.1344	Static wire removal	2020
723	Kilohana Tap to Lihue Substation(b)	0.2187	Diverter installation (Reflective)	2022
723	Kilohana Tap to Lihue Substation(b)	0.2187	Static wire removal	2020
724	Kilohana Tap to Lihue Substation(b)	0.3255	Diverter installation (LED)	2022
724	Kilohana Tap to Lihue Substation(b)	0.3255	Static wire removal	2020
725	Kilohana Tap to Lihue Substation(b)	0.3022	Diverter installation (Reflective)	2021
725	Kilohana Tap to Lihue Substation(b)	0.3022	Static wire removal	2020
726	Kilohana Tap to Lihue Substation(b)	0.0873	Diverter installation (LED)	2022
727	Kilohana Tap to Lihue Substation(b)	0.0737	Diverter installation (Reflective)	2021
727	Kilohana Tap to Lihue Substation(b)	0.0737	Static wire removal	2022
728	Kilohana Tap to Lihue Substation(b)	0.0797	Diverter installation (Reflective)	2022
728	Kilohana Tap to Lihue Substation(b)	0.0797	Static wire removal	2022
729	Kilohana Tap to Lihue Substation(b)	0.1046	Diverter installation (Reflective)	2021
729	Kilohana Tap to Lihue Substation(b)	0.1046	Static wire removal	2022

730	Kilohana Tap to Lihue Substation(b)	0.2566	Diverter installation (Reflective)	2022
730	Kilohana Tap to Lihue Substation(b)	0.2566	Static wire removal	2022
731	Kilohana Tap to Lihue Substation(b)	0.1121	Diverter installation (Reflective)	2022
731	Kilohana Tap to Lihue Substation(b)	0.1121	Static wire removal	2022
732	Kilohana Tap to Lihue Substation(b)	0.0911	Diverter installation (Reflective)	2022
732	Kilohana Tap to Lihue Substation(b)	0.0911	Static wire removal	2022
733	Lihue Substation to Ehiku Street	0.0543	Diverter installation (Reflective)	2022
734	Lihue Substation to Ehiku Street	0.0440	Diverter installation (Reflective)	2022
735	Lihue Substation to Ehiku Street	0.0463	Diverter installation (Reflective)	2022
736	Lihue Substation to Ehiku Street	0.0442	Diverter installation (Reflective)	2022
737	Lihue Substation to Ehiku Street	0.0213	Diverter installation (Reflective)	2022
738	Lihue Substation to Ehiku Street	0.0154	Diverter installation (Reflective)	2022
739	Lihue Substation to Ehiku Street	0.0990	Diverter installation (Reflective)	2022
740	Lihue Substation to Ehiku Street	0.0438	Diverter installation (Reflective)	2022
741	Lihue Substation to Ehiku Street	0.0863	Diverter installation (Reflective)	2022
742	Lihue Substation to Ehiku Street	0.0638	Diverter installation (Reflective)	2022
743	Lihue Substation to Ehiku Street	0.0478	Diverter installation (Reflective)	2022
744	Lihue Substation to Ehiku Street	0.0415	Diverter installation (Reflective)	2022
745	Lihue Substation to Ehiku Street	0.0407	Diverter installation (Reflective)	2022
746	Lihue Substation to Ehiku Street	0.0382	Diverter installation (Reflective)	2022
747	Lihue Substation to Ehiku Street	0.0515	Diverter installation (Reflective)	2022
748	Lihue Substation to Ehiku Street	0.0051	Diverter installation (Reflective)	2022
748	Lihue Substation to Ehiku Street	0.0051	Static wire removal	2022
749	Ehiku Street to Kapaia Substation	0.0431	Diverter installation (Reflective)	2021
749	Ehiku Street to Kapaia Substation	0.0431	Static wire removal	2021
750	Ehiku Street to Kapaia Substation	0.0593	Diverter installation (Reflective)	2021
750	Ehiku Street to Kapaia Substation	0.0593	Static wire removal	2021
751	Ehiku Street to Kapaia Substation	0.0506	Diverter installation (Reflective)	2021
751	Ehiku Street to Kapaia Substation	0.0506	Static wire removal	2021
752	Ehiku Street to Kapaia Substation	0.0538	Diverter installation (Reflective)	2021
752	Ehiku Street to Kapaia Substation	0.0538	Static wire removal	2021
753	Ehiku Street to Kapaia Substation	0.0494	Diverter installation (Reflective)	2021
753	Ehiku Street to Kapaia Substation	0.0494	Static wire removal	2021
754	Ehiku Street to Kapaia Substation	0.0449	Diverter installation (Reflective)	2021
754	Ehiku Street to Kapaia Substation	0.0449	Static wire removal	2021

755	Ehiku Street to Kapaia Substation	0.0542	Diverter installation (Reflective)	2021
755	Ehiku Street to Kapaia Substation	0.0542	Static wire removal	2021
756	Ehiku Street to Kapaia Substation	0.0527	Diverter installation (Reflective)	2021
756	Ehiku Street to Kapaia Substation	0.0527	Static wire removal	2021
757	Ehiku Street to Kapaia Substation	0.0429	Diverter installation (Reflective)	2021
757	Ehiku Street to Kapaia Substation	0.0429	Static wire removal	2021
758	Ehiku Street to Kapaia Substation	0.0543	Diverter installation (Reflective)	2021
758	Ehiku Street to Kapaia Substation	0.0543	Static wire removal	2021
759	Ehiku Street to Kapaia Substation	0.0565	Diverter installation (Reflective)	2021
759	Ehiku Street to Kapaia Substation	0.0565	Static wire removal	2021
760	Ehiku Street to Kapaia Substation	0.0436	Diverter installation (Reflective)	2021
760	Ehiku Street to Kapaia Substation	0.0436	Static wire removal	2021
761	Ehiku Street to Kapaia Substation	0.0702	Diverter installation (Reflective)	2021
761	Ehiku Street to Kapaia Substation	0.0702	Static wire removal	2021
762	Ehiku Street to Kapaia Substation	0.0606	Diverter installation (Reflective)	2021
762	Ehiku Street to Kapaia Substation	0.0606	Static wire removal	2021
763	Ehiku Street to Kapaia Substation	0.0547	Diverter installation (Reflective)	2021
763	Ehiku Street to Kapaia Substation	0.0547	Static wire removal	2021
764	Ehiku Street to Kapaia Substation	0.0532	Diverter installation (Reflective)	2021
764	Ehiku Street to Kapaia Substation	0.0532	Static wire removal	2021
765	Ehiku Street to Kapaia Substation	0.0497	Diverter installation (Reflective)	2021
765	Ehiku Street to Kapaia Substation	0.0497	Static wire removal	2021
766	Ehiku Street to Kapaia Substation	0.0578	Diverter installation (Reflective)	2021
766	Ehiku Street to Kapaia Substation	0.0578	Static wire removal	2021
767	Ehiku Street to Kapaia Substation	0.0445	Diverter installation (Reflective)	2022
767	Ehiku Street to Kapaia Substation	0.0445	Static wire removal	2022
769	Ehiku Street to Kapaia Valley	0.0355	Diverter installation (Reflective)	2022
769	Ehiku Street to Kapaia Valley	0.0355	Static wire removal	2022
770	Ehiku Street to Kapaia Valley	0.0356	Diverter installation (Reflective)	2022
770	Ehiku Street to Kapaia Valley	0.0356	Static wire removal	2022
771	Ehiku Street to Kapaia Valley	0.0193	Diverter installation (Reflective)	2022
771	Ehiku Street to Kapaia Valley	0.0193	Static wire removal	2022
772	Ehiku Street to Kapaia Valley	0.0418	Diverter installation (Reflective)	2022
772	Ehiku Street to Kapaia Valley	0.0418	Static wire removal	2022
773	Ehiku Street to Kapaia Valley	0.0427	Diverter installation (Reflective)	2022

773	Ehiku Street to Kapaia Valley	0.0427	Static wire removal	2022
774	Ehiku Street to Kapaia Valley	0.0522	Diverter installation (Reflective)	2022
774	Ehiku Street to Kapaia Valley	0.0522	Static wire removal	2022
775.1	Ehiku Street to Kapaia Valley	0.0256	Diverter installation (Reflective)	2022
775.1	Ehiku Street to Kapaia Valley	0.0256	Static wire removal	2022
775.2	Ehiku street to Kapaia valley	0.0256	Diverter installation (Reflective)	2022
775.2	Ehiku street to Kapaia valley	0.0256	Static wire removal	2022
778	Ehiku Street to Kapaia Valley	0.1301	Diverter installation (Reflective)	2022
778	Ehiku Street to Kapaia Valley	0.1301	Static wire removal	2022
779	Ehiku Street to Kapaia Valley	0.0622	Diverter installation (Reflective)	2022
779	Ehiku Street to Kapaia Valley	0.0622	Static wire removal	2022
780	Ehiku Street to Kapaia Valley	0.1375	Diverter installation (Reflective)	2022
780	Ehiku Street to Kapaia Valley	0.1375	Static wire removal	2022
781	Ehiku Street to Kapaia Valley	0.1005	Diverter installation (Reflective)	2022
781	Ehiku Street to Kapaia Valley	0.1005	Static wire removal	2022
782	Ehiku Street to Kapaia Valley	0.0424	Diverter installation (Reflective)	2022
782	Ehiku Street to Kapaia Valley	0.0424	Static wire removal	2022
783	Kapaia Valley to Lydgate Substation	0.0356	Diverter installation (Reflective)	2022
784	Kapaia Valley to Lydgate Substation	0.0223	Diverter installation (Reflective)	2022
785	Kapaia Valley to Lydgate Substation	0.0343	Diverter installation (Reflective)	2022
786	Kapaia Valley to Lydgate Substation	0.0765	Diverter installation (Reflective)	2022
787	Kapaia Valley to Lydgate Substation	0.0391	Diverter installation (Reflective)	2022
788	Kapaia Valley to Lydgate Substation	0.0405	Diverter installation (Reflective)	2022
789	Kapaia Valley to Lydgate Substation	0.0725	Diverter installation (Reflective)	2022
790	Kapaia Valley to Lydgate Substation	0.0769	Diverter installation (Reflective)	2022
791	Kapaia Valley to Lydgate Substation	0.0587	Diverter installation (Reflective)	2022
792	Kapaia Valley to Lydgate Substation	0.0490	Diverter installation (Reflective)	2022
793	Kapaia Valley to Lydgate Substation	0.0569	Diverter installation (Reflective)	2022
794	Kapaia Valley to Lydgate Substation	0.0458	Diverter installation (Reflective)	2022
795	Kapaia Valley to Lydgate Substation	0.0439	Diverter installation (Reflective)	2022
796	Kapaia Valley to Lydgate Substation	0.0552	Diverter installation (Reflective)	2022
797	Kapaia Valley to Lydgate Substation	0.0334	Diverter installation (Reflective)	2022
798	Kapaia Valley to Lydgate Substation	0.0411	Diverter installation (Reflective)	2022
799	Kapaia Valley to Lydgate Substation	0.0786	Diverter installation (Reflective)	2022
800	Kapaia Valley to Lydgate Substation	0.0694	Diverter installation (Reflective)	2022

801	Kapaia Valley to Lydgate Substation	0.0606	Diverter installation (Reflective)	2022
802.1	Kapaia Valley to Lydgate Substation	0.0275	Diverter installation (Reflective)	2022
802.2	Kapaia Valley to Lydgate Substation	0.0275	Diverter installation (Reflective)	2022
803	Kapaia Valley to Lydgate Substation	0.0551	Diverter installation (Reflective)	2022
804	Kapaia Valley to Lydgate Substation	0.0715	Diverter installation (Reflective)	2022
805	Kapaia Valley to Lydgate Substation	0.0371	Diverter installation (Reflective)	2022
806	Kapaia Valley to Lydgate Substation	0.0319	Diverter installation (Reflective)	2022
807	Kapaia Valley to Lydgate Substation	0.0713	Diverter installation (Reflective)	2022
808	Kapaia Valley to Lydgate Substation	0.0572	Diverter installation (Reflective)	2022
809	Kapaia Valley to Lydgate Substation	0.0298	Diverter installation (Reflective)	2022
810	Kapaia Valley to Lydgate Substation	0.0569	Diverter installation (Reflective)	2022
811	Kapaia Valley to Lydgate Substation	0.0356	Diverter installation (Reflective)	2022
812	Kapaia Valley to Lydgate Substation	0.0582	Diverter installation (Reflective)	2022
813	Kapaia Valley to Lydgate Substation	0.0763	Diverter installation (Reflective)	2022
814	Kapaia Valley to Lydgate Substation	0.0870	Diverter installation (Reflective)	2022
815	Kapaia Valley to Lydgate Substation	0.0835	Diverter installation (Reflective)	2022
816.1	Kapaia Valley to Lydgate Substation	0.0400	Diverter installation (Reflective)	2022
816.2	Kapaia Valley to Lydgate Substation	0.0400	Diverter installation (Reflective)	2022
817	Kapaia Valley to Lydgate Substation	0.0801	Diverter installation (Reflective)	2022
818	Kapaia Valley to Lydgate Substation	0.0800	Diverter installation (Reflective)	2022
819	Kapaia Valley to Lydgate Substation	0.0862	Diverter installation (Reflective)	2022
820	Kapaia Valley to Lydgate Substation	0.0828	Diverter installation (Reflective)	2022
821	Kapaia Valley to Lydgate Substation	0.0844	Diverter installation (Reflective)	2022
822	Kapaia Valley to Lydgate Substation	0.0838	Diverter installation (Reflective)	2022
823	Kapaia Valley to Lydgate Substation	0.0269	Diverter installation (Reflective)	2022
824	Kapaia Valley to Lydgate Substation	0.0629	Diverter installation (Reflective)	2022
825	Kapaia Valley to Lydgate Substation	0.0772	Diverter installation (Reflective)	2022
826	Kapaia Valley to Lydgate Substation	0.0780	Diverter installation (Reflective)	2022
827	Kapaia Valley to Lydgate Substation	0.0707	Diverter installation (Reflective)	2022
828	Kapaia Valley to Lydgate Substation	0.0626	Diverter installation (Reflective)	2022
829	Kapaia Valley to Lydgate Substation	0.0637	Diverter installation (Reflective)	2022
830	Kapaia Valley to Lydgate Substation	0.0622	Diverter installation (Reflective)	2022
831	Kapaia Valley to Lydgate Substation	0.0686	Diverter installation (Reflective)	2022
832	Kapaia Valley to Lydgate Substation	0.0357	Diverter installation (Reflective)	2022
833	Kapaia Valley to Lydgate Substation	0.0712	Diverter installation (Reflective)	2022

834	Kapaia Valley to Lydgate Substation	0.0424	Diverter installation (Reflective)	2022
835	Kapaia Valley to Lydgate Substation	0.0263	Diverter installation (Reflective)	2022
836	Kapaia Valley to Lydgate Substation	0.0260	Diverter installation (Reflective)	2022
837	Kapaia Valley to Lydgate Substation	0.0232	Diverter installation (Reflective)	2022
838	Kapaia Valley to Lydgate Substation	0.0424	Diverter installation (Reflective)	2022
838	Kapaia Valley to Lydgate Substation	0.0424	Static wire removal	2022
839	Kapaia Valley to Lydgate Substation	0.0465	Diverter installation (Reflective)	2022
839	Kapaia Valley to Lydgate Substation	0.0465	Static wire removal	2022
840	Kapaia Valley to Lydgate Substation	0.0904	Diverter installation (Reflective)	2022
840	Kapaia Valley to Lydgate Substation	0.0904	Static wire removal	2022
841	Kapaia Valley to Lydgate Substation	0.0890	Diverter installation (Reflective)	2022
841	Kapaia Valley to Lydgate Substation	0.0890	Static wire removal	2022
842	Kapaia Valley to Lydgate Substation	0.0908	Diverter installation (Reflective)	2022
842	Kapaia Valley to Lydgate Substation	0.0908	Static wire removal	2022
843	Kapaia Valley to Lydgate Substation	0.0923	Diverter installation (Reflective)	2022
843	Kapaia Valley to Lydgate Substation	0.0923	Static wire removal	2022
844	Kapaia Valley to Lydgate Substation	0.0951	Diverter installation (Reflective)	2022
844	Kapaia Valley to Lydgate Substation	0.0951	Static wire removal	2022
846	Lydgate Substation to Kuamoo Rd	0.0569	Diverter installation (Reflective)	2022
846	Lydgate Substation to Kuamoo Rd	0.0569	Static wire removal	2022
847	Lydgate Substation to Kuamoo Rd	0.0285	Diverter installation (Reflective)	2022
847	Lydgate Substation to Kuamoo Rd	0.0285	Static wire removal	2022
848	Lydgate Substation to Kuamoo Rd	0.0427	Diverter installation (Reflective)	2022
848	Lydgate Substation to Kuamoo Rd	0.0427	Static wire removal	2022
849	Lydgate Substation to Kuamoo Rd	0.0515	Diverter installation (Reflective)	2022
849	Lydgate Substation to Kuamoo Rd	0.0515	Static wire removal	2022
850	Lydgate Substation to Kuamoo Rd	0.0428	Diverter installation (Reflective)	2022
850	Lydgate Substation to Kuamoo Rd	0.0428	Static wire removal	2022
851	Lydgate Substation to Kuamoo Rd	0.0468	Diverter installation (Reflective)	2022
851	Lydgate Substation to Kuamoo Rd	0.0468	Static wire removal	2022
852	Lydgate Substation to Kuamoo Rd	0.0348	Diverter installation (Reflective)	2022
852	Lydgate Substation to Kuamoo Rd	0.0348	Static wire removal	2022
853	Lydgate Substation to Kuamoo Rd	0.0352	Diverter installation (Reflective)	2022
853	Lydgate Substation to Kuamoo Rd	0.0352	Static wire removal	2022
854	Lydgate Substation to Kuamoo Rd	0.0346	Diverter installation (Reflective)	2022

854	Lydgate Substation to Kuamoo Rd	0.0346	Static wire removal	2022
855	Lydgate Substation to Kuamoo Rd	0.0481	Diverter installation (Reflective)	2022
855	Lydgate Substation to Kuamoo Rd	0.0481	Static wire removal	2022
856	Lydgate Substation to Kuamoo Rd	0.0474	Diverter installation (Reflective)	2022
856	Lydgate Substation to Kuamoo Rd	0.0474	Static wire removal	2022
857	Lydgate Substation to Kuamoo Rd	0.0406	Diverter installation (Reflective)	2022
857	Lydgate Substation to Kuamoo Rd	0.0406	Static wire removal	2022
858	Lydgate Substation to Kuamoo Rd	0.0262	Diverter installation (Reflective)	2022
859	Lydgate Substation to Kuamoo Rd	0.0273	Diverter installation (Reflective)	2022
860	Lydgate Substation to Kuamoo Rd	0.0463	Diverter installation (Reflective)	2022
861	Lydgate Substation to Kuamoo Rd	0.0754	Diverter installation (Reflective)	2022
862	Lydgate Substation to Kuamoo Rd	0.0995	Diverter installation (Reflective)	2022
863	Lydgate Substation to Kuamoo Rd	0.0375	Diverter installation (Reflective)	2022
864	Lydgate Substation to Kuamoo Rd	0.0425	Diverter installation (Reflective)	2022
865	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0374	Diverter installation (Reflective)	2022
866	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0459	Diverter installation (Reflective)	2022
867	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0451	Diverter installation (Reflective)	2022
868	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0387	Diverter installation (Reflective)	2022
869	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0436	Diverter installation (Reflective)	2022
870	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0439	Diverter installation (Reflective)	2022
871	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0352	Diverter installation (Reflective)	2022
872	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0290	Diverter installation (Reflective)	2022
873	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0397	Diverter installation (Reflective)	2022
874	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0636	Diverter installation (Reflective)	2022
875	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0613	Diverter installation (Reflective)	2022
876	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0466	Diverter installation (Reflective)	2022
877	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0441	Diverter installation (Reflective)	2022
878	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0423	Diverter installation (Reflective)	2022
879	Kuamoo Rd to Kapaa Bypass Rd (Wailua widening project 2020-2021)	0.0364	Diverter installation (Reflective)	2022
880	Kapaa Bypass Rd to Kapaa Substation	0.0496	Diverter installation (Reflective)	2022
881	Kapaa Bypass Rd to Kapaa Substation	0.0428	Diverter installation (Reflective)	2022
882	Kapaa Bypass Rd to Kapaa Substation	0.0435	Diverter installation (Reflective)	2022
883	Kapaa Bypass Rd to Kapaa Substation	0.0406	Diverter installation (Reflective)	2022
884	Kapaa Bypass Rd to Kapaa Substation	0.0416	Diverter installation (Reflective)	2022
885	Kapaa Bypass Rd to Kapaa Substation	0.0411	Diverter installation (Reflective)	2022

886	Kapaa Bypass Rd to Kapaa Substation	0.0423	Diverter installation (Reflective)	2022
887	Kapaa Bypass Rd to Kapaa Substation	0.0414	Diverter installation (Reflective)	2022
888	Kapaa Bypass Rd to Kapaa Substation	0.0422	Diverter installation (Reflective)	2022
889	Kapaa Bypass Rd to Kapaa Substation	0.0241	Diverter installation (Reflective)	2022
890	Kapaa Bypass Rd to Kapaa Substation	0.0298	Diverter installation (Reflective)	2022
891	Kapaa Bypass Rd to Kapaa Substation	0.0329	Diverter installation (Reflective)	2022
892	Kapaa Bypass Rd to Kapaa Substation	0.0361	Diverter installation (Reflective)	2022
893	Kapaa Bypass Rd to Kapaa Substation	0.0286	Diverter installation (Reflective)	2022
894	Kapaa Bypass Rd to Kapaa Substation	0.0392	Diverter installation (Reflective)	2022
895	Kapaa Bypass Rd to Kapaa Substation	0.0347	Diverter installation (Reflective)	2022
896	Kapaa Bypass Rd to Kapaa Substation	0.0453	Diverter installation (Reflective)	2022
897	Kapaa Bypass Rd to Kapaa Substation	0.0419	Diverter installation (Reflective)	2022
898	Kapaa Bypass Rd to Kapaa Substation	0.0450	Diverter installation (Reflective)	2022
899	Kapaa Bypass Rd to Kapaa Substation	0.0313	Diverter installation (Reflective)	2022
900	Kapaa Bypass Rd to Kapaa Substation	0.0343	Diverter installation (Reflective)	2022
901	Kapaa Bypass Rd to Kapaa Substation	0.0269	Diverter installation (Reflective)	2022
902	Kapaa Bypass Rd to Kapaa Substation	0.0255	Diverter installation (Reflective)	2022
903	Kapaa Bypass Rd to Kapaa Substation	0.0264	Diverter installation (Reflective)	2022
904	Kapaa Bypass Rd to Kapaa Substation	0.0453	Diverter installation (Reflective)	2022
905	Kapaa Bypass Rd to Kapaa Substation	0.0605	Diverter installation (Reflective)	2022
906	Kapaa Bypass Rd to Kapaa Substation	0.0167	Diverter installation (Reflective)	2022
907	Kapaa Bypass Rd to Kapaa Substation	0.0231	Diverter installation (Reflective)	2022
908	Kapaa Bypass Rd to Kapaa Substation	0.0309	Diverter installation (Reflective)	2022
909	Kapaa Bypass Rd to Kapaa Substation	0.0345	Diverter installation (Reflective)	2022
910	Kapaa Bypass Rd to Kapaa Substation	0.0321	Diverter installation (Reflective)	2022
911	Kapaa Bypass Rd to Kapaa Substation	0.0629	Diverter installation (Reflective)	2022
912	Kapaa Bypass Rd to Kapaa Substation	0.0610	Diverter installation (Reflective)	2022
913	Kapaa Bypass Rd to Kapaa Substation	0.0609	Diverter installation (Reflective)	2022
914	Kapaa Bypass Rd to Kapaa Substation	0.0571	Diverter installation (Reflective)	2022
915	Kapaa Bypass Rd to Kapaa Substation	0.0586	Diverter installation (Reflective)	2022
916	Kapaa Bypass Rd to Kapaa Substation	0.0225	Diverter installation (Reflective)	2022
917	Kapaa Bypass Rd to Kapaa Substation	0.0301	Diverter installation (Reflective)	2022
919	Kapaa Bypass Rd to Kapaa Substation	0.0110	Diverter installation (Reflective)	2022
920	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0432	Static wire removal	2021
921	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0398	Diverter installation (Reflective)	2021

921	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0398	Static wire removal	2021
922	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0755	Diverter installation (Reflective)	2021
922	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0755	Static wire removal	2021
922	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0755	Static wire removal	2021
923	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0933	Diverter installation (Reflective)	2021
923	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0933	Static wire removal	2021
924	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0708	Diverter installation (Reflective)	2021
924	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0708	Static wire removal	2021
925	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0716	Diverter installation (Reflective)	2021
925	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0716	Static wire removal	2021
926	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0708	Diverter installation (Reflective)	2021
926	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0708	Static wire removal	2021
926	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0708	Static wire removal	2021
927	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0605	Diverter installation (Reflective)	2022
927	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0605	Static wire removal	2021
928	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1740	Diverter installation (Reflective)	2022
928	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1740	Static wire removal	2021
929	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0945	Diverter installation (Reflective)	2022
929	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0945	Static wire removal	2021
930	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1246	Diverter installation (Reflective)	2021
930	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1246	Static wire removal	2021
931	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1620	Diverter installation (Reflective)	2021
931	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1620	Static wire removal	2021
932	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0856	Diverter installation (Reflective)	2022
932	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0856	Static wire removal	2021
933	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1090	Diverter installation (Reflective)	2022
933	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1090	Static wire removal	2021
934	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1098	Diverter installation (Reflective)	2022
934	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1098	Static wire removal	2021
935	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1602	Diverter installation (Reflective)	2022
935	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1602	Static wire removal	2021
936	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1119	Diverter installation (Reflective)	2022
936	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1119	Static wire removal	2021
937	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0721	Diverter installation (Reflective)	2021
937	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0721	Static wire removal	2021

938	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0696	Diverter installation (Reflective)	2021
938	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0696	Static wire removal	2021
939	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0672	Diverter installation (Reflective)	2021
939	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0672	Static wire removal	2021
940	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0828	Diverter installation (Reflective)	2021
940	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0828	Static wire removal	2021
941	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0569	Diverter installation (Reflective)	2021
941	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0569	Static wire removal	2021
942	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0856	Diverter installation (Reflective)	2021
942	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0856	Static wire removal	2021
943	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0711	Diverter installation (Reflective)	2021
943	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0711	Static wire removal	2021
944	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0769	Diverter installation (Reflective)	2021
944	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0769	Static wire removal	2021
945	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0605	Diverter installation (Reflective)	2021
945	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0605	Static wire removal	2021
946	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.2073	Diverter installation (Reflective)	2021
946	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.2073	Static wire removal	2021
947	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0935	Diverter installation (Reflective)	2021
947	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0935	Static wire removal	2021
948	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0452	Diverter installation (Reflective)	2021
948	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0452	Static wire removal	2021
949	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0469	Diverter installation (Reflective)	2021
949	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0469	Static wire removal	2021
950	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0724	Diverter installation (Reflective)	2021
950	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0724	Static wire removal	2021
951	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0518	Diverter installation (Reflective)	2021
951	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0518	Static wire removal	2021
952	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0639	Diverter installation (Reflective)	2021
952	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0639	Static wire removal	2021
953	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0803	Diverter installation (Reflective)	2021
953	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0803	Static wire removal	2021
954	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0530	Diverter installation (Reflective)	2021
954	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0530	Static wire removal	2021
955	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0623	Diverter installation (Reflective)	2021

955	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0623	Static wire removal	2021
956	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0835	Diverter installation (Reflective)	2021
956	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0835	Static wire removal	2021
957	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0945	Diverter installation (Reflective)	2021
957	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0945	Static wire removal	2021
958	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0671	Diverter installation (Reflective)	2021
958	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0671	Static wire removal	2021
959	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0782	Diverter installation (Reflective)	2021
959	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0782	Static wire removal	2021
960	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0555	Diverter installation (Reflective)	2021
960	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0555	Static wire removal	2021
961	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0747	Diverter installation (Reflective)	2021
961	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0747	Static wire removal	2021
962	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0729	Diverter installation (Reflective)	2021
962	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0729	Static wire removal	2021
963	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0723	Diverter installation (Reflective)	2021
963	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0723	Static wire removal	2021
964	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0827	Diverter installation (Reflective)	2021
964	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0827	Static wire removal	2021
965	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0593	Diverter installation (Reflective)	2021
965	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0593	Static wire removal	2021
966	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0722	Diverter installation (Reflective)	2021
966	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0722	Static wire removal	2021
967	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1040	Diverter installation (Reflective)	2021
967	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1040	Static wire removal	2021
968	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1768	Diverter installation (Reflective)	2021
968	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1768	Static wire removal	2021
969	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1294	Diverter installation (Reflective)	2021
969	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1294	Static wire removal	2021
970	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0856	Diverter installation (Reflective)	2021
970	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0856	Static wire removal	2021
971	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.2212	Diverter installation (Reflective)	2021
971	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.2212	Static wire removal	2021
972	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0773	Diverter installation (Reflective)	2021
972	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.0773	Static wire removal	2021

973	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1124	Diverter installation (Reflective)	2021
973	Kapaa Substation to Olohena/Waipouli Rd Intersection	0.1124	Static wire removal	2021
974	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1767	Diverter installation (Reflective)	2022
974	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1767	Static wire removal	2021
975	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1964	Diverter installation (Reflective)	2022
975	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1964	Static wire removal	2021
976	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.2155	Diverter installation (Reflective)	2022
976	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.2155	Static wire removal	2021
977	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1273	Diverter installation (Reflective)	2022
977	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1273	Static wire removal	2021
978	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.0892	Diverter installation (Reflective)	2022
978	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.0892	Static wire removal	2021
979	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.2038	Diverter installation (Reflective)	2022
979	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.2038	Static wire removal	2021
980	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1911	Diverter installation (Reflective)	2022
980	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1911	Static wire removal	2021
981	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1090	Diverter installation (Reflective)	2022
981	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1090	Static wire removal	2021
982	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.0504	Diverter installation (Reflective)	2022
982	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.0504	Static wire removal	2021
983	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1576	Diverter installation (Reflective)	2022
983	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1576	Static wire removal	2021
984	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.0688	Diverter installation (Reflective)	2022
984	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.0688	Static wire removal	2021
985	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1703	Diverter installation (Reflective)	2022
985	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1703	Static wire removal	2021
986	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.0654	Diverter installation (Reflective)	2022
986	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.0654	Static wire removal	2021
987	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1399	Diverter installation (Reflective)	2022
987	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1399	Static wire removal	2021
988	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1470	Diverter installation (Reflective)	2022
988	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1470	Static wire removal	2021
989	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.2306	Diverter installation (Reflective)	2022
989	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.2306	Static wire removal	2021
990	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1058	Diverter installation (Reflective)	2022

990	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1058	Static wire removal	2021
991	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1094	Diverter installation (Reflective)	2022
991	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1094	Static wire removal	2021
992	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1181	Diverter installation (Reflective)	2022
992	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.1181	Static wire removal	2021
993	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.0808	Diverter installation (Reflective)	2022
993	Olohena/Waipouli Rd Intersection to Hanahanapuni Tap	0.0808	Static wire removal	2021
995	Kapaa Substation to Mailihuna Rd	0.0739	Diverter installation (Reflective)	2021
995	Kapaa Substation to Mailihuna Rd	0.0739	Static wire removal	2022
996	Kapaa Substation to Mailihuna Rd	0.0728	Diverter installation (Reflective)	2021
996	Kapaa Substation to Mailihuna Rd	0.0728	Static wire removal	2022
997	Kapaa Substation to Mailihuna Rd	0.0816	Diverter installation (Reflective)	2021
997	Kapaa Substation to Mailihuna Rd	0.0816	Static wire removal	2022
998	Kapaa Substation to Mailihuna Rd	0.0783	Diverter installation (Reflective)	2021
998	Kapaa Substation to Mailihuna Rd	0.0783	Static wire removal	2022
999	Kapaa Substation to Mailihuna Rd	0.0931	Diverter installation (Reflective)	2021
999	Kapaa Substation to Mailihuna Rd	0.0931	Static wire removal	2022
1000	Kapaa Substation to Mailihuna Rd	0.0969	Diverter installation (Reflective)	2021
1000	Kapaa Substation to Mailihuna Rd	0.0969	Static wire removal	2022
1001	Kapaa Substation to Mailihuna Rd	0.0129	Diverter installation (Reflective)	2021
1001	Kapaa Substation to Mailihuna Rd	0.0129	Static wire removal	2022
1002	Kapaa Substation to Mailihuna Rd	0.0846	Diverter installation (Reflective)	2021
1002	Kapaa Substation to Mailihuna Rd	0.0846	Static wire removal	2022
1003	Kapaa Substation to Mailihuna Rd	0.0753	Diverter installation (Reflective)	2021
1003	Kapaa Substation to Mailihuna Rd	0.0753	Static wire removal	2022
1004	Kapaa Substation to Mailihuna Rd	0.0807	Diverter installation (Reflective)	2021
1004	Kapaa Substation to Mailihuna Rd	0.0807	Static wire removal	2022
1005	Kapaa Substation to Mailihuna Rd	0.0846	Diverter installation (Reflective)	2021
1005	Kapaa Substation to Mailihuna Rd	0.0846	Static wire removal	2022
1006	Kapaa Substation to Mailihuna Rd	0.0404	Diverter installation (Reflective)	2021
1006	Kapaa Substation to Mailihuna Rd	0.0404	Static wire removal	2022
1007	Kapaa Substation to Mailihuna Rd	0.0464	Diverter installation (Reflective)	2022
1007	Kapaa Substation to Mailihuna Rd	0.0464	Static wire removal	2022
1008	Kapaa Substation to Mailihuna Rd	0.0350	Diverter installation (Reflective)	2022
1008	Kapaa Substation to Mailihuna Rd	0.0350	Static wire removal	2022

1009	Kapaa Substation to Mailihuna Rd	0.0358	Diverter installation (Reflective)	2022
1009	Kapaa Substation to Mailihuna Rd	0.0358	Static wire removal	2022
1010	Kapaa Substation to Mailihuna Rd	0.0315	Diverter installation (Reflective)	2022
1010	Kapaa Substation to Mailihuna Rd	0.0315	Static wire removal	2022
1011	Kapaa Substation to Mailihuna Rd	0.0034	Diverter installation (Reflective)	2022
1011	Kapaa Substation to Mailihuna Rd	0.0034	Static wire removal	2022
1012	Kapaa Substation to Mailihuna Rd	0.0240	Diverter installation (Reflective)	2022
1012	Kapaa Substation to Mailihuna Rd	0.0240	Static wire removal	2022
1013	Kapaa Substation to Mailihuna Rd	0.0264	Diverter installation (Reflective)	2022
1013	Kapaa Substation to Mailihuna Rd	0.0264	Static wire removal	2022
1014	Kapaa Substation to Mailihuna Rd	0.0259	Diverter installation (Reflective)	2022
1014	Kapaa Substation to Mailihuna Rd	0.0259	Static wire removal	2022
1015	Kapaa Substation to Mailihuna Rd	0.0325	Diverter installation (Reflective)	2022
1015	Kapaa Substation to Mailihuna Rd	0.0325	Static wire removal	2022
1016	Kapaa Substation to Mailihuna Rd	0.0374	Diverter installation (Reflective)	2022
1016	Kapaa Substation to Mailihuna Rd	0.0374	Static wire removal	2022
1017	Kapaa Substation to Mailihuna Rd	0.0359	Diverter installation (Reflective)	2023
1017	Kapaa Substation to Mailihuna Rd	0.0359	Static wire removal	2023
1018	Kapaa Substation to Mailihuna Rd	0.0247	Diverter installation (Reflective)	2023
1018	Kapaa Substation to Mailihuna Rd	0.0247	Static wire removal	2023
1019	Kapaa Substation to Mailihuna Rd	0.0241	Diverter installation (Reflective)	2023
1019	Kapaa Substation to Mailihuna Rd	0.0241	Static wire removal	2023
1020	Kapaa Substation to Mailihuna Rd	0.0305	Diverter installation (Reflective)	2023
1020	Kapaa Substation to Mailihuna Rd	0.0305	Static wire removal	2023
1021	Kapaa Substation to Mailihuna Rd	0.0116	Diverter installation (Reflective)	2023
1021	Kapaa Substation to Mailihuna Rd	0.0116	Static wire removal	2023
1022	Kapaa Substation to Mailihuna Rd	0.0289	Diverter installation (Reflective)	2023
1022	Kapaa Substation to Mailihuna Rd	0.0289	Static wire removal	2023
1023	Kapaa Substation to Mailihuna Rd	0.0417	Diverter installation (Reflective)	2023
1023	Kapaa Substation to Mailihuna Rd	0.0417	Static wire removal	2023
1024	Kapaa Substation to Mailihuna Rd	0.0340	Diverter installation (Reflective)	2023
1024	Kapaa Substation to Mailihuna Rd	0.0340	Static wire removal	2023
1025	Kapaa Substation to Mailihuna Rd	0.0368	Diverter installation (Reflective)	2023
1025	Kapaa Substation to Mailihuna Rd	0.0368	Static wire removal	2023
1026	Kapaa Substation to Mailihuna Rd	0.0397	Diverter installation (Reflective)	2022

1026	Kapaa Substation to Mailihuna Rd	0.0397	Static wire removal	2023
1027	Kapaa Substation to Mailihuna Rd	0.0368	Diverter installation (Reflective)	2022
1027	Kapaa Substation to Mailihuna Rd	0.0368	Static wire removal	2023
1028	Kapaa Substation to Mailihuna Rd	0.0391	Diverter installation (Reflective)	2022
1028	Kapaa Substation to Mailihuna Rd	0.0391	Static wire removal	2023
1029	Kapaa Substation to Mailihuna Rd	0.0352	Diverter installation (Reflective)	2022
1029	Kapaa Substation to Mailihuna Rd	0.0352	Static wire removal	2023
1030	Kapaa Substation to Mailihuna Rd	0.0362	Diverter installation (Reflective)	2022
1030	Kapaa Substation to Mailihuna Rd	0.0362	Static wire removal	2023
1031	Kapaa Substation to Mailihuna Rd	0.0445	Diverter installation (Reflective)	2022
1031	Kapaa Substation to Mailihuna Rd	0.0445	Static wire removal	2023
1032	Kapaa Substation to Mailihuna Rd	0.0380	Diverter installation (Reflective)	2023
1032	Kapaa Substation to Mailihuna Rd	0.0380	Static wire removal	2023
1033	Kapaa Substation to Mailihuna Rd	0.0407	Diverter installation (Reflective)	2023
1033	Kapaa Substation to Mailihuna Rd	0.0407	Static wire removal	2023
1034	Kapaa Substation to Mailihuna Rd	0.0327	Diverter installation (Reflective)	2023
1034	Kapaa Substation to Mailihuna Rd	0.0327	Static wire removal	2023
1035	Kapaa Substation to Mailihuna Rd	0.0472	Diverter installation (Reflective)	2023
1035	Kapaa Substation to Mailihuna Rd	0.0472	Static wire removal	2023
1036	Kapaa Substation to Mailihuna Rd	0.0472	Diverter installation (Reflective)	2023
1036	Kapaa Substation to Mailihuna Rd	0.0472	Static wire removal	2023
1037	Kapaa Substation to Mailihuna Rd	0.0328	Diverter installation (Reflective)	2023
1037	Kapaa Substation to Mailihuna Rd	0.0328	Static wire removal	2023
1038	Kapaa Substation to Mailihuna Rd	0.0270	Diverter installation (Reflective)	2023
1038	Kapaa Substation to Mailihuna Rd	0.0270	Static wire removal	2023
1039	Kapaa Substation to Mailihuna Rd	0.0345	Diverter installation (Reflective)	2023
1039	Kapaa Substation to Mailihuna Rd	0.0345	Static wire removal	2023
1040	Kapaa Substation to Mailihuna Rd	0.0343	Diverter installation (Reflective)	2022
1040	Kapaa Substation to Mailihuna Rd	0.0343	Static wire removal	2023
1041	Kapaa Substation to Mailihuna Rd	0.0326	Diverter installation (Reflective)	2023
1041	Kapaa Substation to Mailihuna Rd	0.0326	Static wire removal	2023
1042	Kapaa Substation to Mailihuna Rd	0.0402	Diverter installation (Reflective)	2023
1042	Kapaa Substation to Mailihuna Rd	0.0402	Static wire removal	2023
1043	Kapaa Substation to Mailihuna Rd	0.0432	Diverter installation (Reflective)	2023
1043	Kapaa Substation to Mailihuna Rd	0.0432	Static wire removal	2023

1044	Kapaa Substation to Mailihuna Rd	0.0381	Diverter installation (Reflective)	2023
1044	Kapaa Substation to Mailihuna Rd	0.0381	Static wire removal	2023
1045	Kealia Transmission Minimization Project	0.0443	Diverter installation (Reflective)	2023
1045	Kealia Transmission Minimization Project	0.0443	Static wire removal	2023
1046	Kealia Transmission Minimization Project	0.0624	Diverter installation (Reflective)	2022
1046	Kealia Transmission Minimization Project	0.0624	Static wire removal	2023
1047	Kealia Transmission Minimization Project	0.0356	Diverter installation (Reflective)	2022
1047	Kealia Transmission Minimization Project	0.0356	Static wire removal	2023
1048	Kealia Transmission Minimization Project	0.0785	Diverter installation (Reflective)	2022
1048	Kealia Transmission Minimization Project	0.0785	Static wire removal	2023
1049	Kealia Transmission Minimization Project	0.0822	Diverter installation (Reflective)	2022
1049	Kealia Transmission Minimization Project	0.0822	Static wire removal	2023
1050	Kealia Transmission Minimization Project	0.0784	Diverter installation (Reflective)	2022
1050	Kealia Transmission Minimization Project	0.0784	Static wire removal	2023
1051	Kealia Transmission Minimization Project	0.0459	Diverter installation (Reflective)	2022
1051	Kealia Transmission Minimization Project	0.0459	Static wire removal	2023
1052	Kealia Transmission Minimization Project	0.0549	Diverter installation (Reflective)	2022
1052	Kealia Transmission Minimization Project	0.0549	Static wire removal	2023
1053	Kealia Transmission Minimization Project	0.1110	Diverter installation (Reflective)	2022
1053	Kealia Transmission Minimization Project	0.1110	Static wire removal	2023
1054	Kealia Transmission Minimization Project	0.0365	Diverter installation (Reflective)	2022
1054	Kealia Transmission Minimization Project	0.0365	Static wire removal	2023
1055	Kealia Transmission Minimization Project	0.0443	Diverter installation (Reflective)	2022
1055	Kealia Transmission Minimization Project	0.0443	Static wire removal	2023
1056	Kealia Transmission Minimization Project	0.0806	Diverter installation (Reflective)	2022
1056	Kealia Transmission Minimization Project	0.0806	Static wire removal	2023
1057	Kealia to Anahola Substation	0.0321	Diverter installation (Reflective)	2022
1057	Kealia to Anahola Substation	0.0321	Static wire removal	2023
1058	Kealia to Anahola Substation	0.0249	Diverter installation (Reflective)	2022
1058	Kealia to Anahola Substation	0.0249	Static wire removal	2023
1059	Kealia to Anahola Substation	0.0656	Diverter installation (Reflective)	2022
1059	Kealia to Anahola Substation	0.0656	Static wire removal	2023
1060	Kealia to Anahola Substation	0.0802	Diverter installation (Reflective)	2022
1060	Kealia to Anahola Substation	0.0802	Static wire removal	2023
1061	Kealia to Anahola Substation	0.0606	Diverter installation (Reflective)	2022

1061	Kealia to Anahola Substation	0.0606	Static wire removal	2023
1062	Kealia to Anahola Substation	0.0475	Diverter installation (Reflective)	2022
1062	Kealia to Anahola Substation	0.0475	Static wire removal	2023
1063	Kealia to Anahola Substation	0.0816	Diverter installation (Reflective)	2022
1063	Kealia to Anahola Substation	0.0816	Static wire removal	2023
1064	Kealia to Anahola Substation	0.1733	Diverter installation (Reflective)	2022
1064	Kealia to Anahola Substation	0.1733	Static wire removal	2023
1065	Kealia to Anahola Substation	0.0480	Diverter installation (Reflective)	2022
1065	Kealia to Anahola Substation	0.0480	Static wire removal	2023
1066	Kealia to Anahola Substation	0.0580	Diverter installation (Reflective)	2022
1066	Kealia to Anahola Substation	0.0580	Static wire removal	2023
1067	Kealia to Anahola Substation	0.0781	Diverter installation (Reflective)	2022
1067	Kealia to Anahola Substation	0.0781	Static wire removal	2023
1068	Kealia to Anahola Substation	0.0840	Diverter installation (Reflective)	2022
1068	Kealia to Anahola Substation	0.0840	Static wire removal	2023
1069	Kealia to Anahola Substation	0.0588	Diverter installation (Reflective)	2022
1069	Kealia to Anahola Substation	0.0588	Static wire removal	2023
1070	Kealia to Anahola Substation	0.0841	Diverter installation (Reflective)	2022
1070	Kealia to Anahola Substation	0.0841	Static wire removal	2023
1071	Kealia to Anahola Substation	0.0475	Diverter installation (Reflective)	2022
1071	Kealia to Anahola Substation	0.0475	Static wire removal	2023
1072	Kealia to Anahola Substation	0.2423	Diverter installation (Reflective)	2022
1072	Kealia to Anahola Substation	0.2423	Static wire removal	2023
1075.1	Kealia to Anahola Substation	0.0569	Diverter installation (Reflective)	2022
1075.1	Kealia to Anahola Substation	0.0569	Static wire removal	2023
1075.2	Kealia to Anahola Substation	0.0569	Diverter installation (Reflective)	2022
1075.2	Kealia to Anahola Substation	0.0569	Static wire removal	2023
1076	Kealia to Anahola Substation	0.0533	Diverter installation (Reflective)	2022
1076	Kealia to Anahola Substation	0.0533	Static wire removal	2023
1077	Kealia to Anahola Substation	0.0571	Diverter installation (Reflective)	2022
1077	Kealia to Anahola Substation	0.0571	Static wire removal	2023
1078	Kealia to Anahola Substation	0.0563	Diverter installation (Reflective)	2022
1078	Kealia to Anahola Substation	0.0563	Static wire removal	2023
1079	Kealia to Anahola Substation	0.0568	Diverter installation (Reflective)	2022
1079	Kealia to Anahola Substation	0.0568	Static wire removal	2023

1080	Kealia to Anahola Substation	0.0744	Diverter installation (Reflective)	2022
1080	Kealia to Anahola Substation	0.0744	Static wire removal	2023
1081	Kealia to Anahola Substation	0.0227	Diverter installation (Reflective)	2022
1081	Kealia to Anahola Substation	0.0227	Static wire removal	2023
1082	Anahola Substation to Moloaa	0.0714	Static wire removal	2021
1083	Anahola Substation to Moloaa	0.0823	Static wire removal	2021
1084	Anahola Substation to Moloaa	0.0684	Static wire removal	2021
1085	Anahola Substation to Moloaa	0.0412	Static wire removal	2021
1086	Anahola Substation to Moloaa	0.0391	Static wire removal	2021
1087	Anahola Substation to Moloaa	0.0358	Static wire removal	2021
1088	Anahola Substation to Moloaa	0.0386	Static wire removal	2021
1089	Anahola Substation to Moloaa	0.0410	Static wire removal	2021
1090	Anahola Substation to Moloaa	0.0401	Static wire removal	2021
1091	Anahola Substation to Moloaa	0.0377	Static wire removal	2021
1092	Anahola Substation to Moloaa	0.0354	Static wire removal	2021
1093	Anahola Substation to Moloaa	0.0390	Static wire removal	2021
1094	Anahola Substation to Moloaa	0.0412	Static wire removal	2021
1095	Anahola Substation to Moloaa	0.0331	Static wire removal	2021
1096	Anahola Substation to Moloaa	0.0524	static wire removal	2023
1097	Anahola Substation to Moloaa	0.0572	static wire removal	2023
1098	Anahola Substation to Moloaa	0.1054	static wire removal	2023
1099	Anahola Substation to Moloaa	0.0975	static wire removal	2023
1100	Anahola Substation to Moloaa	0.0386	Static wire removal	2021
1101	Anahola Substation to Moloaa	0.0209	Static wire removal	2021
1102	Anahola Substation to Moloaa	0.0714	Static wire removal	2021
1103	Anahola Substation to Moloaa	0.0401	Static wire removal	2021
1104	Anahola Substation to Moloaa	0.0515	Static wire removal	2021
1105	Anahola Substation to Moloaa	0.0341	Static wire removal	2021
1106	Anahola Substation to Moloaa	0.0323	Static wire removal	2021
1107	Anahola Substation to Moloaa	0.0299	Static wire removal	2021
1108	Anahola Substation to Moloaa	0.0430	Static wire removal	2021
1109	Anahola Substation to Moloaa	0.0371	Static wire removal	2021
1110	Anahola Substation to Moloaa	0.0376	Static wire removal	2021
1111	Anahola Substation to Moloaa	0.0298	Static wire removal	2021
1112	Anahola Substation to Moloaa	0.0420	Static wire removal	2021

1113	Anahola Substation to Moloaa	0.0277	Static wire removal	2021
1114	Anahola Substation to Moloaa	0.0385	Static wire removal	2021
1115	Anahola Substation to Moloaa	0.0894	Static wire removal	2021
1116	Anahola Substation to Moloaa	0.0359	Static wire removal	2021
1117	Anahola Substation to Moloaa	0.0379	Static wire removal	2021
1118	Anahola Substation to Moloaa	0.0377	Static wire removal	2021
1119	Anahola Substation to Moloaa	0.0390	static wire removal	2023
1120	Anahola Substation to Moloaa	0.0372	static wire removal	2023
1121	Anahola Substation to Moloaa	0.0376	Static wire removal	2021
1122	Anahola Substation to Moloaa	0.0394	Static wire removal	2021
1123	Anahola Substation to Moloaa	0.0402	Static wire removal	2021
1124	Anahola Substation to Moloaa	0.0407	Static wire removal	2021
1125	Anahola Substation to Moloaa	0.0413	Static wire removal	2021
1126	Anahola Substation to Moloaa	0.0596	Static wire removal	2021
1127	Anahola Substation to Moloaa	0.0610	Static wire removal	2021
1128	Anahola Substation to Moloaa	0.0798	Static wire removal	2021
1129	Anahola Substation to Moloaa	0.0433	Static wire removal	2021
1130	Anahola Substation to Moloaa	0.0777	Static wire removal	2021
1131	Anahola Substation to Moloaa	0.0387	Static wire removal	2021
1132	Anahola Substation to Moloaa	0.0377	Static wire removal	2021
1133	Anahola Substation to Moloaa	0.0663	Static wire removal	2021
1134	Anahola Substation to Moloaa	0.1059	Static wire removal	2021
1135	Anahola Substation to Moloaa	0.0856	Static wire removal	2021
1136	Anahola Substation to Moloaa	0.0936	Static wire removal	2021
1137	Anahola Substation to Moloaa	0.0431	Static wire removal	2021
1138	Anahola Substation to Moloaa	0.0898	Static wire removal	2021
1139	Anahola Substation to Moloaa	0.0839	Static wire removal	2021
1140	Anahola Substation to Moloaa	0.0868	Static wire removal	2021
1141	Anahola Substation to Moloaa	0.0758	Static wire removal	2021
1142	Anahola Substation to Moloaa	0.0841	Static wire removal	2021
1143	Anahola Substation to Moloaa	0.0332	Static wire removal	2021
1144	Anahola Substation to Moloaa	0.0482	Static wire removal	2021
1145	Anahola Substation to Moloaa	0.0687	Static wire removal	2021
1146	Anahola Substation to Moloaa	0.0756	Static wire removal	2021
1147	Anahola Substation to Moloaa	0.0445	Static wire removal	2021

1148	Anahola Substation to Moloaa	0.0373	Static wire removal	2021
1149	Anahola Substation to Moloaa	0.0480	Static wire removal	2021
1150	Anahola Substation to Moloaa	0.0902	Static wire removal	2021
1151	Anahola Substation to Moloaa	0.0388	Static wire removal	2021
1152	Anahola Substation to Moloaa	0.0474	Static wire removal	2021
1153	Anahola Substation to Moloaa	0.0789	Diverter installation (Reflective)	2020
1153	Anahola Substation to Moloaa	0.0789	Static wire removal	2020
1154	Moloaa to Kilauea end of xmission line	0.0782	Diverter installation (Reflective)	2020
1154	Moloaa to Kilauea end of xmission line	0.0782	Static wire removal	2020
1155	Moloaa to Kilauea end of xmission line	0.0826	Diverter installation (Reflective)	2020
1155	Moloaa to Kilauea end of xmission line	0.0826	Static wire removal	2020
1156	Moloaa to Kilauea end of xmission line	0.0526	Diverter installation (Reflective)	2020
1156	Moloaa to Kilauea end of xmission line	0.0526	Static wire removal	2020
1157	Moloaa to Kilauea end of xmission line	0.0498	Diverter installation (Reflective)	2020
1157	Moloaa to Kilauea end of xmission line	0.0498	Static wire removal	2020
1158	Moloaa to Kilauea end of xmission line	0.0504	Diverter installation (Reflective)	2020
1158	Moloaa to Kilauea end of xmission line	0.0504	Static wire removal	2020
1159	Moloaa to Kilauea end of xmission line	0.0966	Diverter installation (Reflective)	2020
1159	Moloaa to Kilauea end of xmission line	0.0966	Static wire removal	2020
1160	Moloaa to Kilauea end of xmission line	0.0490	Diverter installation (Reflective)	2020
1160	Moloaa to Kilauea end of xmission line	0.0490	Static wire removal	2020
1161	Moloaa to Kilauea end of xmission line	0.0492	Diverter installation (Reflective)	2020
1161	Moloaa to Kilauea end of xmission line	0.0492	Static wire removal	2020
1162	Moloaa to Kilauea end of xmission line	0.0488	Diverter installation (Reflective)	2020
1162	Moloaa to Kilauea end of xmission line	0.0488	Static wire removal	2020
1163	Moloaa to Kilauea end of xmission line	0.0433	Diverter installation (Reflective)	2020
1163	Moloaa to Kilauea end of xmission line	0.0433	Static wire removal	2020
1164	Moloaa to Kilauea end of xmission line	0.0418	Diverter installation (Reflective)	2020
1164	Moloaa to Kilauea end of xmission line	0.0418	Static wire removal	2020
1165	Moloaa to Kilauea end of xmission line	0.0503	Diverter installation (Reflective)	2020
1165	Moloaa to Kilauea end of xmission line	0.0503	Static wire removal	2020
1166	Moloaa to Kilauea end of xmission line	0.0467	Diverter installation (Reflective)	2020
1166	Moloaa to Kilauea end of xmission line	0.0467	Static wire removal	2020
1167	Moloaa to Kilauea end of xmission line	0.0472	Diverter installation (Reflective)	2020
1167	Moloaa to Kilauea end of xmission line	0.0472	Static wire removal	2020

1168	Moloaa to Kilauea end of xmission line	0.0464	Diverter installation (Reflective)	2020
1168	Moloaa to Kilauea end of xmission line	0.0464	Static wire removal	2020
1169	Moloaa to Kilauea end of xmission line	0.0932	Diverter installation (Reflective)	2020
1169	Moloaa to Kilauea end of xmission line	0.0932	Static wire removal	2020
1170	Moloaa to Kilauea end of xmission line	0.0995	Diverter installation (Reflective)	2020
1170	Moloaa to Kilauea end of xmission line	0.0995	Static wire removal	2020
1171	Moloaa to Kilauea end of xmission line	0.0937	Diverter installation (Reflective)	2020
1171	Moloaa to Kilauea end of xmission line	0.0937	Static wire removal	2020
1172	Moloaa to Kilauea end of xmission line	0.1010	Diverter installation (Reflective)	2020
1172	Moloaa to Kilauea end of xmission line	0.1010	Static wire removal	2020
1173	Moloaa to Kilauea end of xmission line	0.0478	Diverter installation (Reflective)	2021
1173	Moloaa to Kilauea end of xmission line	0.0478	Diverter installation (Reflective)	2020
1173	Moloaa to Kilauea end of xmission line	0.0478	Static wire removal	2020
1174	Moloaa to Kilauea end of xmission line	0.0785	Diverter installation (Reflective)	2021
1174	Moloaa to Kilauea end of xmission line	0.0785	Diverter installation (Reflective)	2020
1174	Moloaa to Kilauea end of xmission line	0.0785	Static wire removal	2020
1175	Moloaa to Kilauea end of xmission line	0.0458	Diverter installation (Reflective)	2021
1175	Moloaa to Kilauea end of xmission line	0.0458	Static wire removal	2020
1176	Moloaa to Kilauea end of xmission line	0.0829	Static wire removal	2020
1177	Moloaa to Kilauea end of xmission line	0.0761	Diverter installation (Reflective)	2021
1177	Moloaa to Kilauea end of xmission line	0.0761	Static wire removal	2020
1178	Moloaa to Kilauea end of xmission line	0.0712	Diverter installation (Reflective)	2021
1178	Moloaa to Kilauea end of xmission line	0.0712	Static wire removal	2020
1179	Moloaa to Kilauea end of xmission line	0.0909	Diverter installation (Reflective)	2021
1179	Moloaa to Kilauea end of xmission line	0.0909	Static wire removal	2020
1180	Moloaa to Kilauea end of xmission line	0.0596	Diverter installation (Reflective)	2021
1180	Moloaa to Kilauea end of xmission line	0.0596	Static wire removal	2020
1181	Moloaa to Kilauea end of xmission line	0.0505	Diverter installation (Reflective)	2020
1181	Moloaa to Kilauea end of xmission line	0.0505	Static wire removal	2020
1182	Moloaa to Kilauea end of xmission line	0.1072	Diverter installation (Reflective)	2020
1182	Moloaa to Kilauea end of xmission line	0.1072	Static wire removal	2020
1183	Moloaa to Kilauea end of xmission line	0.0862	Diverter installation (Reflective)	2020
1183	Moloaa to Kilauea end of xmission line	0.0862	Static wire removal	2020
1184	Moloaa to Kilauea end of xmission line	0.0451	Diverter installation (Reflective)	2021
1184	Moloaa to Kilauea end of xmission line	0.0451	Static wire removal	2020

1185	Moloaa to Kilauea end of xmission line	0.0462	Diverter installation (Reflective)	2021
1185	Moloaa to Kilauea end of xmission line	0.0462	Static wire removal	2020
1186	Moloaa to Kilauea end of xmission line	0.1041	Diverter installation (Reflective)	2021
1186	Moloaa to Kilauea end of xmission line	0.1041	Static wire removal	2020
1187	Moloaa to Kilauea end of xmission line	0.0469	Diverter installation (Reflective)	2021
1187	Moloaa to Kilauea end of xmission line	0.0469	Static wire removal	2020
1188	Moloaa to Kilauea end of xmission line	0.0474	Diverter installation (Reflective)	2021
1188	Moloaa to Kilauea end of xmission line	0.0474	Static wire removal	2020
1189	Moloaa to Kilauea end of xmission line	0.0461	Diverter installation (Reflective)	2021
1189	Moloaa to Kilauea end of xmission line	0.0461	Static wire removal	2020
1190	Moloaa to Kilauea end of xmission line	0.1110	Diverter installation (Reflective)	2021
1190	Moloaa to Kilauea end of xmission line	0.1110	Static wire removal	2020
1191	Moloaa to Kilauea end of xmission line	0.0380	Diverter installation (Reflective)	2021
1191	Moloaa to Kilauea end of xmission line	0.0380	Static wire removal	2020
1192	Moloaa to Kilauea end of xmission line	0.0378	Diverter installation (Reflective)	2021
1192	Moloaa to Kilauea end of xmission line	0.0378	Static wire removal	2020
1193	Moloaa to Kilauea end of xmission line	0.0455	Static wire removal	2020
1194	Moloaa to Kilauea end of xmission line	0.0452	Diverter installation (Reflective)	2020
1194	Moloaa to Kilauea end of xmission line	0.0452	Static wire removal	2020
1195	Moloaa to Kilauea end of xmission line	0.0442	Diverter installation (Reflective)	2020
1195	Moloaa to Kilauea end of xmission line	0.0442	Static wire removal	2020
1196	Moloaa to Kilauea end of xmission line	0.0596	Diverter installation (Reflective)	2015
1196	Moloaa to Kilauea end of xmission line	0.0596	Static wire removal	2020
1197	Moloaa to Kilauea end of xmission line	0.0382	Diverter installation (Reflective)	2015
1197	Moloaa to Kilauea end of xmission line	0.0382	Static wire removal	2020
1198	Moloaa to Kilauea end of xmission line	0.0476	Diverter installation (Reflective)	2015
1198	Moloaa to Kilauea end of xmission line	0.0476	Static wire removal	2020
1199	Moloaa to Kilauea end of xmission line	0.0525	Diverter installation (Reflective)	2015
1199	Moloaa to Kilauea end of xmission line	0.0525	Static wire removal	2020
1200	Moloaa to Kilauea end of xmission line	0.0495	Diverter installation (Reflective)	2015
1200	Moloaa to Kilauea end of xmission line	0.0495	Static wire removal	2020
1201	Moloaa to Kilauea end of xmission line	0.0509	Diverter installation (Reflective)	2015
1201	Moloaa to Kilauea end of xmission line	0.0509	Static wire removal	2020
1202	Moloaa to Kilauea end of xmission line	0.0458	Diverter installation (Reflective)	2015
1202	Moloaa to Kilauea end of xmission line	0.0458	Static wire removal	2020

1203	Moloaa to Kilauea end of xmission line	0.0451	Diverter installation (Reflective)	2015
1203	Moloaa to Kilauea end of xmission line	0.0451	Static wire removal	2020
1204	Moloaa to Kilauea end of xmission line	0.0483	Diverter installation (Reflective)	2015
1204	Moloaa to Kilauea end of xmission line	0.0483	Static wire removal	2020
1205	Moloaa to Kilauea end of xmission line	0.0469	Diverter installation (Reflective)	2015
1205	Moloaa to Kilauea end of xmission line	0.0469	Static wire removal	2020
1206	Moloaa to Kilauea end of xmission line	0.0480	Diverter installation (Reflective)	2015
1206	Moloaa to Kilauea end of xmission line	0.0480	Static wire removal	2020
1207	Moloaa to Kilauea end of xmission line	0.0489	Diverter installation (Reflective)	2015
1207	Moloaa to Kilauea end of xmission line	0.0489	Static wire removal	2020
1208	Moloaa to Kilauea end of xmission line	0.0503	Diverter installation (Reflective)	2015
1208	Moloaa to Kilauea end of xmission line	0.0503	Static wire removal	2020
1209	Moloaa to Kilauea end of xmission line	0.0483	Diverter installation (Reflective)	2015
1209	Moloaa to Kilauea end of xmission line	0.0483	Static wire removal	2020
1210	Moloaa to Kilauea end of xmission line	0.0495	Diverter installation (Reflective)	2015
1210	Moloaa to Kilauea end of xmission line	0.0495	Static wire removal	2020
1211	Moloaa to Kilauea end of xmission line	0.0510	Diverter installation (Reflective)	2015
1211	Moloaa to Kilauea end of xmission line	0.0510	Static wire removal	2020
1212	Moloaa to Kilauea end of xmission line	0.0493	Diverter installation (Reflective)	2015
1212	Moloaa to Kilauea end of xmission line	0.0493	Static wire removal	2020
1213	Moloaa to Kilauea end of xmission line	0.0512	Diverter installation (Reflective)	2015
1213	Moloaa to Kilauea end of xmission line	0.0512	Static wire removal	2020
1214	Moloaa to Kilauea end of xmission line	0.0473	Diverter installation (Reflective)	2015
1214	Moloaa to Kilauea end of xmission line	0.0473	Static wire removal	2020
1215	Moloaa to Kilauea end of xmission line	0.0658	Diverter installation (Reflective)	2020
1215	Moloaa to Kilauea end of xmission line	0.0658	Static wire removal	2020
1216	Moloaa to Kilauea end of xmission line	0.0489	Diverter installation (Reflective)	2020
1216	Moloaa to Kilauea end of xmission line	0.0489	Static wire removal	2020
1217	Moloaa to Kilauea end of xmission line	0.0463	Diverter installation (Reflective)	2020
1217	Moloaa to Kilauea end of xmission line	0.0463	Static wire removal	2020
1218	Moloaa to Kilauea end of xmission line	0.0475	Diverter installation (Reflective)	2020
1218	Moloaa to Kilauea end of xmission line	0.0475	Static wire removal	2020
1219	Moloaa to Kilauea end of xmission line	0.0512	Diverter installation (Reflective)	2020
1219	Moloaa to Kilauea end of xmission line	0.0512	Static wire removal	2020
1220	Moloaa to Kilauea end of xmission line	0.0472	Diverter installation (Reflective)	2020

1220	Moloaa to Kilauea end of xmission line	0.0472	Static wire removal	2020
1221	Moloaa to Kilauea end of xmission line	0.0923	Diverter installation (Reflective)	2020
1221	Moloaa to Kilauea end of xmission line	0.0923	Static wire removal	2020
1222	Moloaa to Kilauea end of xmission line	0.0478	Diverter installation (Reflective)	2020
1222	Moloaa to Kilauea end of xmission line	0.0478	Static wire removal	2020
1223	Moloaa to Kilauea end of xmission line	0.0516	Diverter installation (Reflective)	2020
1223	Moloaa to Kilauea end of xmission line	0.0516	Static wire removal	2020
1224	Moloaa to Kilauea end of xmission line	0.0701	Diverter installation (Reflective)	2020
1224	Moloaa to Kilauea end of xmission line	0.0701	Static wire removal	2020
1225	Moloaa to Kilauea end of xmission line	0.0577	Diverter installation (Reflective)	2020
1225	Moloaa to Kilauea end of xmission line	0.0577	Static wire removal	2020
1226	Moloaa to Kilauea end of xmission line	0.0472	Diverter installation (Reflective)	2020
1226	Moloaa to Kilauea end of xmission line	0.0472	Static wire removal	2020
1227	Moloaa to Kilauea end of xmission line	0.0386	Diverter installation (Reflective)	2020
1227	Moloaa to Kilauea end of xmission line	0.0386	Static wire removal	2020
1228	Moloaa to Kilauea end of xmission line	0.0793	Diverter installation (Reflective)	2020
1228	Moloaa to Kilauea end of xmission line	0.0793	Static wire removal	2020
1229	Moloaa to Kilauea end of xmission line	0.0766	Diverter installation (Reflective)	2020
1229	Moloaa to Kilauea end of xmission line	0.0766	Static wire removal	2020
1230	Moloaa to Kilauea end of xmission line	0.0403	Diverter installation (Reflective)	2020
1230	Moloaa to Kilauea end of xmission line	0.0403	Static wire removal	2020
1231	Moloaa to Kilauea end of xmission line	0.0390	Diverter installation (Reflective)	2020
1231	Moloaa to Kilauea end of xmission line	0.0390	Static wire removal	2020
1232	Moloaa to Kilauea end of xmission line	0.0534	Diverter installation (Reflective)	2020
1232	Moloaa to Kilauea end of xmission line	0.0534	Static wire removal	2020
1233	Moloaa to Kilauea end of xmission line	0.0654	Diverter installation (Reflective)	2020
1233	Moloaa to Kilauea end of xmission line	0.0654	Static wire removal	2020
1234	Moloaa to Kilauea end of xmission line	0.0383	Diverter installation (Reflective)	2020
1234	Moloaa to Kilauea end of xmission line	0.0383	Static wire removal	2020
1235	Moloaa to Kilauea end of xmission line	0.0416	Diverter installation (Reflective)	2020
1235	Moloaa to Kilauea end of xmission line	0.0416	Static wire removal	2020
1236	Moloaa to Kilauea end of xmission line	0.0405	Diverter installation (Reflective)	2020
1236	Moloaa to Kilauea end of xmission line	0.0405	Static wire removal	2020
1237	Moloaa to Kilauea end of xmission line	0.0366	Diverter installation (Reflective)	2020
1237	Moloaa to Kilauea end of xmission line	0.0366	Static wire removal	2020

1238	Moloaa to Kilauea end of xmission line	0.0380	Diverter installation (Reflective)	2020
1238	Moloaa to Kilauea end of xmission line	0.0380	Static wire removal	2020
1239	Moloaa to Kilauea end of xmission line	0.0464	Diverter installation (Reflective)	2020
1239	Moloaa to Kilauea end of xmission line	0.0464	Static wire removal	2020
1240	Moloaa to Kilauea end of xmission line	0.0331	Diverter installation (Reflective)	2020
1240	Moloaa to Kilauea end of xmission line	0.0331	Static wire removal	2020
1241	Moloaa to Kilauea end of xmission line	0.0741	Diverter installation (Reflective)	2020
1241	Moloaa to Kilauea end of xmission line	0.0741	Static wire removal	2020
1242	Moloaa to Kilauea end of xmission line	0.0491	Diverter installation (Reflective)	2020
1242	Moloaa to Kilauea end of xmission line	0.0491	Static wire removal	2020
1243	Moloaa to Kilauea end of xmission line	0.0385	Diverter installation (Reflective)	2020
1243	Moloaa to Kilauea end of xmission line	0.0385	Static wire removal	2020
1244	Moloaa to Kilauea end of xmission line	0.0369	Diverter installation (Reflective)	2020
1244	Moloaa to Kilauea end of xmission line	0.0369	Static wire removal	2020
1245	Moloaa to Kilauea end of xmission line	0.0327	Diverter installation (Reflective)	2020
1245	Moloaa to Kilauea end of xmission line	0.0327	Static wire removal	2020
1246	Moloaa to Kilauea end of xmission line	0.0467	Diverter installation (Reflective)	2020
1246	Moloaa to Kilauea end of xmission line	0.0467	Static wire removal	2020
1247	Moloaa to Kilauea end of xmission line	0.0382	Diverter installation (Reflective)	2020
1247	Moloaa to Kilauea end of xmission line	0.0382	Static wire removal	2020
1248	Moloaa to Kilauea end of xmission line	0.0469	Diverter installation (Reflective)	2020
1248	Moloaa to Kilauea end of xmission line	0.0469	Static wire removal	2020
1249	Moloaa to Kilauea end of xmission line	0.0483	Diverter installation (Reflective)	2020
1249	Moloaa to Kilauea end of xmission line	0.0483	Static wire removal	2020
1250	Moloaa to Kilauea end of xmission line	0.0625	Diverter installation (Reflective)	2020
1250	Moloaa to Kilauea end of xmission line	0.0625	Static wire removal	2020
1251	Moloaa to Kilauea end of xmission line	0.0199	Diverter installation (Reflective)	2020
1251	Moloaa to Kilauea end of xmission line	0.0199	Static wire removal	2020
1252	Moloaa to Kilauea end of xmission line	0.0314	Diverter installation (Reflective)	2020
1252	Moloaa to Kilauea end of xmission line	0.0314	Static wire removal	2020
1253	Moloaa to Kilauea end of xmission line	0.0414	Diverter installation (Reflective)	2020
1253	Moloaa to Kilauea end of xmission line	0.0414	Static wire removal	2020
1254	Moloaa to Kilauea end of xmission line	0.0540	Diverter installation (Reflective)	2020
1254	Moloaa to Kilauea end of xmission line	0.0540	Static wire removal	2020
1255	Moloaa to Kilauea end of xmission line	0.0378	Diverter installation (Reflective)	2020

1255	Moloaa to Kilauea end of xmission line	0.0378	Static wire removal	2020
1256	Moloaa to Kilauea end of xmission line	0.0402	Diverter installation (Reflective)	2020
1256	Moloaa to Kilauea end of xmission line	0.0402	Static wire removal	2020
1257	Moloaa to Kilauea end of xmission line	0.0399	Diverter installation (Reflective)	2020
1257	Moloaa to Kilauea end of xmission line	0.0399	Static wire removal	2020
1258	Moloaa to Kilauea end of xmission line	0.0379	Diverter installation (Reflective)	2020
1258	Moloaa to Kilauea end of xmission line	0.0379	Static wire removal	2020
1259	Moloaa to Kilauea end of xmission line	0.0383	Diverter installation (Reflective)	2020
1259	Moloaa to Kilauea end of xmission line	0.0383	Static wire removal	2020
1260	Moloaa to Kilauea end of xmission line	0.0396	Diverter installation (Reflective)	2020
1260	Moloaa to Kilauea end of xmission line	0.0396	Static wire removal	2020
1261	Moloaa to Kilauea end of xmission line	0.0384	Diverter installation (Reflective)	2020
1261	Moloaa to Kilauea end of xmission line	0.0384	Static wire removal	2020
1262	Moloaa to Kilauea end of xmission line	0.0462	Diverter installation (Reflective)	2020
1262	Moloaa to Kilauea end of xmission line	0.0462	Static wire removal	2020
1263	Moloaa to Kilauea end of xmission line	0.0481	Diverter installation (Reflective)	2020
1263	Moloaa to Kilauea end of xmission line	0.0481	Static wire removal	2020
1264	Moloaa to Kilauea end of xmission line	0.0480	Diverter installation (Reflective)	2020
1264	Moloaa to Kilauea end of xmission line	0.0480	Static wire removal	2020
1265	Moloaa to Kilauea end of xmission line	0.0415	Diverter installation (Reflective)	2020
1265	Moloaa to Kilauea end of xmission line	0.0415	Static wire removal	2020
1266	Moloaa to Kilauea end of xmission line	0.0231	Diverter installation (Reflective)	2020
1266	Moloaa to Kilauea end of xmission line	0.0231	Static wire removal	2020
1267	Moloaa to Kilauea end of xmission line	0.0446	Diverter installation (Reflective)	2020
1267	Moloaa to Kilauea end of xmission line	0.0446	Static wire removal	2020
1268	Moloaa to Kilauea end of xmission line	0.0437	Diverter installation (Reflective)	2020
1268	Moloaa to Kilauea end of xmission line	0.0437	Static wire removal	2020
1269	Moloaa to Kilauea end of xmission line	0.0385	Diverter installation (Reflective)	2020
1269	Moloaa to Kilauea end of xmission line	0.0385	Static wire removal	2020
1270	Moloaa to Kilauea end of xmission line	0.0383	Diverter installation (Reflective)	2020
1270	Moloaa to Kilauea end of xmission line	0.0383	Static wire removal	2020
1271	Moloaa to Kilauea end of xmission line	0.0372	Diverter installation (Reflective)	2020
1271	Moloaa to Kilauea end of xmission line	0.0372	Static wire removal	2020
1272	Moloaa to Kilauea end of xmission line	0.0355	Diverter installation (Reflective)	2020
1272	Moloaa to Kilauea end of xmission line	0.0355	Static wire removal	2020

1273	Moloaa to Kilauea end of xmission line	0.0426	Diverter installation (Reflective)	2020
1273	Moloaa to Kilauea end of xmission line	0.0426	Static wire removal	2020
1274	Moloaa to Kilauea end of xmission line	0.0370	Diverter installation (Reflective)	2020
1274	Moloaa to Kilauea end of xmission line	0.0370	Static wire removal	2020
1275	Moloaa to Kilauea end of xmission line	0.0429	Diverter installation (Reflective)	2020
1275	Moloaa to Kilauea end of xmission line	0.0429	Static wire removal	2020
1276	Moloaa to Kilauea end of xmission line	0.0401	Diverter installation (Reflective)	2020
1276	Moloaa to Kilauea end of xmission line	0.0401	Static wire removal	2020
1277	Moloaa to Kilauea end of xmission line	0.0428	Diverter installation (Reflective)	2020
1277	Moloaa to Kilauea end of xmission line	0.0428	Static wire removal	2020
1278	Moloaa to Kilauea end of xmission line	0.0385	Diverter installation (Reflective)	2020
1278	Moloaa to Kilauea end of xmission line	0.0385	Static wire removal	2020
1279	Moloaa to Kilauea end of xmission line	0.0403	Diverter installation (Reflective)	2020
1279	Moloaa to Kilauea end of xmission line	0.0403	Static wire removal	2020
1280	Moloaa to Kilauea end of xmission line	0.0541	Diverter installation (Reflective)	2020
1280	Moloaa to Kilauea end of xmission line	0.0541	Static wire removal	2020
1281	Moloaa to Kilauea end of xmission line	0.0495	Diverter installation (Reflective)	2020
1281	Moloaa to Kilauea end of xmission line	0.0495	Static wire removal	2020
1282	Moloaa to Kilauea end of xmission line	0.0474	Diverter installation (Reflective)	2020
1282	Moloaa to Kilauea end of xmission line	0.0474	Static wire removal	2020
1283	Moloaa to Kilauea end of xmission line	0.0386	Diverter installation (Reflective)	2020
1283	Moloaa to Kilauea end of xmission line	0.0386	Static wire removal	2020
1284	Moloaa to Kilauea end of xmission line	0.0355	Diverter installation (Reflective)	2020
1284	Moloaa to Kilauea end of xmission line	0.0355	Static wire removal	2020
1285	Moloaa to Kilauea end of xmission line	0.0429	Diverter installation (Reflective)	2020
1285	Moloaa to Kilauea end of xmission line	0.0429	Static wire removal	2020
1286	Moloaa to Kilauea end of xmission line	0.0444	Diverter installation (Reflective)	2020
1286	Moloaa to Kilauea end of xmission line	0.0444	Static wire removal	2020
1287	Moloaa to Kilauea end of xmission line	0.0491	Diverter installation (Reflective)	2020
1287	Moloaa to Kilauea end of xmission line	0.0491	Static wire removal	2020
1288	Moloaa to Kilauea end of xmission line	0.0991	Diverter installation (Reflective)	2020
1288	Moloaa to Kilauea end of xmission line	0.0991	Static wire removal	2020
1289	Moloaa to Kilauea end of xmission line	0.0361	Diverter installation (Reflective)	2020
1289	Moloaa to Kilauea end of xmission line	0.0361	Static wire removal	2020
1290	Moloaa to Kilauea end of xmission line	0.0696	Diverter installation (Reflective)	2020

1290	Moloaa to Kilauea end of xmission line	0.0696	Static wire removal	2020
1291	Moloaa to Kilauea end of xmission line	0.0467	Diverter installation (Reflective)	2020
1291	Moloaa to Kilauea end of xmission line	0.0467	Static wire removal	2020
1292	Moloaa to Kilauea end of xmission line	0.0467	Diverter installation (Reflective)	2020
1292	Moloaa to Kilauea end of xmission line	0.0467	Static wire removal	2020
1293	Moloaa to Kilauea end of xmission line	0.0477	Diverter installation (Reflective)	2020
1293	Moloaa to Kilauea end of xmission line	0.0477	Static wire removal	2020
1294	Moloaa to Kilauea end of xmission line	0.0482	Diverter installation (Reflective)	2020
1294	Moloaa to Kilauea end of xmission line	0.0482	Static wire removal	2020
1295	Moloaa to Kilauea end of xmission line	0.0531	Diverter installation (Reflective)	2020
1295	Moloaa to Kilauea end of xmission line	0.0531	Static wire removal	2020
1296	Moloaa to Kilauea end of xmission line	0.0514	Diverter installation (Reflective)	2020
1296	Moloaa to Kilauea end of xmission line	0.0514	Static wire removal	2020
1297	Hanalei Tap to Hwy	0.0521	Diverter installation (Reflective)	2023
1298	Hanalei Tap to Hwy	0.0431	Diverter installation (Reflective)	2022
1299	Hanalei Tap to Hwy	0.0494	Diverter installation (Reflective)	2022
1300	Hanalei Tap to Hwy	0.0478	Diverter installation (Reflective)	2022
1301	Hanalei Tap to Hwy	0.0473	Diverter installation (Reflective)	2022
1302	Hanalei Tap to Hwy	0.0454	Diverter installation (Reflective)	2022
1303	Hanalei Tap to Hwy	0.0309	Diverter installation (Reflective)	2023
1304	Hwy Hanalei to Princeville Substation	0.0585	Diverter installation (Reflective)	2022
1305	Hwy Hanalei to Princeville Substation	0.0584	Diverter installation (Reflective)	2022
1306	Hwy Hanalei to Princeville Substation		Diverter installation (Reflective)	2022
1307	Hwy Hanalei to Princeville Substation	0.1123	Diverter installation (Reflective)	2022
1310	Hwy Hanalei to Princeville Substation	0.0275	Diverter installation (Reflective)	2023
1311	Hwy Hanalei to Princeville Substation	0.0275	Diverter installation (Reflective)	2023
1312	Hwy Hanalei to Princeville Substation	0.0438	Diverter installation (Reflective)	2023
1313	Hwy Hanalei to Princeville Substation	0.0689	Diverter installation (Reflective)	2022
1314	Hwy Hanalei to Princeville Substation	0.0528	Diverter installation (Reflective)	2023
1315	Hwy Hanalei to Princeville Substation	0.0575	Diverter installation (Reflective)	2023
1316	Hwy Hanalei to Princeville Substation	0.0556	Diverter installation (Reflective)	2023
1317	Hwy Hanalei to Princeville Substation	0.0561	Diverter installation (Reflective)	2023
1318	Hwy Hanalei to Princeville Substation	0.0545	Diverter installation (Reflective)	2023
1319	Hwy Hanalei to Princeville Substation	0.0365	Diverter installation (Reflective)	2023
1320	Hwy Hanalei to Princeville Substation	0.0993	Diverter installation (Reflective)	2022

1321	None		Diverter installation (Reflective)	2021
1322	Port Allen	0.0427	Diverter installation (Reflective)	2022
1323	Port Allen	0.0638	Diverter installation (Reflective)	2022
1327	Hanalei Tap	0.0088	Diverter installation (Reflective)	2023
1328	Hanalei Tap	0.0078	Diverter installation (Reflective)	2023
1329	Kekaha Substation to Waimea Canyon Dr	0.0552	Diverter installation (Reflective)	2021
1330	Kekaha Substation to Waimea Canyon Dr	0.0526	Diverter installation (Reflective)	2021
1331	Kekaha Substation to Waimea Canyon Dr	0.0583	Diverter installation (Reflective)	2022
1332	Kekaha Substation to Waimea Canyon Dr	0.0574	Diverter installation (Reflective)	2022
1333	Kekaha Substation to Waimea Canyon Dr	0.0502	Diverter installation (Reflective)	2022
1334	Kekaha Substation to Waimea Canyon Dr	0.0512	Diverter installation (Reflective)	2022
1335	Kekaha Substation to Waimea Canyon Dr	0.0540	Diverter installation (Reflective)	2022
1336	Kekaha Substation to Waimea Canyon Dr	0.0563	Diverter installation (Reflective)	2022
1337	Kekaha Substation to Waimea Canyon Dr	0.0567	Diverter installation (Reflective)	2022
1338	Kekaha Substation to Waimea Canyon Dr	0.1075	Diverter installation (Reflective)	2023
1339	Kekaha Substation to Waimea Canyon Dr	0.0423	Diverter installation (LED)	2021
1340	Kekaha Substation to Waimea Canyon Dr	0.0391	Diverter installation (LED)	2021
1341	Kekaha Substation to Waimea Canyon Dr	0.0338	Diverter installation (LED)	2021
1342	Kekaha Substation to Waimea Canyon Dr	0.0407	Diverter installation (LED)	2021
1343	Kekaha Substation to Waimea Canyon Dr	0.0517	Diverter installation (LED)	2021
1344	Kekaha Substation to Waimea Canyon Dr	0.0132	Diverter installation (LED)	2021
1345	Kekaha Substation to Waimea Canyon Dr	0.0768	Diverter installation (LED)	2021
1346	Kekaha Substation to Waimea Canyon Dr	0.0619	Diverter installation (LED)	2023
1347	Kekaha Substation to Waimea Canyon Dr	0.0487	Diverter installation (LED)	2021
1348	Kekaha Substation to Waimea Canyon Dr	0.0486	Diverter installation (LED)	2021
1349	Kekaha Substation to Waimea Canyon Dr	0.0500	Diverter installation (LED)	2021
1350	Kekaha Substation to Waimea Canyon Dr	0.0588	Diverter installation (LED)	2021
1351	Kekaha Substation to Waimea Canyon Dr	0.0401	Diverter installation (LED)	2021
1352	Kekaha Substation to Waimea Canyon Dr	0.0401	Diverter installation (LED)	2021
1353	Kekaha Substation to Waimea Canyon Dr	0.0507	Diverter installation (LED)	2021
1354	Kekaha Substation to Waimea Canyon Dr	0.0517	Diverter installation (LED)	2021
1355	Kekaha Substation to Waimea Canyon Dr	0.0472	Diverter installation (LED)	2021
1356	Kekaha Substation to Waimea Canyon Dr	0.0571	Diverter installation (LED)	2021
1357	Kekaha Substation to Waimea Canyon Dr	0.0560	Diverter installation (LED)	2021
1358	Kekaha Substation to Waimea Canyon Dr	0.0569	Diverter installation (LED)	2021

1359	Kekaha Substation to Waimea Canyon Dr	0.0637	Diverter installation (LED)	2021
1360	Kekaha Substation to Waimea Canyon Dr	0.0415	Diverter installation (LED)	2021
1361	Kekaha Substation to Waimea Canyon Dr	0.0464	Diverter installation (LED)	2021
1362	Kekaha Substation to Waimea Canyon Dr	0.0610	Diverter installation (LED)	2021
1363	Kekaha Substation to Waimea Canyon Dr	0.0397	Diverter installation (LED)	2021
1364	Kekaha Substation to Waimea Canyon Dr	0.0484	Diverter installation (LED)	2021
1365	Kekaha Substation to Waimea Canyon Dr	0.0456	Diverter installation (LED)	2021
1366	Kekaha Substation to Waimea Canyon Dr	0.0504	Diverter installation (Reflective)	2023
1367	Kekaha Substation to Waimea Canyon Dr	0.0523	Diverter installation (Reflective)	2023
1368	Kekaha Substation to Waimea Canyon Dr	0.0500	Diverter installation (Reflective)	2023
1369	Kekaha Substation to Waimea Canyon Dr	0.0500	Diverter installation (Reflective)	2021
1370	Kekaha Substation to Waimea Canyon Dr	0.0500	Diverter installation (Reflective)	2021
1371	Kekaha Substation to Waimea Canyon Dr	0.0501	Diverter installation (Reflective)	2021
1372	Kekaha Substation to Waimea Canyon Dr	0.0493	Diverter installation (Reflective)	2021
1373	Kekaha Substation to Waimea Canyon Dr	0.0575	Diverter installation (Reflective)	2021
1374	Kekaha Substation to Waimea Canyon Dr	0.0560	Diverter installation (Reflective)	2021
1375	Kekaha Substation to Waimea Canyon Dr	0.0570	Diverter installation (Reflective)	2021
1376	Kekaha Substation to Waimea Canyon Dr	0.0414	Diverter installation (Reflective)	2021
1377	Kekaha Substation to Waimea Canyon Dr	0.0523	Diverter installation (Reflective)	2021
1378	Kekaha Substation to Waimea Canyon Dr	0.0600	Diverter installation (Reflective)	2021
1379	Kekaha Substation to Waimea Canyon Dr	0.0394	Diverter installation (Reflective)	2020
1380	Kekaha Substation to Waimea Canyon Dr	0.0373	Diverter installation (Reflective)	2020
1381	Kekaha Substation to Waimea Canyon Dr	0.0519	Diverter installation (Reflective)	2020
1382	Kekaha Substation to Waimea Canyon Dr	0.0437	Diverter installation (Reflective)	2020
1383	Kekaha Substation to Waimea Canyon Dr	0.0556	Diverter installation (Reflective)	2020
1384	Kekaha Substation to Waimea Canyon Dr	0.0390	Diverter installation (Reflective)	2020
1385	Kekaha Substation to Waimea Canyon Dr	0.0422	Diverter installation (Reflective)	2020
1386	Kekaha Substation to Waimea Canyon Dr	0.0418	Diverter installation (Reflective)	2020
1387	Kekaha Substation to Waimea Canyon Dr	0.0503	Diverter installation (Reflective)	2020
1388	Kekaha Substation to Waimea Canyon Dr	0.0458	Diverter installation (Reflective)	2020
1389	Kekaha Substation to Waimea Canyon Dr	0.0466	Diverter installation (Reflective)	2020
1390	Kekaha Substation to Waimea Canyon Dr	0.0465	Diverter installation (Reflective)	2020
1391	Kekaha Substation to Waimea Canyon Dr	0.0498	Diverter installation (Reflective)	2020
1392	Kekaha Substation to Waimea Canyon Dr	0.0510	Diverter installation (Reflective)	2020
1393	Kekaha Substation to Waimea Canyon Dr	0.0605	Diverter installation (Reflective)	2020

1394	Kekaha Substation to Waimea Canyon Dr	0.0604	Diverter installation (Reflective)	2020
1395	Kekaha Substation to Waimea Canyon Dr	0.0585	Diverter installation (Reflective)	2020
1396	Kekaha Substation to Waimea Canyon Dr	0.0564	Diverter installation (Reflective)	2020
1397	Kekaha Substation to Waimea Canyon Dr	0.0563	Diverter installation (Reflective)	2020
1398	Kekaha Substation to Waimea Canyon Dr	0.0664	Diverter installation (Reflective)	2020
1399	Kekaha Substation to Waimea Canyon Dr	0.0407	Diverter installation (Reflective)	2020
1400	Kekaha Substation to Waimea Canyon Dr	0.0472	Diverter installation (Reflective)	2020
1401	Kekaha Substation to Waimea Canyon Dr	0.0558	Diverter installation (Reflective)	2020
1402	Kekaha Substation to Waimea Canyon Dr	0.0483	Diverter installation (Reflective)	2020
1403	Kekaha Substation to Waimea Canyon Dr	0.0427	Diverter installation (Reflective)	2021
1404	Waimea Canyon Dr to Canyon Overlook	0.0391	Diverter installation (Reflective)	2021
1405	Waimea Canyon Dr to Canyon Overlook	0.0566	Diverter installation (Reflective)	2021
1406	Waimea Canyon Dr to Canyon Overlook	0.0478	Diverter installation (Reflective)	2022
1407	Waimea Canyon Dr to Canyon Overlook	0.0489	Diverter installation (Reflective)	2022
1408	Waimea Canyon Dr to Canyon Overlook	0.0531	Diverter installation (Reflective)	2022
1409	Waimea Canyon Dr to Canyon Overlook	0.0438	Diverter installation (Reflective)	2022
1410	Waimea Canyon Dr to Canyon Overlook	0.0503	Diverter installation (Reflective)	2022
1411	Waimea Canyon Dr to Canyon Overlook	0.0468	Diverter installation (Reflective)	2022
1412	Waimea Canyon Dr to Canyon Overlook	0.0503	Diverter installation (Reflective)	2022
1413	Waimea Canyon Dr to Canyon Overlook	0.0518	Diverter installation (Reflective)	2022
1414	Waimea Canyon Dr to Canyon Overlook	0.0563	Diverter installation (Reflective)	2022
1415	Waimea Canyon Dr to Canyon Overlook	0.0373	Diverter installation (Reflective)	2022
1416	Waimea Canyon Dr to Canyon Overlook	0.0370	Diverter installation (Reflective)	2022
1417	Waimea Canyon Dr to Canyon Overlook	0.0714	Diverter installation (Reflective)	2023
1418	Waimea Canyon Dr to Canyon Overlook	0.0459	Diverter installation (Reflective)	2023
1419	Waimea Canyon Dr to Canyon Overlook	0.0416	Diverter installation (Reflective)	2023
1420	Waimea Canyon Dr to Canyon Overlook	0.0450	Diverter installation (Reflective)	2023
1421	Waimea Canyon Dr to Canyon Overlook	0.0927	Diverter installation (Reflective)	2023
1422	Waimea Canyon Dr to Canyon Overlook	0.0493	Diverter installation (Reflective)	2022
1423	Waimea Canyon Dr to Canyon Overlook	0.0438	Diverter installation (Reflective)	2022
1424	Waimea Canyon Dr to Canyon Overlook	0.0515	Diverter installation (Reflective)	2023
1425	Waimea Canyon Dr to Canyon Overlook	0.0582	Diverter installation (Reflective)	2023
1426	Waimea Canyon Dr to Canyon Overlook	0.0438	Diverter installation (Reflective)	2023
1427	Waimea Canyon Dr to Canyon Overlook	0.0408	Diverter installation (Reflective)	2023
1428	Waimea Canyon Dr to Canyon Overlook	0.0386	Diverter installation (Reflective)	2021

1429	Waimea Canyon Dr to Canyon Overlook	0.0378	Diverter installation (Reflective)	2021
1430	Waimea Canyon Dr to Canyon Overlook	0.0440	Diverter installation (Reflective)	2023
1431	Waimea Canyon Dr to Canyon Overlook	0.0603	Diverter installation (Reflective)	2021
1432	Waimea Canyon Dr to Canyon Overlook	0.0535	Diverter installation (Reflective)	2021
1433	Waimea Canyon Dr to Canyon Overlook	0.0492	Diverter installation (Reflective)	2021
1434	Waimea Canyon Dr to Canyon Overlook	0.0584	Diverter installation (Reflective)	2021
1435	Waimea Canyon Dr to Canyon Overlook	0.0480	Diverter installation (Reflective)	2021
1436	Waimea Canyon Dr to Canyon Overlook	0.0504	Diverter installation (Reflective)	2021
1437	Waimea Canyon Dr to Canyon Overlook	0.0945	Diverter installation (Reflective)	2023
1438	Waimea Canyon Dr to Canyon Overlook	0.0548	Diverter installation (Reflective)	2023
1439	Waimea Canyon Dr to Canyon Overlook	0.0545	Diverter installation (Reflective)	2023
1440	Waimea Canyon Dr to Canyon Overlook	0.1188	Diverter installation (Reflective)	2023
1441	Waimea Canyon Dr to Canyon Overlook	0.0893	Diverter installation (Reflective)	2023
1442	Waimea Canyon Dr to Canyon Overlook	0.0567	Diverter installation (Reflective)	2023
1443	Waimea Canyon Dr to Canyon Overlook	0.0574	Diverter installation (Reflective)	2023
1444	Waimea Canyon Dr to Canyon Overlook	0.0571	Diverter installation (Reflective)	2023
1445	Waimea Canyon Dr to Canyon Overlook	0.0521	Diverter installation (Reflective)	2023
1446	Waimea Canyon Dr to Canyon Overlook	0.0475	Diverter installation (Reflective)	2023
1447	Waimea Canyon Dr to Canyon Overlook	0.0663	Diverter installation (Reflective)	2023
1448	Waimea Canyon Dr to Canyon Overlook	0.0986	Diverter installation (Reflective)	2023
1449	Waimea Canyon Dr to Canyon Overlook	0.0708	Diverter installation (Reflective)	2023
1450	Waimea Canyon Dr to Canyon Overlook	0.1314	Diverter installation (Reflective)	2023
1451	Waimea Canyon Dr to Canyon Overlook	0.0865	Diverter installation (Reflective)	2023
1452	Waimea Canyon Dr to Canyon Overlook	0.0400	Diverter installation (Reflective)	2023
1453	Waimea Canyon Dr to Canyon Overlook	0.0476	Diverter installation (Reflective)	2023
1454	Waimea Canyon Dr to Canyon Overlook	0.0049	Diverter installation (Reflective)	2023
1455	Waimea Canyon Dr to Canyon Overlook	0.0069	Diverter installation (Reflective)	2023
1456	Waimea Canyon Dr to Canyon Overlook	0.0434	Diverter installation (Reflective)	2021
1457	Waimea Canyon Dr to Canyon Overlook	0.0697	Diverter installation (Reflective)	2023
1458	Waimea Canyon Dr to Canyon Overlook	0.0519	Diverter installation (Reflective)	2023
1459	Waimea Canyon Dr to Canyon Overlook	0.0461	Diverter installation (Reflective)	2023
1460	Waimea Canyon Dr to Canyon Overlook	0.0472	Diverter installation (Reflective)	2023
1461	Waimea Canyon Dr to Canyon Overlook	0.0426	Diverter installation (Reflective)	2023
1462	Waimea Canyon Dr to Canyon Overlook	0.0488	Diverter installation (Reflective)	2023
1463	Waimea Canyon Dr to Canyon Overlook	0.0388	Diverter installation (Reflective)	2023

1466	Waimea Canyon Dr to Canyon Overlook	0.0612	Diverter installation (Reflective)	2023
1467	Waimea Canyon Dr to Canyon Overlook	0.0502	Diverter installation (Reflective)	2023
1468	Waimea Canyon Dr to Canyon Overlook	0.0482	Diverter installation (Reflective)	2023
1469	Waimea Canyon Dr to Canyon Overlook	0.0492	Diverter installation (Reflective)	2023
1470	Waimea Canyon Dr to Canyon Overlook	0.0540	Diverter installation (Reflective)	2023
1471	Waimea Canyon Dr to Canyon Overlook	0.0557	Diverter installation (Reflective)	2023
1472	Waimea Canyon Dr to Canyon Overlook	0.0555	Diverter installation (Reflective)	2023
1473	Waimea Canyon Dr to Canyon Overlook	0.0440	Diverter installation (Reflective)	2023
1474	Waimea Canyon Dr to Canyon Overlook	0.0677	Diverter installation (Reflective)	2023
1475	Waimea Canyon Dr to Canyon Overlook	0.1154	Diverter installation (Reflective)	2023
1476	Waimea Canyon Dr to Canyon Overlook	0.0404	Diverter installation (Reflective)	2023
1477	Waimea Canyon Dr to Canyon Overlook	0.0351	Diverter installation (Reflective)	2023
1478	Waimea Canyon Dr to Canyon Overlook	0.0605	Diverter installation (Reflective)	2023
1479	Waimea Canyon Dr to Canyon Overlook	0.0448	Diverter installation (Reflective)	2023
1480	Waimea Canyon Dr to Canyon Overlook	0.0480	Diverter installation (Reflective)	2023
1481	Waimea Canyon Dr to Canyon Overlook	0.0596	Diverter installation (Reflective)	2023
1482	Waimea Canyon Dr to Canyon Overlook	0.0363	Diverter installation (Reflective)	2023
1483	Waimea Canyon Dr to Canyon Overlook	0.0427	Diverter installation (Reflective)	2023
1484	Waimea Canyon Dr to Canyon Overlook	0.0362	Diverter installation (Reflective)	2023
1485	Waimea Canyon Dr to Canyon Overlook	0.0422	Diverter installation (Reflective)	2023
1486	Waimea Canyon Dr to Canyon Overlook	0.0579	Diverter installation (Reflective)	2023
1487	Waimea Canyon Dr to Canyon Overlook	0.0572	Diverter installation (Reflective)	2023
1488	Waimea Canyon Dr to Canyon Overlook	0.0619	Diverter installation (Reflective)	2023
1489	Waimea Canyon Dr to Canyon Overlook	0.0674	Diverter installation (Reflective)	2023
1490	Waimea Canyon Dr to Canyon Overlook	0.0577	Diverter installation (Reflective)	2023
1491	Waimea Canyon Dr to Canyon Overlook	0.0693	Diverter installation (Reflective)	2023
1492	Canyon Overlook to Pua Lua	0.0680	Diverter installation (Reflective)	2023
1493	Canyon Overlook to Pua Lua	0.0401	Diverter installation (Reflective)	2023
1494	Canyon Overlook to Pua Lua	0.0293	Diverter installation (Reflective)	2023
1495	Canyon Overlook to Pua Lua	0.0482	Diverter installation (Reflective)	2023
1496	Canyon Overlook to Pua Lua	0.0545	Diverter installation (Reflective)	2023
1497	Canyon Overlook to Pua Lua	0.0788	Diverter installation (Reflective)	2023
1498	Canyon Overlook to Pua Lua	0.0660	Diverter installation (Reflective)	2023
1499	Canyon Overlook to Pua Lua	0.0613	Diverter installation (Reflective)	2023
1500	Canyon Overlook to Pua Lua	0.0376	Diverter installation (Reflective)	2023

1501	Canyon Overlook to Pua Lua	0.0560	Diverter installation (Reflective)	2023
1502	Canyon Overlook to Pua Lua	0.0625	Diverter installation (Reflective)	2023
1503	Canyon Overlook to Pua Lua	0.0563	Diverter installation (Reflective)	2023
1504	Canyon Overlook to Pua Lua	0.0483	Diverter installation (Reflective)	2023
1505	Canyon Overlook to Pua Lua	0.0534	Diverter installation (Reflective)	2023
1506	Canyon Overlook to Pua Lua	0.0420	Diverter installation (Reflective)	2023
1507	Canyon Overlook to Pua Lua	0.0469	Diverter installation (Reflective)	2023
1508	Canyon Overlook to Pua Lua	0.0960	Diverter installation (Reflective)	2023
1509	Canyon Overlook to Pua Lua	0.0633	Diverter installation (Reflective)	2023
1510	Canyon Overlook to Pua Lua	0.0500	Diverter installation (Reflective)	2023
1511	Canyon Overlook to Pua Lua	0.0517	Diverter installation (Reflective)	2023
1512	Canyon Overlook to Pua Lua	0.0539	Diverter installation (Reflective)	2023
1513	Canyon Overlook to Pua Lua	0.0441	Diverter installation (Reflective)	2023
1514	Canyon Overlook to Pua Lua	0.0726	Diverter installation (Reflective)	2023
1515	Canyon Overlook to Pua Lua	0.0645	Diverter installation (Reflective)	2023
1516	Canyon Overlook to Pua Lua	0.0737	Diverter installation (Reflective)	2023
1517	Canyon Overlook to Pua Lua	0.0655	Diverter installation (Reflective)	2023
1518	Canyon Overlook to Pua Lua	0.0667	Diverter installation (Reflective)	2023
1519	Canyon Overlook to Pua Lua	0.0311	Diverter installation (Reflective)	2023
1520	Canyon Overlook to Pua Lua	0.0516	Diverter installation (Reflective)	2023
1521	Pua Lua to NASA	0.0426	Diverter installation (Reflective)	2023
1522	Pua Lua to NASA	0.0326	Diverter installation (Reflective)	2023
1523	Pua Lua to NASA	0.0356	Diverter installation (Reflective)	2023
1524	Pua Lua to NASA	0.0324	Diverter installation (Reflective)	2023
1525	Pua Lua to NASA	0.0451	Diverter installation (Reflective)	2023
1526	Pua Lua to NASA	0.0757	Diverter installation (Reflective)	2023
1527	Pua Lua to NASA	0.0598	Diverter installation (Reflective)	2023
1530	Pua Lua to NASA	0.0437	Diverter installation (Reflective)	2023
1531	Pua Lua to NASA	0.0370	Diverter installation (Reflective)	2023
1532	Pua Lua to NASA	0.0561	Diverter installation (Reflective)	2023
1533	Pua Lua to NASA	0.0531	Diverter installation (Reflective)	2023
1534	Pua Lua to NASA	0.0599	Diverter installation (Reflective)	2023
1535	Pua Lua to NASA	0.0582	Diverter installation (Reflective)	2023
1536	Pua Lua to NASA	0.0671	Diverter installation (Reflective)	2023
1537	Pua Lua to NASA	0.0731	Diverter installation (Reflective)	2023

1538	Pua Lua to NASA	0.0732	Diverter installation (Reflective)	2023
1539	Pua Lua to NASA	0.0366	Diverter installation (Reflective)	2023
1540	Pua Lua to NASA	0.0610	Diverter installation (Reflective)	2023
1541	Pua Lua to NASA	0.0659	Diverter installation (Reflective)	2023
1542	Pua Lua to NASA	0.0745	Diverter installation (Reflective)	2023
1543	Pua Lua to NASA	0.0353	Diverter installation (Reflective)	2023
1544	Pua Lua to NASA	0.0340	Diverter installation (Reflective)	2023
1545	Pua Lua to NASA	0.0675	Diverter installation (Reflective)	2023
1546	Pua Lua to NASA	0.0689	Diverter installation (Reflective)	2023
1547	Pua Lua to NASA	0.0555	Diverter installation (Reflective)	2023
1548	Pua Lua to NASA	0.0998	Diverter installation (Reflective)	2023
1549	Pua Lua to NASA	0.0429	Diverter installation (Reflective)	2023
1550	Pua Lua to NASA	0.0373	Diverter installation (Reflective)	2023
1551	Pua Lua to NASA	0.0405	Diverter installation (Reflective)	2023
1552	Pua Lua to NASA	0.0412	Diverter installation (Reflective)	2023
1553	Pua Lua to NASA	0.0343	Diverter installation (Reflective)	2023
1554	Pua Lua to NASA	0.0594	Diverter installation (Reflective)	2023
1555	Pua Lua to NASA	0.0676	Diverter installation (Reflective)	2023
1556	Pua Lua to NASA	0.0593	Diverter installation (Reflective)	2023
1557	Pua Lua to NASA	0.0624	Diverter installation (Reflective)	2023
1558	Pua Lua to NASA	0.0525	Diverter installation (Reflective)	2023
1559	Pua Lua to NASA	0.0315	Diverter installation (Reflective)	2023
1560	Pua Lua to NASA	0.0474	Diverter installation (Reflective)	2023
1561	Pua Lua to NASA	0.0555	Diverter installation (Reflective)	2023
1562	Pua Lua to NASA	0.0392	Diverter installation (Reflective)	2023
1563	Pua Lua to NASA	0.0547	Diverter installation (Reflective)	2023
1564	Pua Lua to NASA	0.0464	Diverter installation (Reflective)	2023
1565	NASA to Kokee Nature Center	0.0366	Diverter installation (Reflective)	2023
1566	NASA to Kokee Nature Center	0.0468	Diverter installation (Reflective)	2023
1567	NASA to Kokee Nature Center	0.0373	Diverter installation (Reflective)	2023
1568	NASA to Kokee Nature Center	0.0532	Diverter installation (Reflective)	2023
1569	NASA to Kokee Nature Center	0.0671	Diverter installation (Reflective)	2023
1570	NASA to Kokee Nature Center	0.0545	Diverter installation (Reflective)	2023
1571	NASA to Kokee Nature Center	0.0434	Diverter installation (Reflective)	2023
1572	NASA to Kokee Nature Center	0.0290	Diverter installation (Reflective)	2023

1573	NASA to Kokee Nature Center	0.0470	Diverter installation (Reflective)	2023
1574	NASA to Kokee Nature Center	0.0515	Diverter installation (Reflective)	2023
1575	NASA to Kokee Nature Center	0.0509	Diverter installation (Reflective)	2023
1576	NASA to Kokee Nature Center	0.0518	Diverter installation (Reflective)	2023
1577	NASA to Kokee Nature Center	0.0638	Diverter installation (Reflective)	2023
1578	NASA to Kokee Nature Center	0.0536	Diverter installation (Reflective)	2023
1579	NASA to Kokee Nature Center	0.0568	Diverter installation (Reflective)	2023
1580	NASA to Kokee Nature Center	0.0606	Diverter installation (Reflective)	2023
1581	NASA to Kokee Nature Center	0.0580	Diverter installation (Reflective)	2023
1582	NASA to Kokee Nature Center	0.0394	Diverter installation (Reflective)	2023
1583	NASA to Kokee Nature Center	0.0609	Diverter installation (Reflective)	2023
1584	NASA to Kokee Nature Center	0.0601	Diverter installation (Reflective)	2023
1585	Kokee Nature Center to Makaha Ridge	0.0516	Diverter installation (Reflective)	2023
1586	Kokee Nature Center to Makaha Ridge	0.0532	Diverter installation (Reflective)	2023
1587	Kokee Nature Center to Makaha Ridge	0.0631	Diverter installation (Reflective)	2023
1588	Kokee Nature Center to Makaha Ridge	0.0654	Diverter installation (Reflective)	2023
1589	Kokee Nature Center to Makaha Ridge	0.0608	Diverter installation (Reflective)	2023
1590	Kokee Nature Center to Makaha Ridge	0.0615	Diverter installation (Reflective)	2023
1591	Kokee Nature Center to Makaha Ridge	0.0665	Diverter installation (Reflective)	2023
1592	Kokee Nature Center to Makaha Ridge	0.0792	Diverter installation (Reflective)	2023
1593	Kokee Nature Center to Makaha Ridge	0.0254	Diverter installation (Reflective)	2023
1594	Kokee Nature Center to Makaha Ridge	0.0461	Diverter installation (Reflective)	2023
1595	Kokee Nature Center to Makaha Ridge	0.0518	Diverter installation (Reflective)	2023
1596	Kokee Nature Center to Makaha Ridge	0.0520	Diverter installation (Reflective)	2023
1597	Kokee Nature Center to Makaha Ridge	0.0418	Diverter installation (Reflective)	2023
1598	Kokee Nature Center to Makaha Ridge	0.0521	Diverter installation (Reflective)	2023
1599	Kokee Nature Center to Makaha Ridge	0.0741	Diverter installation (Reflective)	2023
1600	Kokee Nature Center to Makaha Ridge	0.0519	Diverter installation (Reflective)	2023
1601	Kokee Nature Center to Makaha Ridge	0.0398	Diverter installation (Reflective)	2023
1602	Kokee Nature Center to Makaha Ridge	0.0396	Diverter installation (Reflective)	2023
1603	Kokee Nature Center to Makaha Ridge	0.0554	Diverter installation (Reflective)	2023
1604	Kokee Nature Center to Makaha Ridge	0.0705	Diverter installation (Reflective)	2023
1605	Kokee Nature Center to Makaha Ridge	0.0585	Diverter installation (Reflective)	2023
1606	Kokee Nature Center to Makaha Ridge	0.0535	Diverter installation (Reflective)	2023
1607	Kokee Nature Center to Makaha Ridge	0.0557	Diverter installation (Reflective)	2023

1608	Kokee Nature Center to Makaha Ridge	0.0682	Diverter installation (Reflective)	2023
1609	Kokee Nature Center to Makaha Ridge	0.0642	Diverter installation (Reflective)	2023
1610	Kokee Nature Center to Makaha Ridge	0.0588	Diverter installation (Reflective)	2023
1611	Kokee Nature Center to Makaha Ridge	0.0298	Diverter installation (Reflective)	2023
1612	Kokee Nature Center to Makaha Ridge	0.0306	Diverter installation (Reflective)	2023
1613	Kokee Nature Center to Makaha Ridge	0.0543	Diverter installation (Reflective)	2023
1614	Kokee Nature Center to Makaha Ridge	0.0601	Diverter installation (Reflective)	2023
1615	Kokee Nature Center to Makaha Ridge	0.0561	Diverter installation (Reflective)	2023
1616	Kokee Nature Center to Makaha Ridge	0.0580	Diverter installation (Reflective)	2023
1617	Kokee Nature Center to Makaha Ridge	0.0618	Diverter installation (Reflective)	2023
1618	Kokee Nature Center to Makaha Ridge	0.0626	Diverter installation (Reflective)	2023
1619	Kokee Nature Center to Makaha Ridge	0.0604	Diverter installation (Reflective)	2023
1620	Kokee Nature Center to Makaha Ridge	0.0641	Diverter installation (Reflective)	2023
1621	Kokee Nature Center to Makaha Ridge	0.0531	Diverter installation (Reflective)	2023
1622	Kokee Nature Center to Makaha Ridge	0.0439	Diverter installation (Reflective)	2023
1623	Kokee Nature Center to Makaha Ridge	0.0443	Diverter installation (Reflective)	2023
1624	Kokee Nature Center to Makaha Ridge	0.0620	Diverter installation (Reflective)	2023
1625	Kokee Nature Center to Makaha Ridge	0.0567	Diverter installation (Reflective)	2023
1626	Kokee Nature Center to Makaha Ridge	0.0299	Diverter installation (Reflective)	2023
1627	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0278	Diverter installation (Reflective)	2022
1628	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0431	Diverter installation (Reflective)	2022
1629	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0408	Diverter installation (Reflective)	2022
1630	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0878	Diverter installation (Reflective)	2022
1631	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0438	Diverter installation (Reflective)	2022
1632	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0701	Diverter installation (Reflective)	2022
1633	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0347	Diverter installation (Reflective)	2022
1634	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0327	Diverter installation (Reflective)	2022
1635	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0228	Diverter installation (Reflective)	2022
1636	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0231	Diverter installation (Reflective)	2022
1637	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0262	Diverter installation (Reflective)	2022
1638	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0250	Diverter installation (Reflective)	2022
1639	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0145	Diverter installation (Reflective)	2022
1640	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0292	Diverter installation (Reflective)	2022
1641	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0278	Diverter installation (Reflective)	2022
1642	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0217	Diverter installation (Reflective)	2022

1643	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0169	Diverter installation (Reflective)	2022
1644	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0200	Diverter installation (Reflective)	2022
1645	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0190	Diverter installation (Reflective)	2022
1646	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0286	Diverter installation (Reflective)	2022
1647	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0311	Diverter installation (Reflective)	2022
1648	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0318	Diverter installation (Reflective)	2022
1649	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0324	Diverter installation (Reflective)	2022
1650	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0284	Diverter installation (Reflective)	2022
1651	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0275	Diverter installation (Reflective)	2022
1652	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0273	Diverter installation (Reflective)	2022
1653	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0370	Diverter installation (Reflective)	2022
1654	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0295	Diverter installation (Reflective)	2022
1655	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0272	Diverter installation (Reflective)	2022
1656	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0359	Diverter installation (Reflective)	2022
1657	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0308	Diverter installation (Reflective)	2022
1658	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0277	Diverter installation (Reflective)	2022
1659	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0283	Diverter installation (Reflective)	2022
1660	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0147	Diverter installation (Reflective)	2022
1661	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0406	Diverter installation (Reflective)	2022
1662	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0637	Diverter installation (Reflective)	2022
1663	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0764	Diverter installation (Reflective)	2022
1664	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0766	Diverter installation (Reflective)	2022
1665	Kekaha Mauka 57kV to Port Allen/Kapaa	0.2129	Diverter installation (Reflective)	2022
1666.1	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0849	Diverter installation (Reflective)	2022
1666.2	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0849	Diverter installation (Reflective)	2023
1667	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0552	Diverter installation (Reflective)	2023
1670	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0437	Diverter installation (Reflective)	2023
1671	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0538	Diverter installation (Reflective)	2022
1672	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0521	Diverter installation (Reflective)	2022
1673	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0327	Diverter installation (Reflective)	2022
1674	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0432	Diverter installation (Reflective)	2022
1675	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0341	Diverter installation (Reflective)	2022
1676	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0339	Diverter installation (Reflective)	2022
1677	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0394	Diverter installation (Reflective)	2022
1678	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0496	Diverter installation (Reflective)	2022

1679	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0627	Diverter installation (Reflective)	2023
1680	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0324	Diverter installation (Reflective)	2023
1681	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0449	Diverter installation (Reflective)	2023
1682	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0383	Diverter installation (Reflective)	2023
1683	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0322	Diverter installation (Reflective)	2022
1684	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0393	Diverter installation (Reflective)	2022
1685	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0425	Diverter installation (Reflective)	2022
1686	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0456	Diverter installation (Reflective)	2022
1687	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0302	Diverter installation (Reflective)	2023
1688	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0826	Diverter installation (Reflective)	2023
1689	Kekaha Mauka 57kV to Port Allen/Kapaa	0.0454	Diverter installation (Reflective)	2023
1691	Puu Lua Kokee	0.0356	Diverter installation (Reflective)	2023
2021	Kahili	0.0739	Diverter installation (LED)	2023
2022	Kahili	0.0697	Diverter installation (LED)	2023
2023	Kahili	0.0766	Diverter installation (LED)	2023
2024	Kahili	0.0641	Diverter installation (LED)	2023
2025	Kahili	0.1053	Diverter installation (LED)	2023
2026	Kahili	0.1328	Diverter installation (LED)	2023
2027	Kahili	0.0875	Diverter installation (LED)	2023
2028	Kahili	0.0616	Diverter installation (LED)	2023
2029	Kahili	0.2727	Diverter installation (LED)	2023
2030	Kahili	0.4821	Underground	2015
2031	Kahili	0.0308	Diverter installation (LED)	2023
2032	Kahili	0.1233	Diverter installation (LED)	2023

Appendix 4C

Best Management Practices for Invasive Plan Species Control

Australian Tree Ferns- ***Cyathea cooperi****,* ATF - ATF's are widespread throughout ULP and although control has been done for years, it is still common to encounter large ferns while doing weed work. It is most common to find them in disturbed areas such as clearings and landslides although they can be present anywhere. ATFs can be identified by having many stiff, upright/horizontal fronds covered in thick white scales. Generally the fronds are far more numerous than the native hapu'u fern and form a definitive round "helicopter" top. In areas where large ferns were killed in the past there will often be many regenerating seedlings and juveniles. ATF's can be very difficult to kill. Common knowledge is that you can cut the trees down without using herbicide and the trunk or remaining crown will not re-sprout. It has been found that this is not the case in the ULP, possibly due to the wet environment.

Herbicide Used- 30% Habitat.

Control Method-

- Seedlings- For seedlings of ATF's up to one foot tall it is best to pull the plant, and hike out the remaining meristem and root ball. Fronds can be removed.
- Juveniles- The main meristem on Juvenile ATF's can almost always be reached. If this is possible first remove all fronds so that you can access the top of the meristem where new croziers (curled fronds) are sprouting up. Using a saw, cut down into the stalk about 8 inches from both sides to remove a large V-shaped wedge. It is important that you have cut far enough down to reach the starchy heart of the fern. Remove the V-shaped wedge and apply Habitat to the main stem and the wedge piece then. Following this replace the wedge back in the main stem. Replacing the wedge assists in keeping rain from washing away the herbicide and also insures that the plant dies as one unit.
- Adults- For large ATF's where you cannot reach the meristem of the plant it will be necessary to cut down the tree somewhere along the trunk. Do this where it is easiest to access as sometimes large trees can fall abruptly causing a safety hazard and you may have to move out of the way. Once you have felled the tree apply herbicide to the starchy heart that you have exposed on both sides of the cut (pic below). Do this as quickly as possible! Then move up to the main mersitem and follow the same wedge procedure as outlined for Juvenile ferns. This insures that no part of the plant will regrow.

ATF cut down with herbicide applied and ATF in the forest w characteristic "helicopter shaped fronds".

Himalayan Ginger- *Hedychium gardnerianum,* HEDGAR - Himalayan Ginger is widely known as one of the top threats to native Hawaiian forests. The herbaceous shrub can grow upwards of 6' tall and can completely smother the ground with thick rhizomes and an even thicker layer of canopy produced by large waxy leaves. Observations have been made of these rhizomes growing over the entrance to seabird burrows. This species is one of the most widespread and persistent weed species in ULP. Eradication is not an option for ginger only holding back the tide. The plants are always vigorous, the seeds are bird dispersed, and seedlings can sprout up in pristine areas with no disturbance. Due to this fact, the only way to insure you are doing an effective job of mitigating the threat is to searchcover all areas where the plants will sprout up, searching methodically searching every square meter of suitable area at that site in the days work area. Ginger, although it will sprout up anywhere, prefers shady open areas under trees, and wet areas along streams and gulches. It seems the seeds get stuck in Uluhe and Uluhe lau nui and desiccate slowing down sprouting in these areas. In general once you have reached an area that is open, sunny and covered in Uluhe or uluhe lau nui your search is complete. However if you see a stand of trees up the slope that appears to have a shady open area underneath you must go and check for HEDGAR. This search method is a bit esoteric to explain but with experience and dedication to comprehensively searching an area it becomes clear with time where the plants tend to grow.

Herbicide Used- 1% Escort

Control Method-

- Cut stems a couple/several inches above rhizome (on Himalayan ginger; where the pink base of the stem begins to fade to a green color) and stack stalks on the side.
- Stack all of the fronds that you remove off to the side of the patch as you will need them after treating to cover your work.
- It is important to "Undress" the patch before applying herbicide so you can clearly see all the rhizomes that need to be treated. Scrape away all leaves, dirt and debris.
- Once you have cleaned the work area make cuts in all rhizomes including the ones that you just cut the fronds off of. Each section of rhizome should get 4-6 cuts up to ¼" deep with a machete or saw, with particular focus on the nodes where new growth will be

sprouting from. Make sure to look under and around the sides of the patch to make sure you make cuts and/or stabs in rhizomes that are hiding underneath the bulk of the patch. Also be careful not to cut chunks of rhizome and send them flying into the bushes as these will surely re-sprout.

- Liberally coat all rhizomes and cuts with Escort. Don’t skimp on herbicide as under-treated patches can regrow.
- Once the patch has been treated it is time to cover it or “build a hale” to prevent rain from washing away all of your hard work. The best way to do this is to remove individual leaves from your largest fronds. The leaves can then be stacked, overlapping to reduce runoff. Sometimes it is necessary to build a scaffold using leafless stems to stack your overlapping leaves on.
- Seedlings up to 1’ in height can be pulled, taken back to camp and thrown in the trash. The leaves and stems can be ripped off.

HEDGAR stems cut at the proper height and a large flower stalk.

Guava Trees ***Psidium cattleianum,*** Strawberry Guava, PSICAT and ***Psidium guajava,*** Common Guava, PSIGUA- Strawberry guava seems to be appearing more often in the ULP although relative to other areas on Kauai numbers are pretty low. Trees can be found anywhere and are generally scattered, solitary individuals. Common Guava is only found at lower elevations close to basecamp and has not been seen for years. Some sources recommend applying Garlon directly to the trunk on Common Guava trees but it is believed this treatment should be avoided in the ULP due to the wet environment.

Herbicide Used- 25% Garlon 4.

Control Method-

- Cut the tree down within 1’ of the ground.
- Apply Garlon 4 to the trunk liberally.
- Apply to the cut on the tree and make sure to elevate the tree off the ground.
- Make sure to search the area for seedlings and juveniles if the tree you are treating is mature. These can usually be pulled with ease.


PPSICAT growth form, flowers, trunk and fruit.


PSIGUA fruit and smooth trunk bark.

Hardwood Trees- ***Melaleuca quinquenervia,*** Paperbark Tree, MELQUI; *and* ***Grevillea robusta,*** Silk Oak, GREROB- These trees are becoming less common in the ULP due to successful control and are mainly seen around Basecamp. They are somewhat difficult to spot. **Paperbark Tree-** This species has a very conspicuous straight trunk that is bright white with dark olive green leaves. The bark is very papery and sheds off of the tree. Leaves have a pleasant herbal fragrance.

Grevillea- This species is rarely seen in the ULP. The leaves are very lacey and the round canopy is very different from the other trees in the *Metrosideros* dominated forest however, they it can be difficult to spot unless they are large trees. The wood of this species can be toxic, and so care must be taken for anyone who cuts down this species. The flowers are bright orange and spiky, very conspicuous, even from great distances.

Herbicide Used- 30% Habitat.

Control Method-

- Cut down the tree and directly apply Habitat to the cut stump and also to the cut on the part of the tree you have felled.
- It is very important to be mindful of how and where cut materials are being disposed. Most tree species in ULP will re-root from cut pieces and grow into full trees. It is best to prop the trees in the bushes or Uluhe in a site where they will desiccate in the sun.
- It is also important to apply the herbicide quickly (within 30 sec. or as soon as the applicator can safely apply the herbicide) after the tree has been cut since some of these species can close up their wounds shortly after being damaged.

Paperbark flowers and leaves, Natalia Tangalin cuts down a tree, and treated stump.

Grevillea robusta leaves and flowers.

Softwood Trees- ***Spathodea campanulata*****,** African Tulip, SPACAM; ***Schefflera actinophylla*****,** Octopus tree, SCHACT; ***Clusia rosea,*** Autograph Tree, CLUROS-

African Tulip although beautiful, is one of the most invasive species in Hawaii. The huge orange or yellow flowers can cover these trees and the large seed pods that follow are filled with papery wind dispersed seeds. When sterile and at a distance, this species can be confused with some *Polyscias* species. The large trees will have a straight white trunk and a sparse but contained canopy of dark bluish compound leaves. These trees are quite common in the lower sections of the ULP near Basecamp.

Schefflera, a very common house plant throughout the nation, has taken over a large portion of the Lower Limahuli Preserve. The bird dispersed seeds can grow epiphytically. As the trees grow they will eventually strangle their host tree. These trees have very glossy leaves on relatively sparse (thick) branches with whitish bark. Seed heads and flower spikes are bright red and resemble the outstretched arms of an octopus. From a distance this species could be confused with native *Polyscias* species (which are in the same family). Although uncommon in the ULP as compared to other weed species, this is also a very problematic species.

Autograph Tree is yet to be spotted in the ULP, but it is known from the ridges in nearby Mānoa Valley and occurs hanging on the steep cliffs of Lower Limahuli preserve. It is a matter of when and not if the species will make it into the ULP and when it does it will be a formidable foe. *Clusea* is a medium to large terrestrial or epiphytic tree with a dense canopy of dark green, waxy stiff leaves. Flowers are white-pink, large and waxy, while the fruits are greenish-brown and fleshy. The dark brown bark can become very rough on the trunk and the trees often send down adventitious root suckers similar to Banyan.

Herbicide Used- 50% RounduUp.

Control Method-

- Although these species have softer wood they are generally much more difficult to kill. Felled branches have a much higher tendency to re-root and grow into a new tree.
- To effectively remove the species use a saw or drill to make 1/2'" deep cuts/holes around all parts of the trunk on the trunk (or all trunks if there are multiple).
- Cuts should be spaced every 2-3" and be as close to the base of the tree as possible.
- It is very important to make cuts in all aerial roots and suckers as well to insure all parts of the tree die.
- On larger trees it is necessary to stop after 5 cuts and apply herbicide so that the wounds don't heal over. Or get help from a co-worker.
- Liberally apply RounduUp to all holes and cuts.

- USE EXTRA caution as the chemical is very concentrated!!
- Autograph Tree can be much more difficult to kill than the other trees in this section. It is best to make more cuts and use more herbicide to be cautious.

SPACAM leaves and flowers and the small papery, wind dispersed seeds.

SCHACT octopus-like leaves and growth habit showing bright red flowers.

CLUROS growth habit and leaf, flower, fruit and seed capsule.

Mules Foot Fern- *Angiopteris evecta*, *ANGEVE*- Mules foot fern is a new arrival to the ULP only spotted within the last 3 years. The occurrence of this very large fern seems to be increasing although of yet only juvenile plants have been found. Native to SE Asia and Australia, *Angiopteris* can grow to become massive and when they mature they have with fronds up to 7 meters in length and 3 meters in width. The base of the frond stems (stipes) appear swollen and bear two flat, rounded, dark brown, leathery growths- this section of the fern is called the “mules foot”. Look for Mules Foot Fern in and around shady wet gulches. The base of the plant closely resembles that of *Marratia douglasii,* a native fern, so it is important to be aware of which taxa you are looking at before making a kill.

Herbicide Used- 30% Habitat.

Control Method-

- Remove all fronds from the fern.
- Around the scaly base of the fern make ¼- ½” deep incisions with a machete or saw, every inch or so.
- Apply 30% Habitat to the wounds as quickly as possible.
- It is good to try and cover the treated area with a nearby HEDGAR leaf or Clidemia.

ANGEVE fronds and pinna and base with fleshy stipules or “Mules Foot”.

Albizia- *Falcataria moluccana,* FALMOL-
Only a few individuals of this species are known to occur within Limahuli. Unfortunately, the locations are very difficult to access. The seeds disperse easily and the incredibly fast growing tree can be difficult to cut down. The white bark and large flat/layered canopy of this tree makes it easy to spot. It is good to keep an eye out for seedlings and juveniles in landslides and other disturbed areas.

Herbicide Used- 30% Habitat

Control Method-

- Albizia can be controlled by stripping the bark from the base of the tree however it is prudent to apply Habitat to the cuts as well.
- Use a hand saw and cut in through the bark and cambium layer (approx. 1-1.5”) in a circle around the tree about 3’ from the base.
- Go down the trunk 1’ foot and cut another circle around the tree.
- Try to make a vertical cut in between your 2 previous cuts.
- With some work you can begin to pry the bark from the tree and it should come off with ease.
- Apply Habitat to the lower and upper exposed parts of the cambium.

Albizia’s large spreading trunk and leaves and flowers.

Vines/Brambles (*Rubus sp., Passiflora sp., Lantana camara*)-

Rubus argutus is a relatively new species to the upper preserve. This prickly vine can rip rain jackets and cut skin. The large black fruit are tasty and hold lots of bird dispersed seeds. This fast growing species can form large thick patches quickly and should be viewed as a very high priority for incipient removal. When in fertile, the vines are covered in white flowers.

***Passiflora* sp**. (Lilikoi, Passion Fruit) – Any species of this genus that naturalizes in the ULP could pose a huge threat to the preserve. The long, fast growing vines can smother large areas and the edible fruit is will readily dispersed by birds. Although it has only been observed a few times in the ULP, staff should be on the look-out for a uniform mat of foliage on the canopy (or fruit on the ground).

Lantana camara*-* Lantana is a vigorously growing shrub with recurved prickles and a strong odor when crushed. Its root system is very strong, and it gives out a new flush of shoots even after repeated cuttings. The flowers are usually orange or yellow, but can also occur in a range from red to white. Seeds are bird dispersed.

Herbicide Used- 30% Habitat.

Control Method-

- As most of the vegetative parts of these plants are growing through and on top of surrounding plants, you must first identify where the stems are growing out of the ground.
- Cut the stem and liberally apply Habitat to the fresh cut.
- Look for any signs of aerial roots growing out of the vines, if they are present cut and treat as much stem as possible, ideally placing the treated parts off the ground so that there is little chance of them rooting down.
- For **Blackberry** it is best to leave the stem intact and girdle the base by stripping it of the bark. Apply habitat to the stripped area. Blackberry will often have to be re-treated and is very difficult to kill.

Invasive Species Best Management Practices

[Photo on website]

Caption: If project activities occur in natural areas or native habitat, or have a high risk of introducing invasive species, we recommend that the following best management practices for biosecurity be incorporated into the project design as applicable.

Recommended Best Management Practices to Minimize the Introduction/Spread of Invasive Species

(Updated August 2021)

Invasive species pose a significant worldwide threat to native plants and animals, resulting in economic, ecological, cultural, and human health impacts (Lowe et al. 2004; Global Invasive Species Database (GISD) 2021). These impacts often include habitat degradation and loss, agricultural impacts, altered landscapes, increased costs associated with management of impacts to human quality of life, and loss of biodiversity, sometimes resulting in extirpations and extinctions of native species (International Union for Conservation of Nature and Natural Resources (IUCN) 2017; Ebersole 2020). Beginning with the first inadvertent introductions of invasive species by humans hundreds of years ago, all of these impacts continue to affect native species and habitats in the Hawaiian (Staples and Cowie 2001; Duffy and Martin 2019; Hawaii Invasive Species Council (HISC) and Coordinating Group on Alien Pest Species (CGAPS) 2020; National Tropical Botanical Garden 2021) and Mariana Islands (Rogers et al. 2012; Dawson et al. 2017;; Ossola 2018; College of Natural and Applied Sciences,).

In general, project activities can increase the likelihood of introducing or spreading invasive species to new areas or islands. For example, seeds of invasive plant species can be inadvertently transported on equipment or gear from a previous work site to a new site where they are not present. Likewise, equipment used in an area infected with a pathogen (i.e., Rapid ʻŌhiʻa Death (ROD) or *Ceratocystis spp.*), if not properly decontaminated, can act as a vector to introduce the pathogen into a new area (College of Tropical Agriculture, University of Hawaii 2021). Likewise, vehicles must be properly inspected and cleaned to ensure vertebrate pests do not stowaway and spread to other areas. These are just a few examples of how even well-intended project activities may inadvertently introduce invasive species.

To improve biosecurity and prevent and minimize the introduction or spread of invasive species, projects should incorporate best management practices (BMPs). In particular, vigilance is necessary when project activities occur in natural areas, including National Parks, National Wildlife Refuges, and Hawaiʻi State Natural Areas; or habitat areas containing primarily native vegetation (referred to hereafter as native habitat). We recommend that all projects occurring in natural areas or native habitat adhere to the following procedures, termed the “General Invasive Species BMPs.” Activities involving a substantial amount of transportation of materials (i.e., construction materials or aggregate, etc.), vehicles, machinery, equipment, or personnel between sites have a higher risk of spreading invasive species, and should also follow the "General Invasive Species BMPs" to the extent practicable. Additional consultation is recommended if the project involves transportation of materials, equipment, vehicles, etc. between islands.

There are also a few select invasive species of concern in the Pacific Islands of which species-specific BMPs have already been developed in partnership with species experts. These species-specific BMPs are recommended for projects that occur in certain geographic areas, and / or involve an activity that is a known pathway for the spread of specific species or groups of species. Please refer to Table 1 for the current distribution of these invasive species. If your project occurs within the geographic area of any of these species, please review and incorporate the relevant species-specific BMP(s) into your project design. As new invasive species threats emerge that require development of species-specific BMPs, those may be added to this list.

General Invasive Species Best Management Practices

The following protocol is recommended to the extent practicable when the project activities occur in natural areas or native habitat. These procedures should also be applied to any project that involves a substantial amount of transportation of materials (i.e., construction materials or aggregate, etc.), vehicles, machinery, equipment, or personnel between multiple work sites. Additional consultation is recommended if the project involves transportation of materials, equipment, vehicles, etc. between islands.

1. Cleaning and treatment:

   Project applicants should assume that all project materials, vehicles, machinery, and equipment contain dirt and mud, debris, plant seeds, and other invasive species and therefore require thorough cleaning. Treatment for specific pests, for example, trapping and poison baiting for rodents, or baiting and fumigation for insects, should be considered when necessary. For effective cleaning we offer the following recommendations prior to entry into a project site:

   a. Project materials, vehicles, machinery, and equipment must be pressure washed thoroughly (preferably with hot water) in a designated cleaning area. Project materials, vehicles, machinery, and equipment should be visibly free of mud, dirt, seeds, plant debris, insects, spiders, frogs (including frog eggs), and other vertebrate species such as rats, and mice and rubbish. Areas of particular concern include bumpers, grills, hood compartments, wheel wells, undercarriage, cabs, and truck beds. Truck beds with accumulated material are prime sites for hitchhiking invasive species.

   b. The interior and exterior of vehicles, machinery, and equipment must be free of rubbish and food. The interiors of vehicles and the cabs of machinery should be vacuumed clean.

2. Inspection:

   a. Following cleaning and or treatment, project materials, vehicles, machinery, and equipment, must be visually inspected by its user, and be free of mud, dirt, debris, and invasive species prior to entry into a project site. For example, inspection for ants would include the use of ant bait attractants which could confirm the absence / presence of ants in a vehicle. Another example would be the careful visual inspection of a vehicle's tires and undercarriage for any remaining mud that could contain invasive plant seeds.

3. Re-treatment:

    a. Any project materials, machinery, vehicles, and equipment found to contain invasive species after initial cleaning including any plant material must be re-cleaned before entry to the project site. Likewise, if materials, vehicles, machinery, or any equipment contain ants, other invertebrates, or vertebrates, including rats and mice, after initial treatment, they must be re-treated for extermination (i.e., poison baiting, trapping, fumigation, etc.) before entry into the project site. Cleaning, treatment, and inspection are the responsibility of the equipment or vehicle owner and operator. However, it is ultimately the responsibility of the action agency to ensure that all project materials, vehicles, machinery, and equipment are free of mud and invasive species before entry to a project site with a natural area or native habitat site.

4. Base yards and staging areas:

    a. Base yards and staging areas should be inspected for invasive species at least weekly during the duration of the project. Invasive species found in the site must be immediately removed or treated. Vehicles should be parked within a 10 square meter buffer area free of debris and/or vegetation. Ideally, vehicles should be parked on pavement and not under trees or in tall grass and other vegetation.

    b. Temporary storage of project vehicles or equipment outside of a base yard or staging area, such as a private residence, is discouraged. If necessary, they should be kept in a pest free area.

5. For all project site personnel:

    a. Prior to departing your residence or place of employment to transit to the project site, visually inspect and clean your clothes, boots or other footwear, backpack, radio harness, tools and other personal gear and equipment for insects, seeds, soil, plant parts, , or other debris.

    b. Immediately prior to departing a project site, visually inspect and clean your clothes, boots, pack, radio harness, tools, and other personnel gear and equipment for insects, seeds, soil, plant parts, , or other debris. Seeds found on clothing, footwear, backpacks, etc., should be placed in a secure bag or similar container and discarded in the trash rather than being dropped to ground at the project site or elsewhere.

6. Additional considerations (if applicable):

    a. Conduct a risk evaluation for activities that involve an uncertain potential for invasive species introduction, and therefore require further assessment in order to determine additional prevention guidelines.

    b. When applicable, use pest-free or low-risk sources of plants, mulch, wood, animal feed or other materials to be transported to a project site.

    c. For projects involving plants from nurseries (e.g., outplanting activities, etc.), all plants should be inspected and, if necessary, appropriately cleaned or treated for invasive species prior to being transported to the project site.

    d. Avoid unnecessary exposure to invasive species at a particular site (to the extent practical) to reduce contamination and spread. For example, plan or organize timelines so that work commences in a less infested area and toward a more contaminated site as best as practical.

e. When applicable, limit ground disturbing activities while working in natural areas. For example, utilize existing trails or roadways to avoid creation of new corridors that may be exploited by opportunistic vertebrates.

f. Maintain good communication about invasive species risks between project managers and personnel working on the project site. Ensure prevention measures are communicated to the entire project team. Report any species of concern or possible introduction of invasive species to appropriate land managers.

Rapid ʻŌhiʻa Death (ROD)

Rapid ʻŌhiʻa Death (ROD) is a caused by a fungal pathogen (*Ceratocystis* spp.) that attacks and kills ʻōhiʻa trees (*Metrosideros polymorpha*). ʻŌhiʻa is endemic to the Hawaiian Islands and is the most abundant native tree species, comprising approximately 80% of Hawaiʻi's native forests.

The following decontamination protocol and BMPs are recommended for projects occurring in any natural area or native habitat where ʻōhiʻa is present on islands where ROD is currently found. If working directly with ʻōhiʻa trees (e.g., sampling suspected trees, clearing an area of ʻōhiʻa, etc.) or in area(s) known to be highly infested with ROD, additional consultation is recommended. Additional consultation is also recommended if the project involves transportation of materials, equipment, vehicles, etc. between islands.

Current Distribution of ROD: Hawaiʻi Island, Oʻahu, Kauaʻi

- For more information about ROD including current confirmed distribution, ROD science updates, and the latest on ROD protocol, please visit www.rapidohiadeath.org.

Best Management Practices for Projects on Islands with ROD

1. Never transport any part of an ʻōhiʻa tree between different areas of an island or to a different island.
2. Do not use equipment from ROD infected islands on another island unless it is very specialized equipment and follows the decontamination protocols described below.
3. Avoid wounding ʻōhiʻa trees and roots with mowers, chainsaws, weed eaters, and other tools. If an ʻōhiʻa receives a minor injury like a small broken branch, then give the injury a clean, pruning-type cut (close to the main part of the trunk or branch) to promote healing, and then spray the entire wounded area with a pruning seal.
4. Always report suspect ROD ʻōhiʻa trees. ROD is a wilt disease that cuts off the supply of water and nutrients to the tree. The primary symptom to look for is an entire canopy or a large branch with dying leaves or red discolored leaves. Please record the GPS coordinates and location and take a picture of the tree if possible. Please report suspected ROD ʻōhiʻa trees to the following agencies:

    d. Kauaʻi – KISC: 808-821-1490 (kisc@hawaii.edu)

ROD Decontamination Protocol Projects on Islands with ROD

1. Clothes, footwear, backpacks, and other personal equipment
    a. Before leaving the project site, remove as much mud and other contaminants as possible. Use of a brush with soap and water to clean gear is preferred. Footwear, backpacks, and other gear must be sanitized by spraying with a solution of >70% isopropyl alcohol or a freshly mixed 10% bleach solution.
2. Vehicles, machinery, and other equipment
    a. Vehicles, machinery, and other equipment must be thoroughly hosed down with water (pressure washing preferred) and visibly free of mud and debris, then sprayed with a solution of >70 isopropyl alcohol or a freshly mixed 10% bleach solution. Use of a "pump-pot" sprayer is recommended for the solution and a hot water wash is preferred. Be sure to thoroughly clean the undercarriage, truck bed, bumpers, and wheel wells.
    b. If non-decontaminated personnel or items enter a vehicle , then the inside of the vehicle (i.e., floor mats, etc.) must be subsequently decontaminated by removing mud and other contaminants and sprayed with the one of the same aforementioned sanitizing solutions.
3. Cutting tools
    a. All cutting tools, including machetes, chainsaws, and loppers must be sanitized to remove visible mud and other contaminants. Tools must be sanitized using a solution of >70% isopropyl alcohol or a freshly mixed 10% bleach solution. One minute after sanitizing, one may apply an oil-based lubricant to chainsaw chains or other metallic parts to prevent corrosion as bleach is corrosive to metal.

NOTE: When using a 10% bleach solution, surfaces should be cleaned with a minimum contact time of 30 seconds. Bleach must be mixed daily and used within 24 hours, as once mixed it degrades. Bleach will not work to disinfect surfaces that have high levels of organic matter such as sawdust or soil. Because bleach is also corrosive to metal, a water rinse after proper sanitization is recommended to avoid corrosion.

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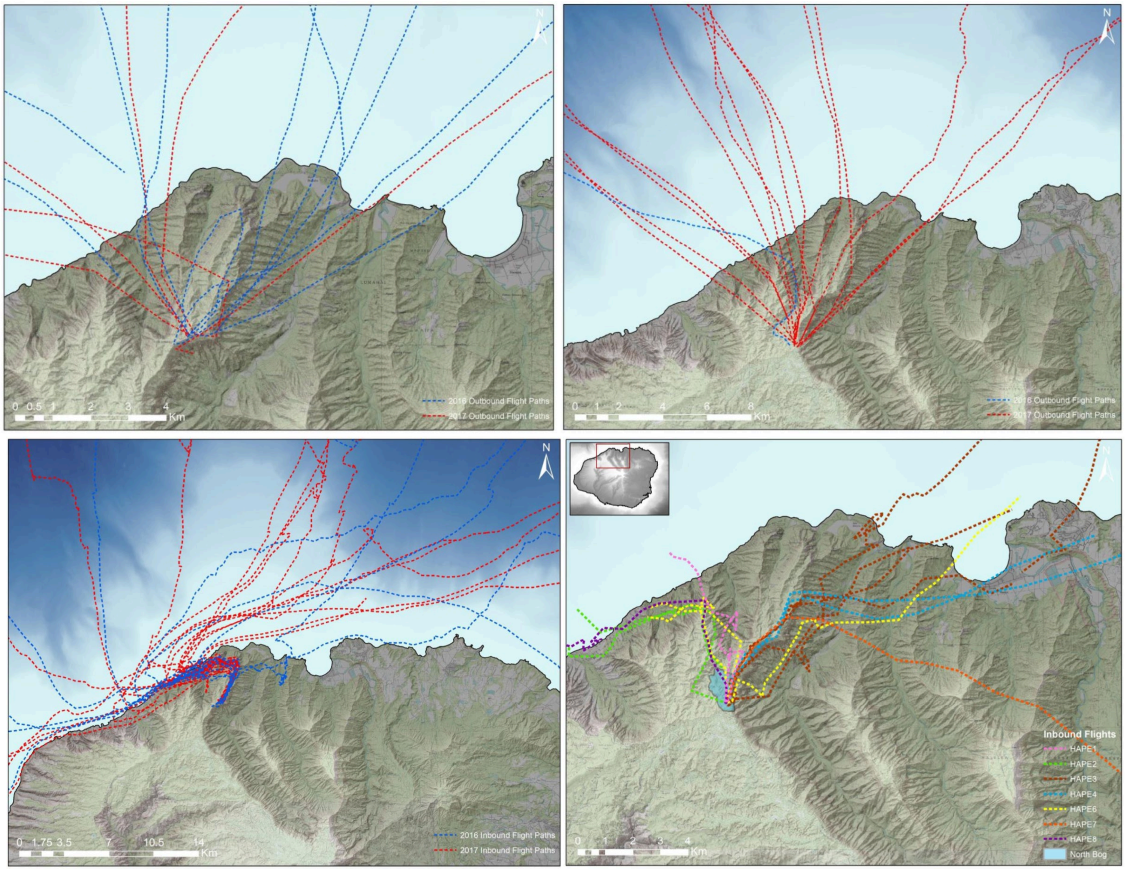
Appendix 5A

Variables Influencing Powerline Strikes

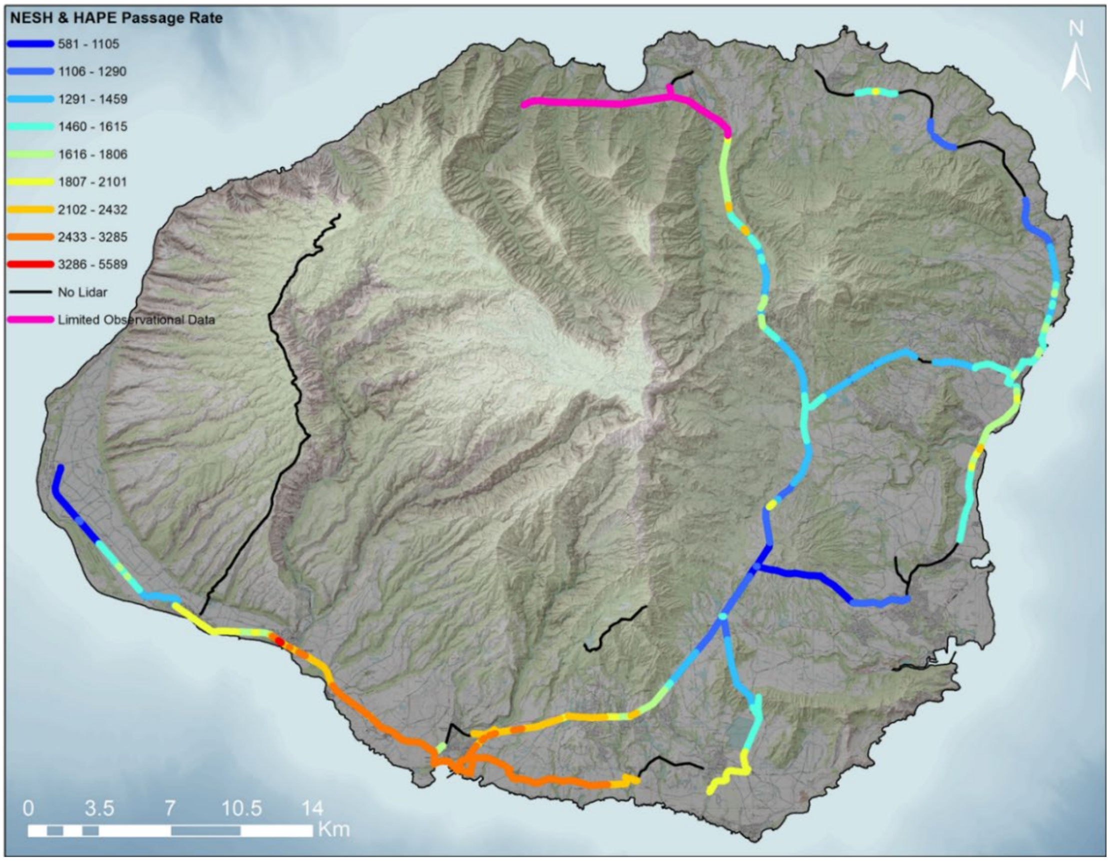
5A.1 Powerline Location

Seabirds in the colonies in the northwestern portion of Kauaʻi are thought to be relatively safe from powerline collisions because there is a lack of powerlines in that part of Kauaʻi. Recent tracking data are consistent with this assumption; most observed flight paths from colonies take relatively direct routes to and from sea that do not cross powerlines in other parts of Kauaʻi (Figure 5A-1; Raine et al. 2017). However, during the tracking study, an adult Hawaiian petrel (ʻuaʻu) breeding in North Bog was tracked crossing over the interior of Kauaʻi from the ocean back to its colony, making multiple crossings while en route of the powerlines along one of the highest collision hot spots on Kauaʻi on the Powerline Trail (Raine et al. 2017). It is not clear if this is a regular route for this bird since only one inbound route was collected, but it does indicate that some seabirds from colonies in the northwestern portion of Kauaʻi may also be at risk from powerline collisions (Figure 5A-1 lower right map; Raine et al. 2017). The tracking data indicate, therefore, that the risk of powerline collision mortalities for breeding colonies in northwestern Kauaʻi is relatively low, but not zero. Figures 5A-2 and 5A-3 show the combined passage rates and annual strikes rates for Newell's shearwaters (ʻaʻo) and Hawaiian petrels (ʻuaʻu) in the Plan Area, respectively. The results clearly show that birds in relatively safe areas such as the northwest of Kauaʻi may still have some risk of powerline collision.



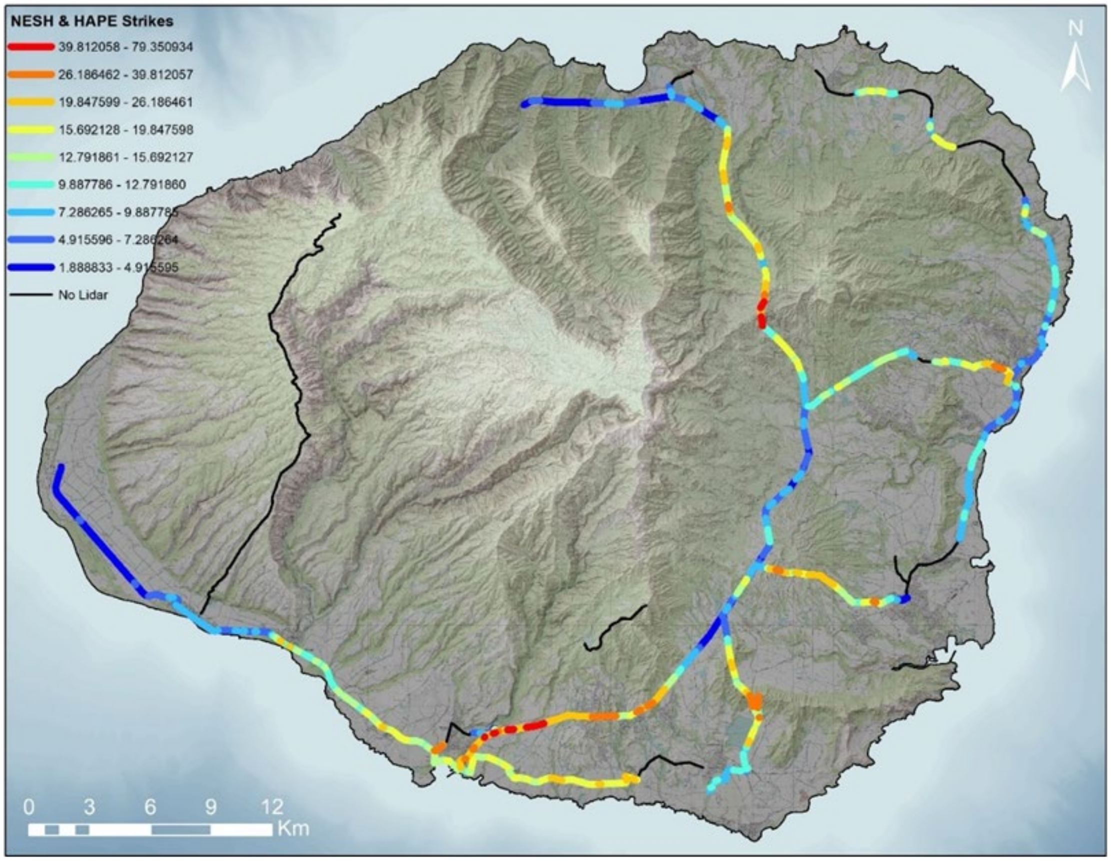
Source: Raine et al. 2017

Figure 5A-1. All recorded tracks recorded in 2016 and 2017 for Newell's shearwater (ʻaʻo) (left two maps) and Hawaiian petrel (ʻuaʻu) (right two maps). Outbound tracks are shown in the top two maps and inbound tracks are shown in the bottom two maps. Inbound tracks for Hawaiian petrel (ʻuaʻu) are only from 2017; no inbound tracks were recorded for this species in 2016.



Source: Travers et al. 2019

Figure 5A-2. Combined Passage Rates for Newell's Shearwaters (ʻaʻo) (NESH) and Hawaiian Petrels (ʻuaʻu) (HAPE) for Monitored Powerlines for One Season



Source: Travers et al. 2019

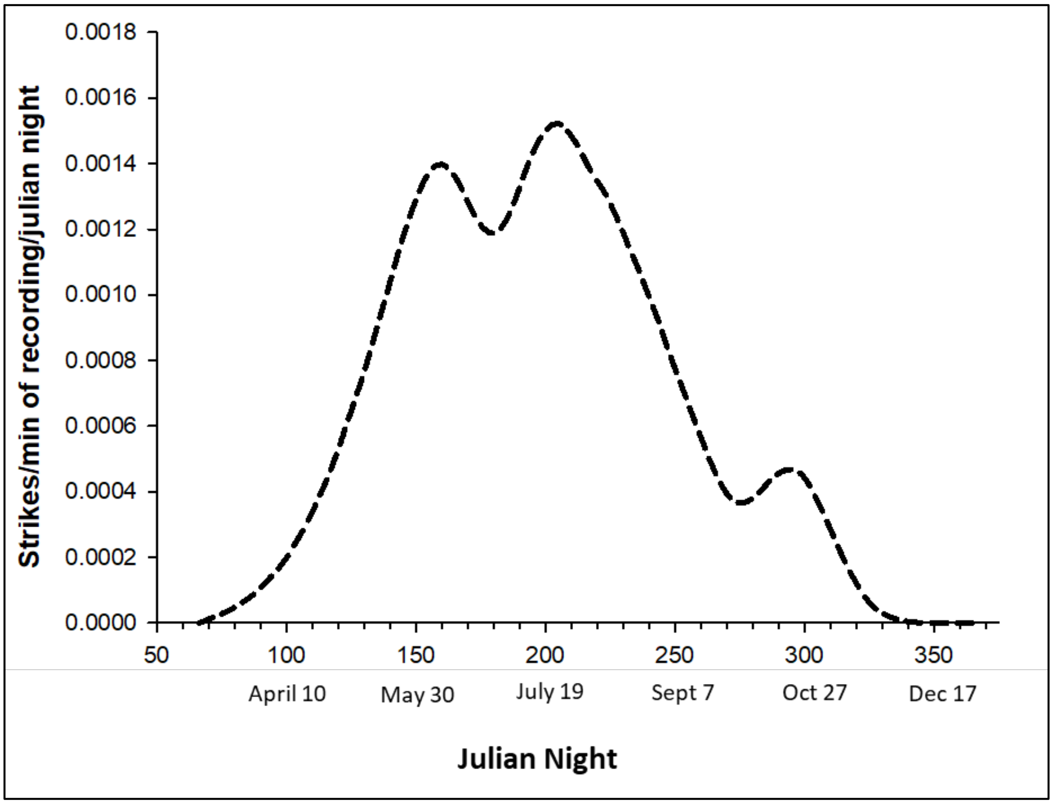
Figure 5A-3. Annual Estimated Strike Rates of Newell's Shearwaters (ʻaʻo) (NESH) and Hawaiian Petrels (ʻuaʻu) (HAPE) Colliding with Monitored Powerlines

5A.2 Seasonality

Powerline collisions occur annually in conjunction with the covered seabird breeding season and times of transition between breeding colonies and the sea. Newell's shearwaters (ʻaʻo) and Hawaiian petrels (ʻuaʻu) are at risk of powerline collisions from March to the end of December (Travers et al. 2018). This time period coincides with the Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) breeding season. The majority of powerline collisions occur from April to the end of November (Travers et al. 2018).

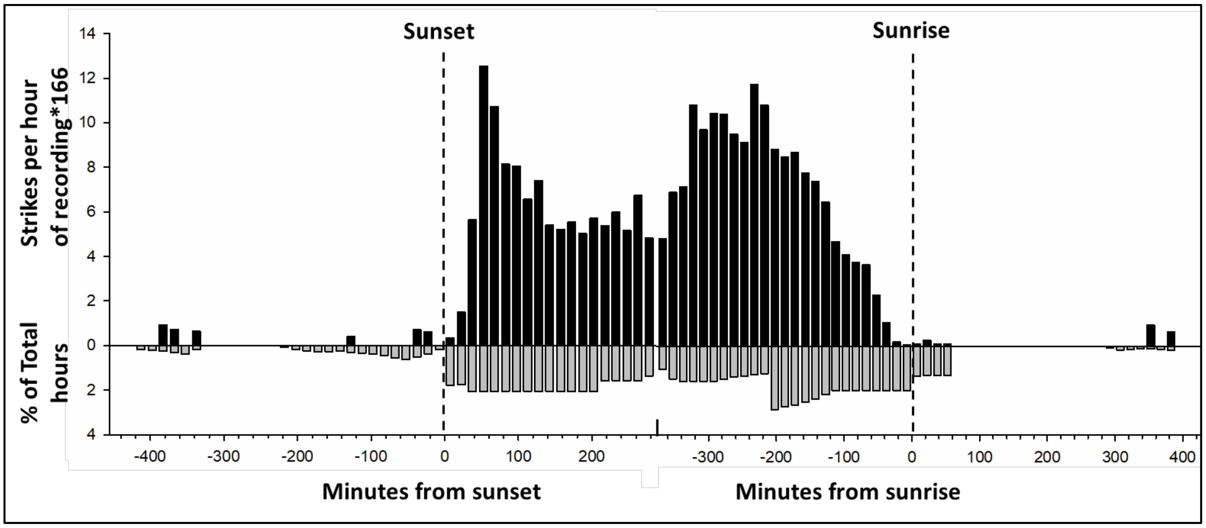
The amount of powerline collisions fluctuates throughout the breeding season. As seabirds return to their breeding grounds in March, detection of powerline collisions commences. Powerline detections fluctuate throughout the various stages of the breeding season, which on Kauaʻi is as follows; arrival (mid-April), exodus (May), incubation (May–mid July), chick rearing (late July–September), fledging (late September–mid-November for Newell's shearwaters [ʻaʻo] and November–mid-December for Hawaiian petrels [ʻuaʻu]), and ends when seabirds have left for the winter (Raine et al. 2019; Travers et al. 2014, 2019). Figure 5A-4 shows the distribution of powerline strike detection rates in relation to the time of year, with a peak during the middle of the Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) breeding season (as described above). Thus, detection rates of powerline collisions begin to increase as Newell's shearwaters (ʻaʻo) and Hawaiian petrels (ʻuaʻu) arrive at the breeding colonies, peak in the middle of the seabird breeding season, and then decline to zero after chicks have fledged and seabirds have left for the winter (Travers et al. 2019).

Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) movement between breeding colonies and the sea takes place during crepuscular periods (sunset to sunrise) and full darkness (Travers et al. 2019). Based on acoustic monitoring of powerline strikes and observations of the covered seabirds at monitored powerline spans, the pattern of collisions corresponds to the daily movement of Newell's shearwaters (ʻaʻo) and Hawaiian petrels (ʻuaʻu). As seen in Figure 5A-5, strike detections start to increase when seabirds transit powerlines during crepuscular periods and reach their high point during the peak movement of seabirds, which occurs during full darkness (Travers et al. 2019). Visual observations and monitoring of burrows with cameras have observed movement patterns of Newell's shearwaters (ʻaʻo) and Hawaiian petrels (ʻuaʻu) to and from breeding colonies on Kauaʻi. Breeding adult Newell's shearwater (ʻaʻo) movement is primarily restricted to near crepuscular periods, while Hawaiian petrels (ʻuaʻu) arrive and depart throughout the night (Travers et al. 2017). Newell's shearwaters (ʻaʻo) have been estimated to account for approximately 70 percent of powerline passages, compared to 30 percent of Hawaiian petrel (ʻuaʻu) (Travers et al. 2020). This observed proportion is a function of the increased frequency with which Newell's shearwaters (ʻaʻo) visit their burrows compared to Hawaiian petrels (ʻuaʻu), as well as the portion of the night during which monitoring occurred (Travers et al. 2019).



Source: Travers et al. 2019

Figure 5A-4. Seasonal Pattern of Acoustically Detected Nocturnal Powerline Strike Sounds



Source: Travers et al. 2019

Figure 5A-5. Timing of Powerline Strikes Acoustically Detected Throughout a 24-hour Period Based Upon Information Collected from 2013 to 2017

5A.3 Topography

Topography surrounding powerlines varies and may increase or decrease powerline collision risks. For example, powerlines strung across valleys increase their aboveground height. Though power poles are 75 feet (ft) (23 meters [m]) tall, placing these poles up a valley can result in powerlines 279 ft (85 m) above the ground, in the middle of seabird flight heights (Travers et al. 2019). Additionally, ridgelines above deep valleys can cause birds to fly very low as they come up and over the ridges, increasing the risk of seabirds colliding with powerlines located at ridgelines.

5A.4 Vegetation Height

The height of vegetation surrounding powerlines may increase or decrease seabird powerline collision risks. For example, trees taller than the powerlines force birds to fly over the powerlines (Travers et al. 2019), thereby reducing the risk of collision. If trees are lower than the powerlines, the lines are exposed to birds flying at the height of those wires, thereby potentially exposing them to risk of collision. For vegetation to result in an entire powerline span having zero risk of a bird collision, tall trees must shield the full length of the span to prevent a seabird from flying at the height of the wires. If there are any gaps in the tree line that expose a portion of the powerline, seabirds may fly lower and thus be exposed to the space occupied by the powerlines (Travers et al. 2019). This applies to areas where birds are flying to or from colonies. If powerlines are strung up through colonies, tree cover will not necessarily reduce collisions because birds may be flying through the trees to land at their burrows.

5A.5 Wires

Wire height and covered seabird flight height can affect the potential for a powerline collision. Wires that are taller (higher above ground) are more likely to be positioned within the bird flight height distribution (Travers et al. 2019). Therefore, within a wire array, the top wire has greater risk than the second highest wires, and the second wire has greater risk than the third wire. This factor is important for minimization planning.

The height of a powerline depends, in part, on the type of powerline: static wire, transmission line, distribution line, or communication line. Figure 2-2a and 2-2b in Chapter 2, *Covered Activities*, displays the major wire types and their relative positions on the pole. Sometimes in place of a standard static wire, there is a fiber-optic cable. Fiber-optic cable is important to identify and map because, unlike standard static wires, fiber-optic cable does not produce a strike sound when hit (Travers et al. 2014). The covered bird species may collide with any of these lines.

Wire configuration influences collision risk. For example, vertically arrayed wires have greater risk than if those same wires were constructed horizontally because the vertical array takes up more physical airspace in which birds transit, increasing the probability that birds will be flying at wire height.

Wire thickness can affect the wire's visibility to a bird transiting the area, as well as the rate of mortality if struck. Bundling wires or using thicker wires are potential minimization tools, but it is not clear what effect this would have on reducing powerline collisions (i.e., birds may see thicker wires better and thus would be more likely to avoid them, or depending on the array, bundled wires could increase collisions because it reduces the chance of avoidance) (Raine *in litt.* 2019). Using insulated wires does, however, allow the wires to be lowered closer to the ground (because they have different regulations than uninsulated wires), which in many scenarios would reduce collision risk.

The greater the number of wires the more objects that occur in the birds' flight path, thereby increasing the risk of a seabird colliding with a powerline.

5A.6 Seabird Flight Height

For the tracking study done on Kauaʻi by Raine et al. (2017), described above, regarding the flight height of these species to and from two colonies in the northwest portion of the island, birds were outfitted with global positioning system (GPS) tracking tags, which recorded the location, height, distance, and speed at they traveled. A GPS-tagged Hawaiian petrel (ʻuaʻu) was recorded crossing powerlines multiple times at low altitude, in a known high-strike area along the Powerline Trail (Raine et al. 2017). For Newell's shearwaters (ʻaʻo) flying from their breeding colonies out to sea, birds flew high as they left the colony until they reached the sea. When coming in from the sea to the breeding colony, birds flew low over the sea until turning inland, then increased sharply in altitude and departed from sea level about 0.6 mile (mi) (1 kilometer [km]) from the coast. When flying from their breeding colony out to sea, Hawaiian petrels (ʻuaʻu) flew high, gradually losing height and reaching sea level about 4.5 mi (7.3 km) from the coast. As they returned from the sea to their breeding colony, they flew low over the sea until approaching land and then increased sharply in altitude, departing sea level 2.5 mi (4.1 km) from the coast.

5A.7 Flight Speed and Maneuverability

Flight speed of the covered seabirds at powerlines is a function of bird direction (inland or seaward) and flight direction relative to wind direction and speed. Radar studies at powerlines indicated that seabirds transit at rates of 30 km/hour (18.6 mi/hour) to 100 km/hr (62.1 mi/hour) (Travers et al. 2014). The information herein is based on limited data available regarding movement patterns of

Newell's shearwaters (ʻaʻo) and Hawaiian petrels (ʻuaʻu) from a study by Raine et al. (2017), including flight speed of these species to and from two colonies in the northwest portion of Kauaʻi.

Table 5A-1 provides the average speed of each species as it flew over land and water on the way from its breeding colony to sea and from sea back to its breeding colony (Raine et al. 2017). The speed at which seabirds fly puts them at an increased likelihood of collision with powerlines. An observed trend is that Hawaiian petrels (ʻuaʻu) have a higher avoidance of powerline collisions, likely due to their increased flight maneuverability and sometimes slower flight speed than Newell's shearwaters (ʻaʻo) (Travers et al. 2018).

Table 5A-1. Average speed of Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) as it flies over land and water from its breeding colonies to the sea and from the sea to its breeding colonies.

	Outbound (breeding colony to sea)	Inbound (sea to breeding colony)
Newell's shearwater (ʻaʻo)		
Land	42.9 km/hr	35.7 km/hr
Water	56.6 km/hr	42.4 km/hr
Hawaiian petrel (ʻuaʻu)		
Land	51 km/hr	34 km/hr
Water	61.4 km/hr	27.3 km/hr

Hawaiian petrels have increased flight maneuverability due to lower wing loading (weight to wing surface area ratio) and in some instances a slower flight speed than the Newell's shearwater (ʻaʻo) (Travers et al. 2018). Direct observations of powerline interactions show that Hawaiian petrels (ʻuaʻu) are better able to make large correcting maneuvers such as stalling or flaring upwards to avoid powerlines, when the wires are detected. Newell's shearwaters (ʻaʻo) struggle to make large correcting maneuvers unless flying with a steady head wind (Travers et al. 2018).

5A.8 Flight Path

The flight path of seabirds varies by the side of island and inland and seaward directions of flight as well as other factors such as wind direction and speed. For example, for inland flights seabirds on the north, east, and south to southwest shores of the island tend to take a direct flight path (Travers et al. 2019). Seabirds breeding in the Nā Pali, Waimea Canyon, and Makaweli/Olokele drainages use the lee of the island to gain elevation using calm areas or the wind that circles inland and upslope (Travers et al. 2019). Flight paths that result in lower aboveground flight height increase powerline collision risk. For example, when a flight path forces them to fly into a strong head wind, the birds fly lower. This occurs typically on the seaward flight on the east side of the island and on the inland flight on the south/west side of the island.

5A.9 Wind- and Weather-Related Factors

Seabird flight heights and flight path are influenced by wind and topography (Travers et al. 2019). Seabirds flying into a headwind fly slower and have greater lift and maneuverability, but it also causes seabirds to fly lower increasing the likelihood of flying at wire height (Travers et al. 2018). Seabirds flying with a tailwind fly higher (Travers et al. 2019) and have less maneuverability and less ability to gain elevation (Travers et al. 2013). Thereby, a seabird flying with a tailwind may fly over land at greater altitudes to avoid obstacles (Travers et al. 2013). Typically, the wind is light to moderate from the northeast direction in the summer (Travers et al. 2018), which is the peak breeding season for Newell's shearwaters (ʻaʻo) and Hawaiian petrels (ʻuaʻu). This results in varied flight directions relative to wind for the north/east, south/west, and Nā Pali Coast, further resulting in varied flight height and behaviors in these three large regions.

Heavy mist or rain may obscure powerlines from flying birds, reducing the bird's ability to detect them, and increasing the risk of collision with powerlines.

5A.10 References

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Appendix 5B

Rapid Waterbird Powerline Collision Assessment

Underline Monitoring Project
Rapid Waterbird Powerline Collision Assessment

Marc Travers & André F. Raine

Assessment requested by KIUC on June 26, 2020
Assessment provided July 23, 2020 for comments

The Underline Monitoring Project (UMP) is part of the Kauaʻi Endangered Seabird Recovery Project (KESRP), which is a joint project of the Pacific Cooperative Studies Unit of the University of Hawaiʻi and the Division of Forestry and Wildlife (DOFAW)/State of Hawaiʻi Department of Land and Natural Resources.

Preface

On June 26th, the team developing the KIUC HCP (consisting of representatives from USFWS, DOFAW, KIUC and HT Harvey) requested information from KESRP on the likelihood and frequency of waterbirds hitting KIUC powerlines. Due to the current timeline for the development of the HCP, the deadline for this information was only a couple of weeks later and took place during the peak KESRP field season. To help the HCP team meet this timeline, KESRP offered to conduct a rapid assessment with the data available. While KESRP always recommends developing research programs designed to answer specific questions, we also understand the urgency at this stage for incorporating this information into the HCP document. However, we would like to make it clear from the outset that because of this short timeline and lack of a research project to investigate this issue, the assessment presented in this document has been produced, by necessity, with numerous untested assumptions.

The regional assessments in the document have varying levels of supporting data. The information and results for Mānā are robust as we have data from both acoustic monitoring and observations. In contrast, UMP has not conducted powerline observations in Hanalei waterbird dense locations and similarly there is minimal acoustic effort in the waterbird dense locations. In the absence of observational and robust acoustic data, Hanalei powerlines should be considered to have the same risk as Mānā.

2.0 Methods

In this document we employ two levels of analysis based on the available data. The first level of analysis uses a combination of observer and acoustic based data sets to determine powerline collisions of most native waterbirds (Sections 2.1.0–2.1.3). The second separate analysis uses grounded bird detections to determine powerline collision mortalities (not strikes) of the Hawaiian gallinule (ʻalae ʻula) (*Gallinula galeata sandvicensis*) and Hawaiian coot (ʻalae keʻokeʻo) (*Fulica alai*). Neither waterbird species have supporting observational data (Section 2.2).

2.1.0 Explanation and background

For the purposes of the first analysis (which uses observation and acoustic data) we have split waterbird collisions into three areas; (i) Mānā, (ii) Hanalei National Wildlife Refuge (NWR) and surrounding wetlands and (iii) all other areas, as outlined below. The Mānā is the most data-rich waterbird area UMP has monitored. Mānā is the only waterbird area with a full range of UMP data including observation data, acoustic monitoring, acoustic detections of strikes, and modeling of acoustic strike patterns across a season. For this reason, we use Mānā data as the foundation for the determination of waterbird powerline collisions elsewhere in Sections 2.1.2 and 2.1.3.

To understand the available data and how it is utilized in this assessment, we present the following background information based on data that was collected in 2014 and 2015 for the UMP. In 2014, UMP expanded acoustic monitoring to low elevation powerlines next to highways, which included the Mānā. UMP acoustic monitoring based on strike sounds[1] detected a high rate of nocturnal powerline collisions in the Mānā area, which was unexpected given the relatively low number of seabirds moving in that area based on observer data (Travers et al. 2015).

In 2015 we identified through observer data that although there was certainly Newell's shearwater (ʻaʻo) (*Puffinus auricularis newelli*) passage in the Mānā area, the most common birds moving through the region were waterbirds (Travers et al. 2016). Given the high number of strike sounds and waterbirds in the region, we determined that waterbirds were at highest risk of hitting the powerlines and inferred that they were responsible for a large portion of the detected acoustic collisions (Travers et al. 2016). Since there was no further study to facilitate the separation of strikes in Mānā to species or provide species-specific avoidance behavior, at KIUC direction, the Bayesian Model assumes that all of the Mānā strikes are seabirds. However, as recommended by UMP in the years 2015–2020, a proportion of strikes in Mānā can be attributed to species other than Newell's shearwaters (ʻaʻo) (Hawaiian petrels [ʻuaʻu] [*Pterodroma sandwichensis*] have not been observed passing over this area), and we have developed an analysis to estimate the risk to waterbirds.

Our first step in the below analysis was to develop a collision risk score that ranks each species' relative collision risk at Mānā. We then apply that proportional risk for each species to the modeled strikes determined by the Bayesian Acoustic Strike model, obtaining an acoustic strike count for each species. Using the acoustic strike model output, we include all bird species that have a collision risk (Table 2), including the Newell's shearwater (ʻaʻo).

2.1.1 Mānā waterbird powerline collisions

To develop a rapid assessment that assigns powerline collisions to multiple species, we produced a collision risk score for each bird species based on available information. The risk score is based on a combination of the frequency of powerline crossings, above ground flight height, and whether birds were flying singly or in pairs or flocks. We have made no attempt to determine species-specific avoidance rates though waterbird species may vary considerably in their ability to avoid powerlines. This rapid assessment was requested in a 14-day timeline without additional research, and as such relies heavily on assumptions where data does not exist; therefore, we recommend updating this assessment when new information is obtained.

Calculations

Waterbird risk for powerline collisions is based on a cumulative point scale that assigns an overall species risk score. Height risk is given a score of either 0 or 1, with 0 indicating minimum risk due to high flight height, and 1 indicating increased risk due to low flight height. Flocking risk is given a score of 2. Each species risk is ranked proportional to all other species. The species-specific proportional risk is then applied to the acoustic strikes for the region to get species-specific annual strike totals.

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[1] A strike sound is produced only when the vibrations, generated by a bird colliding with the powerlines, traveling along a cable makes contact with the insulator that is connecting the wire to a power pole (Travers et al. 2015)

Species risk score = Sum for each species (*height risk rank*flocking*)

- ***Height risk rank* = 1- percentile rank of above ground flight height.** This assumes a linear decrease in collision risk from the maximum risk of 1 assigned to the lowest recorded flight to the minimum risk of 0 assigned to the highest recorded flight.
- ***Flocking* = 2.** The trailing birds in pairs or flocks have increased risk of collision because in these scenarios the trailing bird is continuously following the leading bird/s and not scanning for hazards. When the leading bird sees a hazard and reacts the trailing bird's reaction is slightly delayed increasing collision risk. UMP recently observed this phenomenon when the trailing bird in a flock of three Hawaiian geese (nēnē) (*Branta sandvicensis*) collided with a powerline in the Mānā, but more generally this has been observed when flocks of Hawaiian geese (nēnē) approach powerlines, resulting in a closer encounter with the powerlines for the trailing birds. Marc Travers has also observed this phenomenon hundreds of times while studying common eider ducks in the Canadian Arctic. In Table 2, we provide the risk score without the flocking multiplier to present to readers the influence of the flocking term.

Species proportion of risk = Species risk score/Sum all species risk

Partitioning of Annual strikes = Acoustic Night Strikes (Species proportion of risk **Bayesian Acoustic Strike Estimate PMRF*) + Crepuscular strikes (Species proportion of riskCrepuscular Collision estimate PMRF*)**

- ***Bayesian Acoustic Strike Estimate PMRF = 640.*** UMPKESRP Bayesian Acoustic Model estimate for the Mānā area, which is calculated as 640 strikes annually. It should be noted that this model only estimated strike numbers for the acoustic strike night (30 min post sunset to 30 before sunrise) and does not therefore include any assessment of diurnal or crepuscular collision risk.
- ***Crepuscular Collision estimate PMRF = (Bayesian strike Estimate/Raw Night strikes)*Raw crepuscular strikes = 77.*** There is no estimate or model results for the crepuscular period as the Bayesian model was specifically designed around the acoustic night to ensure that the results were conservative. The above cross multiplication was used to adjust the raw crepuscular strikes to a strike estimate proportionally equivalent to the Bayesian Model estimate.
- **Immediate grounding = 0.13*Strikes.** This is the endangered seabird minimum grounding rate (Travers et al. 2020). Without any data on waterbird grounding rates following collision, we have used this as a proxy measure. This is possibly a conservative estimate for some slow flying waterbirds, given that seabirds fly at higher speeds than some waterbirds.

2.1.2 Hanalei National Wildlife refuge, Hanalei River, and Taro Fields

We have no observation information for the Hanalei refuge powerlines as we have not conducted nocturnal observations in this area. This is because the area has difficult land access and because we had determined it to be low collision risk for endangered seabirds. Given the complete absence of data we have been asked to apply the collision rates of Mānā powerlines to Hanalei in proportion to powerline length. That is, if Hanalei has the same length of powerlines we will apply the identical Mānā strike rate divided amongst the waterbirds. In the absence of observer data, however, we have had to assume the scenario is the same.

2.1.3 Remainder of powerlines studied by UMP

To assess collision risk outside of Mānā or Hanalei, we calculated the collision risk score for waterbirds observed at all other powerlines island-wide proportional to Mānā. Specifically, collision risk score was determined for each waterbird species and subsequently the risk scores were partitioned into the categories of Mānā or the remainder of the island. The scores were divided to determine relative risk outside of Mānā for strikes and groundings (Remainder of island risk score/Mānā risk score* Mānā strikes or Mānā Immediate grounding). This calculation was iterated separately across species. Unlike in Mānā, this estimate of waterbird strikes did not necessarily occur in areas where we had acoustic monitoring or had ever recorded acoustic strikes. For this reason, the strikes estimated in this section should not be subtracted from Newell's shearwater (ʻaʻo) or Hawaiian petrel (ʻuaʻu) strike totals as should be done for the Mānā/PMRF area strikes.

2.2.0 Background on the grounded bird detection analysis- Hawaiian Gallinule (ʻalae ʻula) & Hawaiian Coot (ʻalae keʻokeʻo)

Hawaiian gallinules (ʻalae ʻula) and Hawaiian coots (ʻalae keʻokeʻo) have rarely been documented flying during UMP observations, and therefore we have insufficient observation data to conduct an observer-based analysis for these species. However, there is sufficient evidence to show that Hawaiian gallinules (ʻalae ʻula) and Hawaiian coots (ʻalae keʻokeʻo) have definitive powerline collision risk as they have been found by staff dead under powerlines, in some cases a long distance from water. In the absence of observation data, we used waterbird mortality data as a metric for powerline collisions. It should be noted that the other native waterbirds mentioned above (and of course endangered seabirds) have also been found dead under powerlines. Mortality data was not used for the remaining waterbirds assessed because we had sufficient observation and acoustic data to determine collision risk.

2.2.1 Determining detection biases and powerline mortality using dead birds

UMP ranks each detected carcass on the probability that the bird died as a result from a powerline collision. For Hawaiian gallinules (ʻalae ʻula) and Hawaiian coots (ʻalae keʻokeʻo) in the UMP database, powerline collision ranking is as follows; 3 definitive powerline collisions, 5 probable, and 7 possible. Hawaiian gallinules (ʻalae ʻula) and Hawaiian coots (ʻalae keʻokeʻo) were listed as definitive powerline collisions when they were found dead under powerlines with no other hazards or water nearby. For example, Hawaiian gallinules (ʻalae ʻula) found in the coffee fields under wires without any water nearby; that is, there is no other reason this bird would be on the ground dead. Hawaiian gallinules (ʻalae ʻula) were listed as probable powerline collisions when a bird was found under powerlines along or near a road with water located away from the roadway and present on only one side of the road. That is, probable collisions are cases where it is more likely that the source of mortality was the powerline than vehicle collisions given the lack of habitat across the roadway, but vehicle collision cannot be completely discounted given the roadway hazard. Hawaiian gallinules (ʻalae ʻula) listed as 'Possible' were birds where the carcass was found under powerlines along or near the side of the road, but water was present adjacent to the roadway or on both sides of the road and therefore there is a higher possibly that the bird was killed by a vehicle as it transited across the road between the two water sources.

Only two Hawaiian coots (ʻalae keʻokeʻo) were in the database and we categorized them both as possible powerline collisions, as per the definitions outlined above.

The carcass numbers are multiplied by the various biases that result in undercounting, which include detection bias, carcass removal, and searchable space at powerlines. Pending further research, the formula and undercounting biases and multipliers that we use for these calculations are as follows:

Estimated carcasses = found carcasses *2*8*1.3*3*1/8

- **KESRP staff frequent < half of the islands powerlines = 2.** Based on where staff live, go to work and recreate KESRP staff drive along the roads from Waimea to Līhuʻe with regularity. The roads in this area cover far less than half of the powerlines island-wide but for simplicity we have suggested a multiplier of 2.
- **Detection bias = 8.** Podolsky et al. (1998) stated their team found 1 in 4 carcasses when actively searching, with multiple biologists in the vehicle, at highway speed. The question here is what should the detection rate for a single biologist who is not actively searching while driving? Although an underestimate, for simplicity we have set this at the same rate as Podolsky et al. (1998). However, there is an addition consideration. Hawaiian gallinules (ʻalae ʻula) and Hawaiian coots (ʻalae keʻokeʻo) are harder to identify then Newell's shearwaters (ʻaʻo) while driving at highway speed. They can easily look like a dead black chicken (of which there are many road casualties), especially when flattened by a car. For this reason, we halved the detection rate, which doubles the multiplier.
- **Carcass removal = 1.3.** As outlined in previous reports, UMP found that 17% of carcasses disappeared on day 1, 33% by day 3 and 52% removed by day 10 (Travers et al. 2012). We set the bias at the 3-day removal rate because KESRP staff do not frequent all roads every day.
- **Searchable space at powerlines = 3**. UMP has conducted an analysis of the searchable space around all powerlines on the island to 30 meters on either side of the wires. We summed the square meters within the 60-meter-wide transect in which a biologist can enter to search. Roads and road shoulders make up the largest percentage of searchable space. Nearly all powerlines next to roads have inaccessible private land on one side, which results in the highest searchability, for example, 39% in the Western powerline region, and approaches zero in much of the PL Trail or central regions. Searchability within the half of the island frequented by KESRP staff is in reality far lower than a third but for simplicity we set the searchable space at 33%.
- **Annual rate = 1/8.** The carcasses used in this calculation were detected across 8 seasons.

3.0 Results

3.1.0 Analyses using observations and acoustic modeling results

3.1.1 Mānā estimate

For native bird species, black-crowned night-herons (BCNH) accounted for the largest proportion of collision risk based on flight height and passage rate, followed by Hawaiian goose (nēnē) (HAGO), Hawaiian ducks (koloa) (HAWD), Newell's shearwaters (ʻaʻo) (NESH), Hawaiian stilts (aeʻo) (HAST), and Pacific-golden plovers (PAGP) (see Table 2). Non-native species had the greatest risk during the crepuscular period but low risk during the night.

At Mānā, we have directly observed powerline collisions of the two waterbird species with the highest collision risk, the black-crowned night-heron and the Hawaiian goose (nēnē).

3.1.2 Hanalei National Wildlife Refuge and taro fields

In the absence of Hanalei specific data, and if a number is required, we recommend using the Mānā rate per km as a place holder for the Hanalei collision rate. The Hanalei section of powerlines is 7.75 km and is 95% the length of the Mānā powerlines which are 8.18 km (See Table 3 for numbers).

3.1.3 Remainder of powerlines studied by UMP

Much of the remainder of the islands powerlines studied by UMP had zero or near zero risk of waterbird powerline collisions. Overall, the remainder of the island collectively had a much lower risk of waterbird collisions than Mānā, indicating that Mānā has very high relative risk (see Table 4). Only Hawaiian goose (nēnē) and Pacific-golden plovers had more risk at the island scale and this risk was only slightly larger than Mānā for Hawaiian goose (nēnē) and amounted to 1.9 total strikes for plovers. All other species had far less risk or zero risk at all other powerlines monitored. Note that in 2015 a plover was found with a fractured wing under powerlines that cross the powerline trail near Pole 138.

3.2.0 Dead bird analysis for the Hawaiian Gallinule (ʻalae ʻula) and Hawaiian Coot (ʻalae keʻokeʻo)

3.2.1 Hawaiian Gallinule (ʻalae ʻula)

Accounting for biases (as outlined in the Methods), there would have been 7.8, 20.8, 39.0 dead Hawaiian gallinules (ʻalae ʻula) annually across the entire island, considering the definitive, definitive + probable, and definitive + probable + possible powerline collisions, respectively.

3.2.2 Hawaiian Coot (ʻalae keʻokeʻo)

Accounting for biases (as outlined in the Methods), there would have been 0, 0, 15.2 dead Hawaiian coots (ʻalae keʻokeʻo) annually, considering the definitive, definitive + probable, and definitive + probable + possible powerline collisions, respectively.

4.0 Brief discussion

Mānā clearly has the highest documented powerline collision risk to waterbirds on Kauaʻi, based on available data. We calculated Hanalei powerline collision risk in proportion to Mānā by considering relative powerline length, exposure height, and population of waterbirds. Relative to powerline length the remainder of powerlines studied by UMP have considerably lower collision risk approaching zero for most of the power grid. However, it should be noted that the scenario of wetland and powerlines in Hanalei is not the same as that for Mānā in that powerlines are distributed differently relative to the location of water and that powerlines differ in their construction heights. Therefore, there is potential Hanalei waterbirds do not follow the same collision patterns as Mānā.

The collision risk for Hawaiian goose (nēnē) was high in Mānā and, relative to other waterbird species, higher at other powerlines on the island. This is not surprising if you consider that there are an estimated 1,500 Hawaiian goose (nēnē) on Kauaʻi, most of whom move daily in or across areas with powerlines. In a single day of movement there are likely at least hundreds of Hawaiian goose (nēnē) powerline crossings across Kauaʻi as there are few areas on this island without powerlines, and this will be repeated 365 days a year. Just like with Newell's shearwaters (ʻaʻo) and Hawaiian petrels (ʻuaʻu), even if only a small percentage of crossing result in a collision there can be a large sum across the year and 208 km of major powerlines and additional hundreds of kilometers of distribution powerlines. To date, we have observed a Hawaiian goose (nēnē) collision during 210 hours of observations—observations that were not temporally centered on Hawaiian goose (nēnē) movement times. Mānā powerlines alone have ~ 370,110 hours annually in which Hawaiian goose (nēnē) regularly cross powerlines. In the 8 years UMP has been conducting research we were present in Mānā < 0.007% of the time Hawaiian goose (nēnē) regularly move, yet in that very small window of time relative to total movement, we have confirmed Hawaiian goose (nēnē) collide with powerlines, indicating a high probability of greater collision numbers.

We recommend that reflective diverters be attached to the Mānā powerlines to reduce collision for all species, and that this should also be considered for the Hanalei powerlines. Research would be required to determine diverter efficacy, but we suspect that in Mānā they would be highly effective because the dry conditions will lead to the most consistent visibility and available ambient light to reflect off of the diverters.

4.1.0 Factors not considered

We have not attempted to quantify collision risk at the >800 km of distribution powerlines UMP does not monitor.

We have not attempted to determine species specific powerline avoidance behavior or capabilities. However, based on our observations of the species and theoretical risk determine by flight ability (Bevanger 1998), Hawaiian goose (nēnē), Hawaiian ducks (koloa), Hawaiian gallinules (ʻalae ʻula), and Hawaiian coots (ʻalae keʻokeʻo) would all have relatively low avoidance capabilities, and would likely be similar to Newell's shearwaters (ʻaʻo). Plovers and stilts would likely have considerably better avoidance capabilities.

We have not attempted to determine species-specific grounding rates or mortality. We can make the following statement based on flight speed—Hawaiian ducks (koloa), Hawaiian gallinules (ʻalae ʻula) and Hawaiian coots (ʻalae keʻokeʻo) will all have transiting speeds similar to Newell's shearwater (ʻaʻo) under certain conditions. We cannot comment on the likelihood of waterbirds hitting powerlines and flying off unharmed. The Hawaiian geese (nēnē) we observed colliding and crashing into the ground did manage to take off from the ground, but with "strained flight". Newell's shearwaters (ʻaʻo) we have observed on the ground were not capable of flying away, even when there was no clear visible injury. Note though, had the Hawaiian geese (nēnē) crashed into the highway, it could have easily been hit by a car before recovering flight.

5.0 Conclusion

Lastly, it should be clear from the seabird research and waterbird data that birds found dead in the road crushed by a vehicle does not definitively indicate that the bird was killed by a car. Furthermore, for a bird to be labeled “killed by car” that bird has to be shown to behaviorally frequent landing or walking in the middle of highways or crossing highways on foot or flight that is car height. For a coot or a gallinule, low flight at car height could be considered a common behavior from water source to water source when no other obstructions exist (e.g. as seen on golf courses). However, we see this type of flight as highly unlikely if there is taller vegetation on either side of the road. Overall, we have definitive evidence from seabirds to Hawaiian geese (nēnē) to ducks to gallinules that powerlines cause these birds to crash uncontrolled to the ground. Most powerlines on the island are positioned next to roads, meaning a crash landing has a high likelihood of resulting in a bird on the road. All dead birds found in the road should be considered, at minimum, possible powerline collision victims if wires are present.

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Table 2. Mānā Waterbird Collision Risk Scores Applied to Acoustic Detected Strikes

Species	Time Period	Risk Score Flocking	n	Proportion of Risk Flocking	Bayesian Acoustic Estimate	Annual Strikes	Immediate Ground
BCNH	Acoustic Night	41	58	0.44	640	282	36.7
NENE	Acoustic Night	21	17	0.22	640	141	18.3
NESH	Acoustic Night	14	72	0.15	640	96	12.5
HAWD	Acoustic Night	12	16	0.13	640	83	10.8
HAST	Acoustic Night	4	2	0.04	640	26	3.4
Non-Native	Acoustic Night	2	2	0.02	640	13	1.7
					Crepuscular estimate		
Non-Native	Crepuscular	87	99	0.29	77	22	2.9
HAWD	Crepuscular	74	65	0.25	77	19	2.5
NENE	Crepuscular	58	47	0.2	77	15	2
BCNH	Crepuscular	51	60	0.17	77	13	1.7
HAST	Crepuscular	17	18	0.06	77	5	0.6
PAGP	Crepuscular	10	12	0.03	77	2	0.3
	Combine above two time periods						
BCNH	Sunset to Sunrise					295	38.4
NENE	Sunset to Sunrise					156	20.3
HAWD	Sunset to Sunrise					102	13.3
HAST	Sunset to Sunrise					31	4
PAGP	Sunset to Sunrise					2	0.3

*note birds that do not regularly fly in pairs or flocks have a relatively low flocking score compared with the number of Birds observed when compared to birds commonly observed in pairs or flocks.

Table 3. Hanalei waterbird collision risk proportional to Mānā collision risk by length of powerlines

Species	Time Period	Annual Strikes	Immediately Grounded
BCNH	Sunset to Sunrise	280	36.5
NENE	Sunset to Sunrise	148	19.3
HAWD	Sunset to Sunrise	97	12.6
HAST	Sunset to Sunrise	29	3.8
PAGP	Sunset to Sunrise	2	0.3

Table 4. Waterbird collision risk at all remaining powerlines monitored by UMP proportional to Mānā collision risk

	Mānā PMRF Area				Remainder of islands Powerlines monitored by UMP				
Species	multiplier	Risk Rank Flocking	Strikes	Immediately Grounded	multiplier	Risk Rank Flocking	Relative Risk	Strikes	Immediately Grounded
BCNH	118	79	295	38.4	34	13	0.16	49	6.3
NENE	64	103	156	20.3	121	107	1.04	162	21.1
HAWD	81	85	102	13.3	16	3	0.04	4	0.5
HAST	20	20	31	4	0	0	0.00	0	0
PAGP	12	12	2	0.3	106	77	6.42	13	1.9

Appendix 5C

Light Attraction Modeling

5C.1 Introduction

5C.1.1 Purpose

The purpose of this document is to describe the process for quantifying take of the covered seabirds, Newell's shearwater (ʻaʻo), Hawaiian petrel (ʻuaʻu), and band-rumped storm-petrel (ʻakēʻakē), on Kauaʻi resulting from attraction to Kauaʻi Island Utility Cooperative (KIUC) streetlights and facility lights for the KIUC Habitat Conservation Plan (HCP). The methods to quantify take resulting from KIUC streetlights is different from the methods used to quantify take resulting from lights associated with KIUC facilities. The methods and outcomes for both types of lights are discussed in this appendix.

5C.1.2 Mechanism of Take

Artificial lighting can attract various species in the family *Procellaridae*, including the covered seabirds. When fledglings leave their nest for the first time in the hours following sunset, they have the propensity to become attracted to artificial lights. After flying around the lights, birds attracted to artificial light can tire or inadvertently hit a structure and may become grounded, an event referred to as *fallout* (Imber 1975; Telfer et al. 1985). If the light-attracted individuals that become grounded are not rescued, they are at risk for succumbing to injury or mortality due to starvation, predation, collisions with cars, or a combination thereof. This attraction often occurs after young fledglings reach the ocean and are then attracted inland by coastal lights, which explains why they are frequently grounded in coastal areas that are quite distant from their colony (Troy et al. 2013; Rodríguez et al. 2015). There is also a potential for attraction to occur on their outbound journey prior to reaching the ocean (Troy et al. 2013). In uncommon events, adults can also exhibit light attraction (Center for Biological Diversity 2016).

Despite lacking knowledge of the exact mechanism causing attraction, it is understood that observed patterns of fallout on Kauaʻi are complex and result from various independent conditions (Troy et al. 2013). The primary source of attraction is bright lights; An early study on Kauaʻi showed that the shielding of bright lights can reduce fallout by 40 percent (Reed et al. 1985), and recent studies continue to indicate that the reduction of lateral light spillage is beneficial to reducing light-induced fallout (Rodríguez et al. 2017a, 2017b). While efforts to shield lights can effectively reduce fallout, these efforts do not appear to eliminate it. Several studies have shown that fallout patterns are also influenced by the location and brightness of artificial lights relative to seabird colonies, the proximity of lights to the coastline, and the wavelengths emitted by different light types (Troy et al. 2011, 2013; Rodrigues et al. 2012; Rodríguez et al. 2015, 2017a, 2017b, 2017c; Longcore et al. 2018).

5C.1.2.1 Streetlights

KIUC owns and operates approximately 4,150 streetlights located along roadways and in residential developments, primarily along the developed southern, eastern, and northern perimeter of Kauaʻi up to 5 miles (8.1 kilometers) inland and generally coinciding with urban centers and residential areas. KIUC streetlights are 3000K Light Emitting Diode (LED) bulbs that have been retrofitted with full-cutoff luminaries to minimize lateral light spillage (KIUC 2017). It is estimated that an additional 1,050 streetlights will be installed in the Plan Area over the 30-year permit term.

5C.1.2.2 Facility Lights

KIUC owns and operates only two facilities which maintain nighttime lights for safety and visibility; the Port Allen Generating Station and the Kapaia Generating Station. Due to the location of Port Allen Generating Station along the southern coastline of Kauaʻi, the risk of grounding is greater than at Kapaia Generating Station, which is located 2.2 miles (3.5 kilometers) inland from the nearest coastline. At the Port Allen Generating Station, KIUC installed green LED 41- and 90-watt lights (KIUC 2017). Before the fallout season in 2019, dimming capabilities were also enabled on these facility lights (KIUC 2019). Based on the significantly reduced number of birds found at the Port Allen Generating Station and Kapaia Generating Station in 2019 and 2020 relative to previous years at KIUC facilities, dimming the lights appears to have minimized light attraction.

Nighttime Lighting for Repairs

Any potential impacts related to nighttime lighting used for KIUC facility repairs are addressed in Chapter 5 but are not discussed in this appendix since they did not require any modeling. See Chapter 5, *Effects Analysis*, for the assessments of nighttime light for repairs and the associated take estimate.

5C.2 Assessment of Fallout from Streetlights

5C.2.1 Existing Streetlights

The streetlight assessment used a novel approach, developed in collaboration with the U.S. Fish and Wildlife Service, to assign fallout documented by the Save our Shearwater (SOS) program to streetlights based on the proportional contribution of those lights to the lightscape of Kauaʻi (Figure 1). This proportional assessment was developed using remotely sensed radiance, often casually called “brightness”, collected by a sensor that is designed to provide global measurement of the intensity of nocturnal visible and near-infrared light on a daily basis (Cao et al. 2017); measurements of radiance made by this sensor were in units of nanowatts per square-centimeter per steradian. The process used to estimate fallout due to streetlights included the following steps:

- Partition all data associated with this assessment according to the existing spatially explicit SOS sectors that encompass all areas of the island with streetlights (Section 2.1.1, *Partitioning Data by Sector*).
- Assess island-wide satellite data of the lightscape on *Kauaʻi* (Section 2.1.2, *Assessing the Lightscape of Kauaʻi*).
- Estimate the radiance generated by a single streetlight (Section 2.1.3, *Estimating the Radiance Generated by a Single Streetlight*).
- Estimate the proportional contribution of streetlights to radiance by sector (Section 2.1.4 *Estimating the Proportional Contribution of Streetlights to Radiance by Sector*).
- Derive an estimate of fallout occurring due to streetlights in each sector (Section 2.1.5, *Uncorrected Fallout Estimate for Streetlights*).
- Apply a correction factor to account for seabirds that were grounded but not detected (Section 2.1.6, *Detectability Correction Factor for Fallout*).

The assessment included 641 SOS database records of grounded hatch-year and unknown age Newell's shearwaters (ʻaʻo) documented from September 1 to December 31 of each year from 2015 to 2019. This assessment conservatively included all reported fallout regardless of the source of the light attraction.[1] Ideally, all birds that could not be assigned to a specific, non-streetlight light source would have been removed from this analysis. However, the radiance associated with these non-streetlight light sources could not be partitioned out of the VIIRS radiance measures due to the coarse resolution of these data (discussed in Section 2.1.2, *Assessing the Lightscape on Kaua'i*) and, therefore, it was mathematically inappropriate to remove birds without also removing the corresponding radiance.

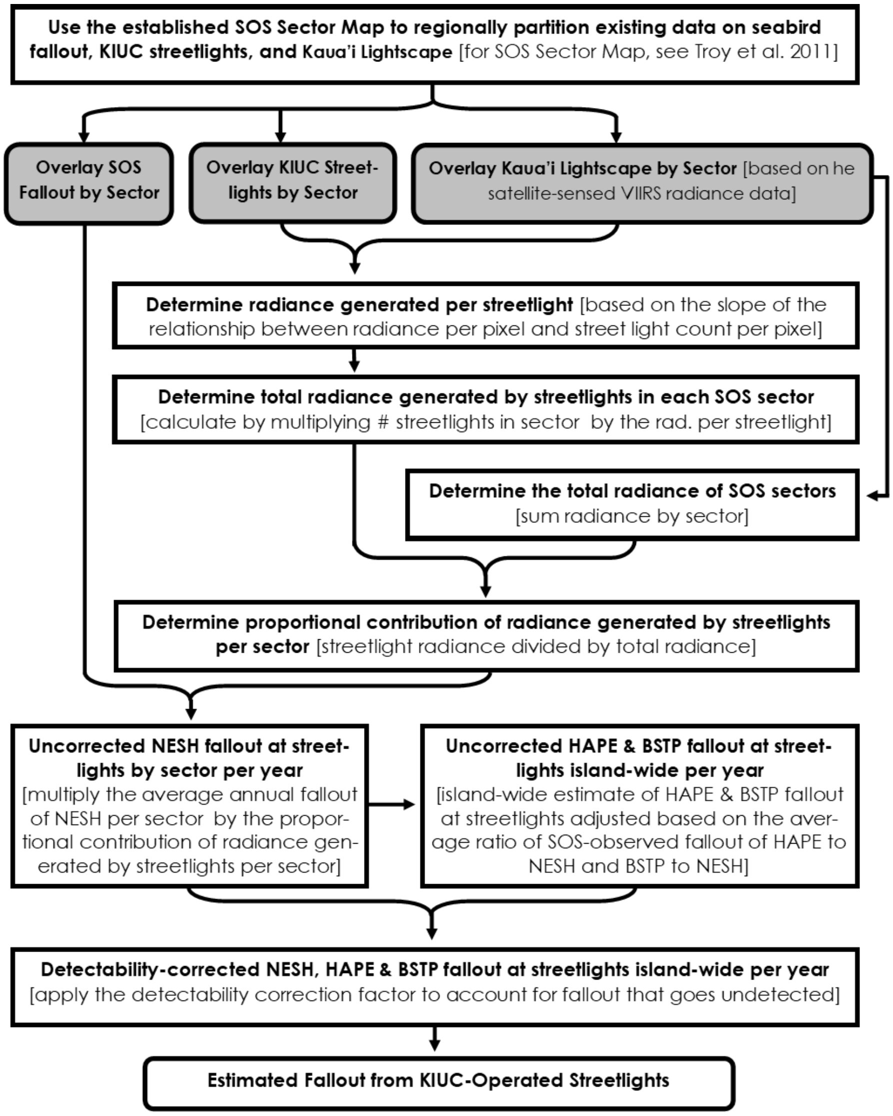

Figure 1. Conceptual schematic of the approach used to determine the proportional contribution of KIUC streetlights to the radiance of Kauaʻi on a regional basis as a proxy for the proportion of annual seabird fallout resulting from these streetlights.

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[1] Over half of the 641 Newell's shearwater (ʻaʻo) fallout records in the SOS database could be assigned to non-streetlight sources (e.g., KIUC facility lights, fallout claimed by participants in the Kauaʻi Seabird Habitat Conservation Plan, and other lights) (DOFAW 2020).

5C.2.1.1 Partitioning Data by Sector

All streetlights, lightscape, and fallout data used for this assessment were partitioned according to SOS sector (Figure 2) (SOS program unpubl. data, as described by Troy et al. 2013). There are 35 sectors[2] that vary in size, ranging from 1237 to 98,926 square kilometers, and cover developed areas as well as areas with no development and no artificial lighting. The benefits of partitioning fallout, lightscape, and streetlight data by SOS sector is that these sectors have been used since the 1990s to understand long-term patterns of fallout across Kauaʻi (Troy et al. 2011, 2013), and partitioning data by SOS sector enables this assessment to account for spatial heterogeneity of fallout across the Plan Area.

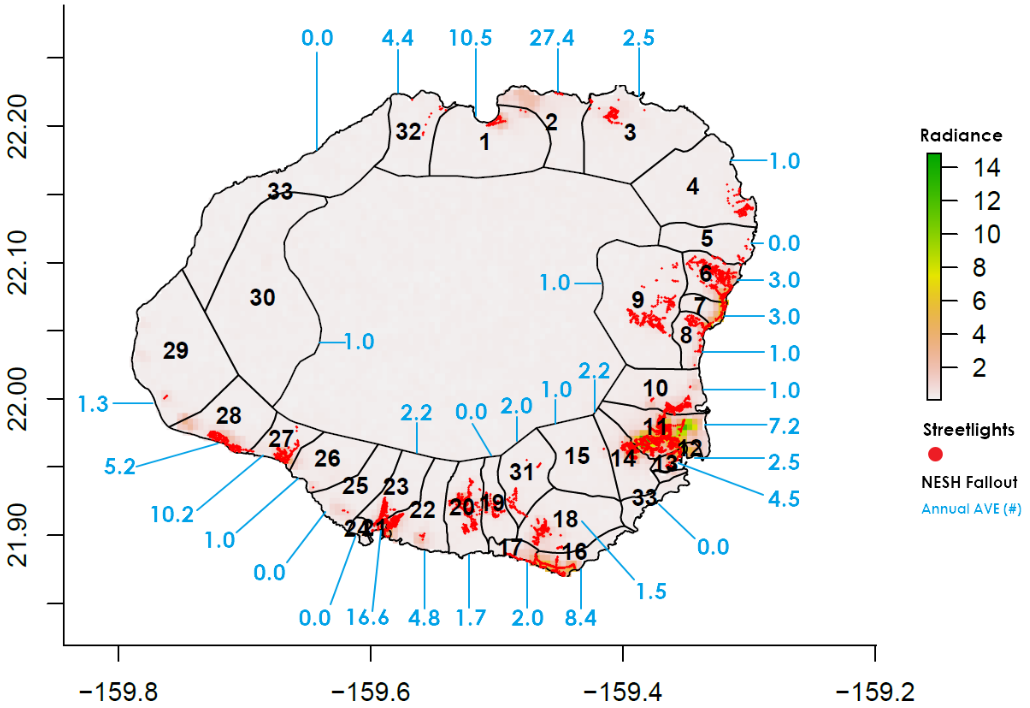

Figure 2. SOS sectors (delineated with black outlines and identified with black numbers) and the annual average (AVE) fallout of Newell's shearwater (ʻaʻo) reported by SOS over the previous 5 years (blue numbers) with the radiance and streetlights across the Plan Area. The radiance data was derived from October 2018 measurements.

5C.2.1.2 Assessing the Lightscape on Kauaʻi

The lightscape of Kauaʻi was assessed using radiance data collected via satellite, which is the only data available at an island-wide scale . Globally, radiance produced by lights at night have been remotely sensed on a daily basis by the Day-Night Band (DNB) sensor on the Visible Infrared Imaging Radiometer Suite (VIIRS) installed on the Suomi National Polar-Orbiting Partnership Satellite (Cao and Bai 2014). The DNB sensor is one of 23 sensors on the VIIRS. The purpose of the DNB sensor is to measure radiance (nanowatt (nW) per square centimeters (cm^2) per steradian (sr)) from as low as a quarter moon illumination to the brightest daylight in the 0.5 to 0.9 micrometer range of the electromagnetic spectrum (Cao and Bai 2014). For this assessment, both

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[2] A sector is a geographic area varying in size.

the October and November[3] 2018 stray-light corrected composite maps of Kauaʻi's radiance were used. These maps were compiled by the National Oceanic and Atmospheric Administration's (NOAA) Earth Observation Group (2020), and provided by NOAA's National Center for Environmental Information (2018a, 2018b).

The resolution of radiance measures derived from the DNB were much lower than what would be needed to directly measure the contribution of a single streetlight. The on-board aggregation scheme allows the DNB sensor to maintain a nearly constant 0.46 miles (742 meters) resolution over the entire 186-mile (300-kilometer) sampling swath for raw images (Cao and Bai 2014; Cao et al. 2017) and NOAA's National Geophysical Data Center's Earth Observation Group uses these raw images to make monthly composites of radiance data. Due to the way the daily images are gridded using a 15 arc-second resolution, these monthly composites have greater resolution than can be measured by the DNB sensor (on the order of 430 by 460 meters [hereafter, pixel] at the latitude of Kauaʻi) (Baugh et al. 2013). While this is an improvement in resolution from the DNB radiance measurements, monthly composites of radiance data are still too coarse to estimate the radiance generated by a single streetlight (e.g., a single radiance pixel can contain as many as 41 KIUC streetlights as well as numerous other light sources that inflate and/or mask the actual radiance emitted by the streetlights). Therefore, since it is not possible to directly measure the radiance generated by a single streetlight, the contribution of streetlights to radiance has been inferred by relating the degree to which radiance increased as a function of increased counts of streetlights per pixel using methods described in Section 2.1.3, *Estimating the Radiance Generated by a Single Streetlight*.

5C.2.1.3 Estimating the Radiance Generated by a Single Streetlight

To estimate the contribution of streetlights to radiance, a regression was used to describe the degree to which radiance increased as a function of increasing numbers of streetlights per pixel. Because the light generated by streetlights is difficult to separately identify when contributing to light associated with commercial and urban centers, using all radiance data in the Plan Area would not provide a meaningful estimate of the relationship between streetlights and radiance. Thus, it was necessary to restrict the data to include only the minimum radiance per streetlight count, as these darker pixels were more likely to represent areas where the light generated only by streetlights and not additional lights associated with commercial areas and urban centers. The approach to estimate the radiance generated by a single streetlight included the following steps:

- Isolate the radiance data needed to assess how radiance per pixel varied as a function of streetlight count (see Section 2.1.3.1, *Radiance Data Subset*).
- Produce a probabilistic estimate of radiance generated per streetlight that incorporates uncertainty into the estimate of slope (see Section 2.1.3.2, *Radiance Generated per Streetlight*).
- Extrapolate the proportional contribution of streetlights to total radiance by sector (Section 2.1.4, *Estimating the Proportional Contribution of Streetlights to Radiance by Sector*).

Radiance Data Subset

Visualizing the radiance for all pixels on Kauaʻi in October (Figure 3A) and November (Figure 3B) as a function of streetlight count per pixel showed that there were many situations where the radiance

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[3] Over the last 5 years (2015-2019), 72 percent of the fallout on Kauaʻi happened during the months of October and November, with 41.2 percent occurring in October and 30.8 percent occurring in November.

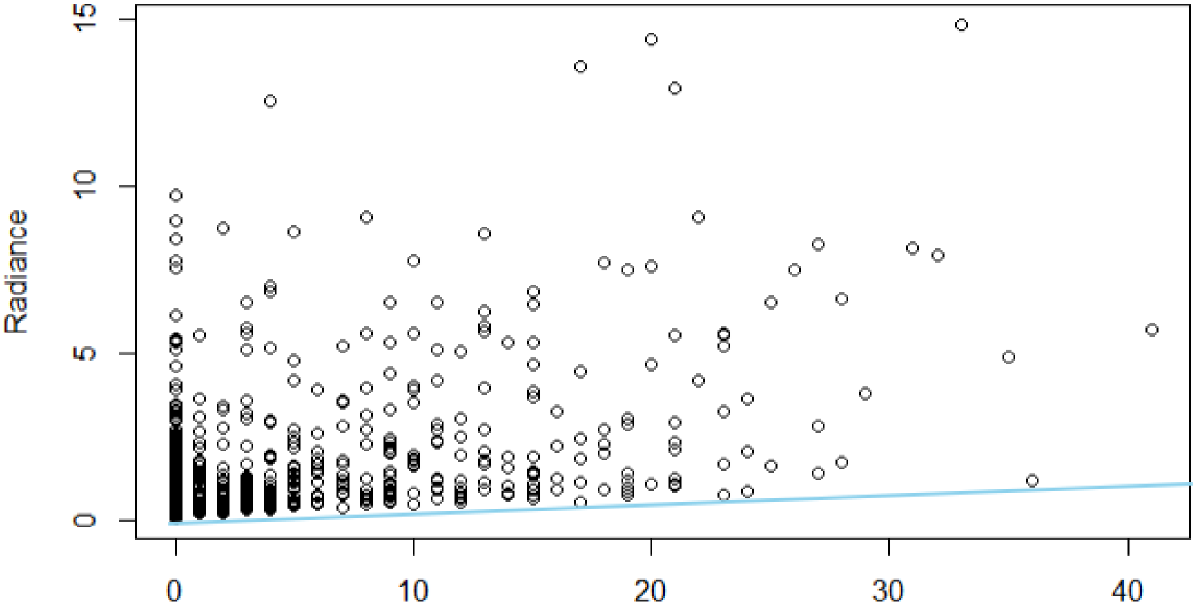
of a particular pixel was unrelated to the radiance produced by streetlights. For example, in areas where there were no streetlights (streetlight count equal to zero), non-streetlight lights present in those pixels produced large radiance measures. Including radiance measures from pixels where streetlights were not present would not facilitate estimation of radiance added by streetlights. Furthermore, for pixels with the same streetlight count, the range of associated radiance per pixel varied from relatively dark to very bright; these bright pixels were associated with commercial areas that had lights that produced more radiance than streetlights, and thus masked the streetlight signal. Because of this, inclusion of radiance measures from all pixels with streetlights would have inappropriately introduced measures of various confounding light sources that mask the streetlight signal. Thus, to isolate the streetlight signal for individual streetlight radiance, the data used for this assessment was restricted to consider only the darker rural or residential areas (i.e., locations where there are relatively few non-streetlight light sources).

Assumptions were made to isolate pixels that could inform an estimate of the radiance added by streetlights. A single datapoint, the pixel with the lowest radiance, was selected for each category of streetlight count (Figure 4). For each streetlight count, the pixel with the lowest radiance was assumed to be derived from an area where there was minimal presence of non-streetlight light sources, thus there was minimal masking of the streetlight signal by other lights.

When looking at the minimum radiance for each streetlight count, there was a strong and consistent linear pattern between radiance added per increase in streetlight count (Figure 4). Notably, this strong and consistent relationship was evident for lower streetlight counts but appeared to breakdown once the count of streetlights exceeded 21 streetlights per pixel (Figure 4); this pattern was similar in both October (Figure 4A) and November (Figure 4B). We hypothesized that this apparent breakdown in the relationship was artificial, resulting in part from the fact that these larger streetlight counts per pixel were relatively rare (generally three or fewer instances on the island for a given streetlight count; Figure 3) and in part because greater densities of streetlights were more likely to be associated with urban centers and commercial areas rather than darker, residential-only areas. Thus, each pixel presented in Figure 4 with a streetlight count greater than 20 was manually reviewed using satellite imagery in Google Earth to assess if the pixel was overlapping a darker residential area or if the pixel was overlapping a brighter commercial area. Pixels characterized as residential were assumed to have a radiance that was generated primarily by streetlights (and to a lesser extent, households); all pixels categorized as residential were included in the regression (black dashes in Figure 4). Pixels characterized as commercial were assumed to have a radiance that was generated by a variety of non-streetlight light sources that likely masked the streetlight signal; all pixels categorized as commercial were excluded from the regression (red dashes in Figure 4).

In both October (Figure 4A) and November (Figure 4B), the manual review classified 8 of 15 pixels as commercial and the remaining 7 of 15 pixels as residential. The commercial pixels were brighter than the residential pixels (October: $t=4.6$, $df=7.2$, $p=0.001$; November: $t=5.1$, $df=7.4$, $p< 0.001$) and were located primarily in Lihue adjacent to the airport (the brightest spot on the island) whereas the residential areas contained between 75 and 150 houses per pixel and were distributed across multiple towns including Hanapepe, Kapaa, Wailua Homesteads, Lawai, and Kilauea.

(A) October Radiance Data



(B) November Radiance Data

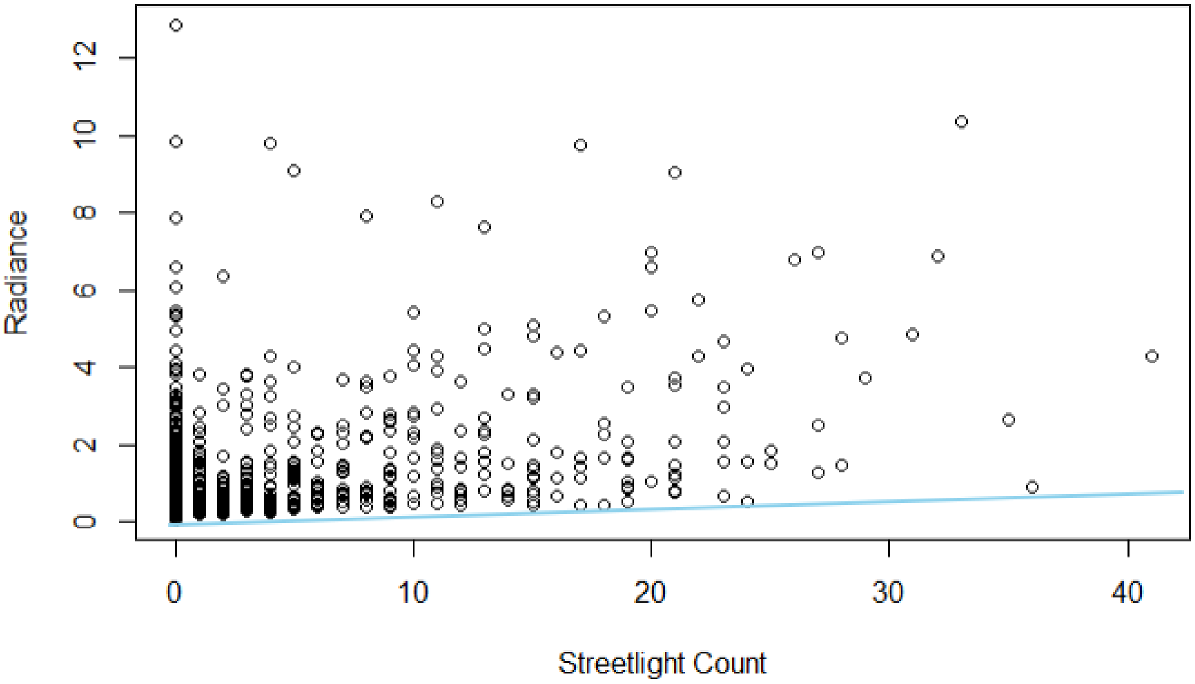
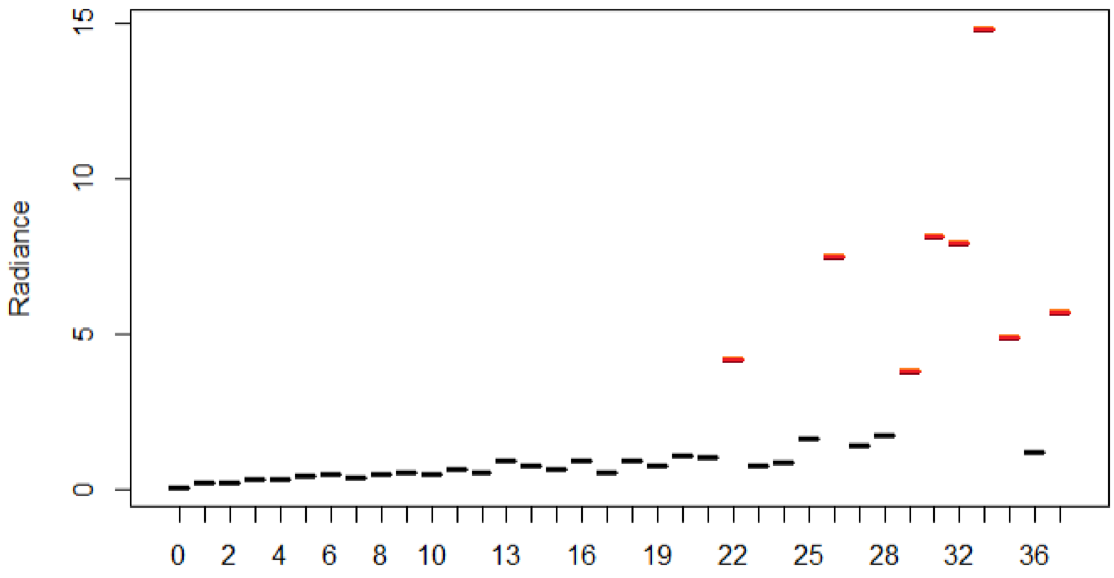


Figure 3. Radiance and streetlight count for all pixels on Kauaʻi using the October (A) and November (B) based on 2018 VIIRS satellite radiance data.

(A) October Radiance Data



(B) November Radiance Data

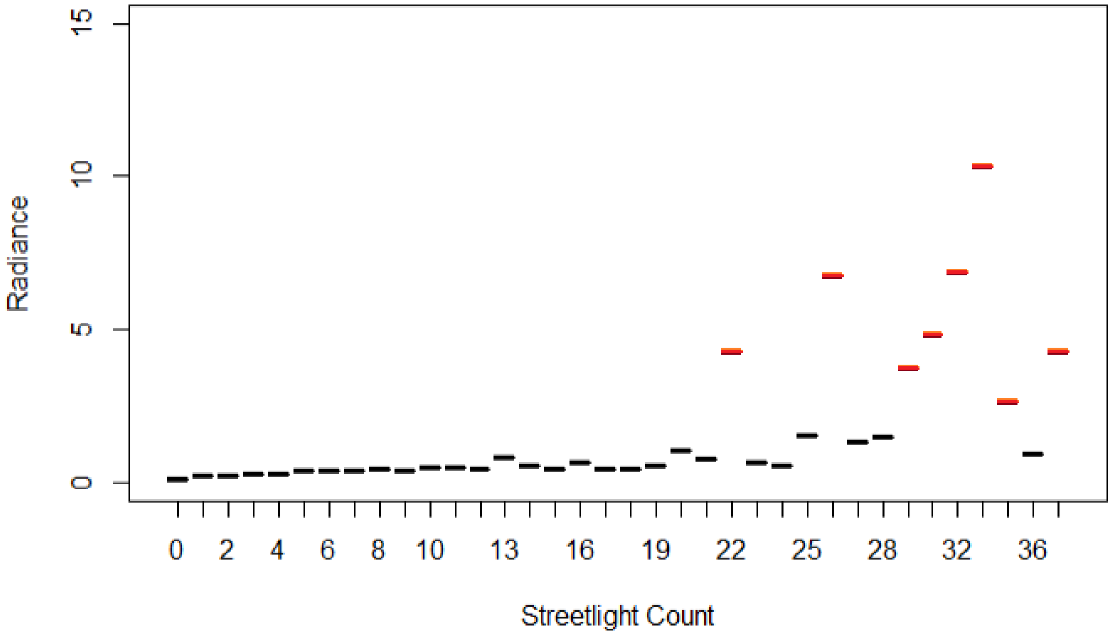


Figure 4. Subset of Plan Area radiance that includes only the darkest pixel per streetlight count for October (A) and November (B) based on 2018 VIIRS satellite radiance data. Black dashes represented pixels categorized as residential and were therefore included in the assessment of radiance added by streetlights. Red dashes represented pixels categorized as commercial and were therefore considered to be unrepresentative of radiance generated by streetlights and were excluded in the assessment of radiance added by streetlights.

Radiance Generated per Streetlight

Once the dataset relevant for quantifying the functional relationship between radiance and streetlight count was compiled, a linear regression was used to estimate how much radiance increased as the streetlight count per pixel increased. This rate of increase is also known as the slope.

Comparison of Three Analytical Approaches

Three analytical approaches for estimating the variance in radiance added by a single streetlight were explored: bootstrapping, Bayesian regression, and cross-validation. All three approaches were implemented to assess variance in radiance added per additional streetlight (i.e., the slope). Cross-validation was also used to determine model fit metrics as a means of assessing whether the predictive power of the relationship between radiance and streetlight count was similar using data from October relative to November. Below is a brief description of each approach:

- Bootstrapping, which falls under the broader class of resampling methods, uses random sampling with replacement to assign measures of accuracy (bias, variance, confidence intervals, etc.) to sample estimates (Mooney and Duval 1993).
- A linear regression within the context of Bayesian inference was also implemented for comparative purposes (Kruschke 2015).
- Cross-validation, sometimes called rotation estimation or out-of-sample testing, is a suite of similar model validation techniques generally used to assess how well the results of a statistical analysis will generalize to an independent data set (Stone 1974); specifically, leave-one-out cross-validation was used (Fushiki 2011). The most common goal of cross-validation is to estimate the expected level of fit of a model to data that is independent of the data used to create or train the regression.

Bootstrapping, Bayesian, and cross-validation approaches each have their advantages and drawbacks, but in this context were generally complimentary. Each were used to estimate the variance about the regression parameters (e.g., intercept and slope). Cross-validation had the added benefit of providing insight into how well the model predicted out-of-sample data.

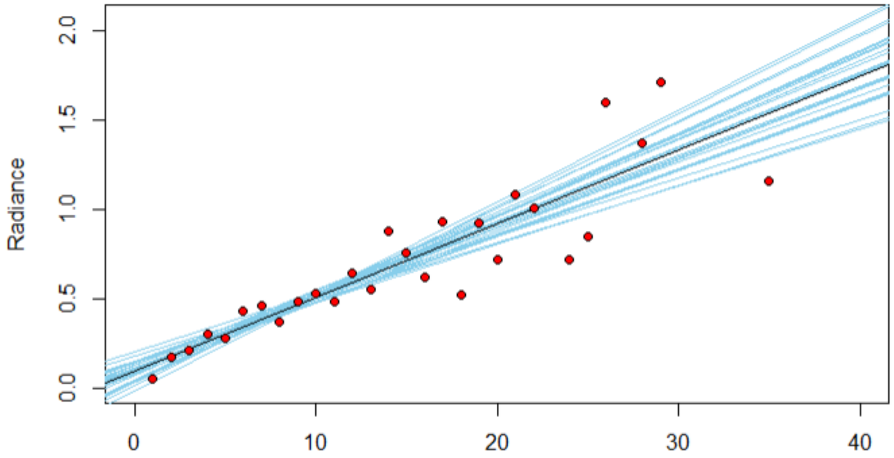
Radiance and Streetlight Count

Based on the regression using October satellite imagery, the radiance emitted by a single streetlight was estimated to be 0.04 nW/cm^2/sr (95% HDI: 0.03–0.05) (Figure 5A). For comparison, Bayesian and cross-validation methods produced similar estimates of slope (Bayesian Approach: 0.04 (0.03-0.05 nW/cm^2/sr; Cross Validation Approach: 0.04 (0.03-0.05 nW/cm^2/sr). Based on the regression using November satellite imagery, the radiance emitted by a single streetlight was estimated to be 0.03 nW/cm^2/sr (95% HDI: 0.02–0.04) (Figure 5B). Again, Bayesian and cross-validation methods produced similar estimates of slope (Bayesian Approach: 0.03 (0.02-0.04 nW/cm^2/sr; Cross Validation Approach: 0.03 (0.02-0.04 nW/cm^2/sr). Thus, the estimate of radiance produced per streetlight was similar using data from October and November (i.e., overlapping confidence intervals), with the mean estimate being 0.01 nW/cm^2/sr greater in October relative to November.

Cross-validation was also used to determine model fit metrics and assess whether the predictive power of the relationship between radiance and streetlight count was similar using data from October relative to November. Leave-one-out cross-validation indicated that model fit metrics were relatively good in both months but slightly better in October (root-mean-square error = 0.21, mean absolute error = 0.15, R-squared = 0.73) relative to November (root-mean-square error = 0.23, mean absolute error = 0.17, R-squared = 0.58).

Since the October 2018 data produced a larger point estimate of the light added per streetlight and the predictive relationship between streetlight count and radiance was stronger, all estimates of streetlight take presented in Section 4.2, *Take Estimates for Covered Seabird Species* were derived using the October 2018 radiance data.

(A) October Radiance Data



(B) November Radiance Data

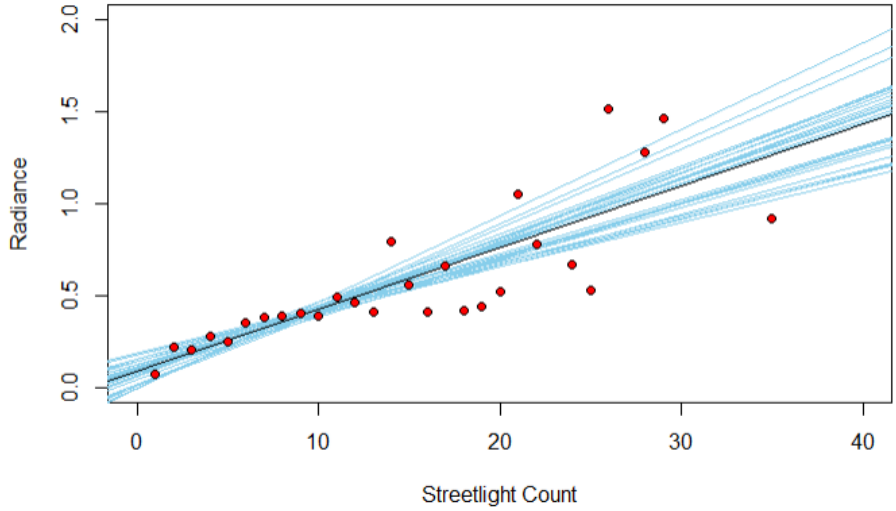


Figure 5. Radiance regressed against streetlight count per pixel using 2018 VIIRS satellite radiance data from October (A) and November (B). The black line represents the average relationship between radiance and streetlight count and the blue lines are examples of credible regression lines generated via bootstrapping.

5C.2.1.4 Estimating the Proportional Contribution of Streetlights to Radiance by Sector

Once radiance per streetlight was determined, the proportional contribution of streetlights to the total radiance was determined on a sector-by-sector basis by:

1. Extrapolating the radiance of a single streetlight to the total number of streetlights in each sector;
2. Summing the radiance of each pixel within an SOS sector; and
3. Dividing the total radiance generated by streetlights by the sum of the radiance in each sector.

Across all sectors, the proportional contribution of streetlights to sector radiance averaged 6.1 percent but the proportion of radiance added in individual sectors was variable, ranging from sectors without streetlights (and therefore having a 0 percent contribution to radiance) to sectors with streetlights intermixed non-streetlight light types (e.g., residential, commercial, etc.). Both Kapa’a and Hanapēpē were found to have the greatest proportional contribution of streetlights to overall radiance at 13.2 percent. There are no sectors that have areas of lighting that was only contributed to by a streetlight and no sectors where streetlights contribution to overall radiance was greater than non-streetlight sources .

5C.2.1.5 Uncorrected Fallout Estimate for Streetlights

Newell’s Shearwater (ʻaʻo)

The average annual fallout for Newell’s shearwater (ʻaʻo) was summarized by sector and multiplied by the proportional contribution of streetlights in each sector to derive an estimate of fallout attributable to KIUC streetlights. The majority (89.75 percent) of Newell’s shearwater (ʻaʻo) fallout between 2015 and 2019 could be assigned to an SOS sector. The sector of fallout was not known for the remaining 10.25 percent of Newell’s shearwater (ʻaʻo) because the location information was not provided by the citizen collector and not included in the SOS records. For birds where the sector of fallout was unknown, the proportional contribution of streetlights to sector radiance was averaged across all land-based sectors to proportionally assign fallout of birds with unknown locations to KIUC streetlights.

Hawaiian Petrel & Band-Rumped Storm-Petrel

Fallout of Hawaiian petrel (ʻuaʻu) and band-rumped storm-petrel (ʻakēʻakē) was too infrequent to develop a robust assessment of sector-by-sector patterns following the method used for Newell’s shearwater (ʻaʻo). Due to the very limited fallout data for Hawaiian petrel (ʻuaʻu) and band-rumped storm-petrel (ʻakēʻakē), the sector-by-sector patterns determined using Newell’s shearwater (ʻaʻo) were applied to these other seabird species. The total fallout estimated for Newell’s shearwater (ʻaʻo) was adjusted using the ratio of each species to Newell’s shearwater (ʻaʻo). For Hawaiian petrel (ʻuaʻu), these ratios were determined using the total observed fallout of Newell’s shearwater (ʻaʻo) relative to Hawaiian petrel (ʻuaʻu) annually from 2015 to 2019 (Table 2) and then calculating the 5-year average. For band-rumped storm-petrel (ʻakēʻakē), the analysis used a 15-year timeseries of fallout. A single value for the annual average of Newell’s shearwater (ʻaʻo) to band-rumped storm-petrel (ʻakēʻakē) fallout was calculated. The average annual ratio indicated that for every Newell’s shearwater (ʻaʻo) take, an additional 0.061 Hawaiian petrel (ʻuaʻu) and 0.01 band-rumped storm-petrel (ʻakēʻakē) are estimated to occur.

Table 2. Annual number of Newell's shearwater ('a'o), Hawaiian petrel ('ua'u), and Band-rumped storm-petrel ('akē'akē) reported in the SOS database

YEAR	NESH[1]	HAPE[2]	BSTP[3]	HAPE:NESH	BSTP:NESH
2005	*	*	0	-	-
2006	*	*	1	-	-
2007	*	*	6	-	-
2008	*	*	2	-	-
2009	*	*	2	-	-
2010	*	*	2	-	-
2011	*	*	1	-	-
2012	*	*	1	-	-
2013	*	*	0	-	-
2014	*	*	3	-	-
2015	154	4	0	0.026	-
2016	100	1	1	0.010	-
2017	142	14	0	0.099	-
2018	161	4	0	0.025	-
2019	84	12	0	0.143	-
AVE	**128.2****	**7**	**1.3**	**0.061**	**0.01**

[1]NESH = Newell's shearwater ('a'o)

[2]HAPE = Hawaiian petrel ('ua'u)

[3]BSTP = Band-rumped storm-petrel ('akē'akē)

*For Newell's shearwater ('a'o) and Hawaiian petrel ('ua'u), a 5-year timeseries of data were used for these species and therefore data were only summarized for the previous 5 years (but there was fallout of both species prior to 2015.)

**Annual fluctuations in SOS numbers occur based on the moon phase during peak fallout, as well as the size of the breeding population, annual variation in breeding effort, annual variation in reproductive success, inconsistencies in observer effort, and changes to the lightscape across Kaua'i.

5C.2.1.6 Detectability Correction Factor for Streetlight Fallout

Not all grounded birds are located and turned into SOS for rehabilitation and, therefore, the SOS database does not fully represent the total number of birds that are attracted by lights in the Plan Area each year. Therefore, an estimate of detectability is needed to adjust the estimated fallout resulting from using the SOS database to account for the additional birds that were not turned into SOS.

The exact probability of a grounded Newell's shearwater (a'o') being located and turned into SOS has not been previously quantified for birds grounded at streetlights and there is a paucity of data to support making such an estimate. An accurate estimate would require specific data on the number of grounded birds that are not turned into SOS because they were not located opportunistically at their grounding location, , hid in nearby bushes where they could not be found, were removed from the site and/or consumed by predators, or were hit by vehicles and not retrieved. There are no data to inform any of these specific components that contribute to fallout.

Given the lack of data on the necessary metrics, the literature related to searching for dead and grounded seabirds on Kaua'i was reviewed to provide additional insight into the potential lower limit of detectability Specific studies reviewed were Podolsky et al. (1998), and Travers et al. (2012), which documented similar patterns described by Podolsky et al. (1998).

Podolsky et al. (1998) compared the findings of two parallel programs that located dead birds.

- searches conducted by Podolsky et al. (1998), which relied on trained biologists to intensively search for dead birds
- searches associated with the SOS program, which relied on citizens to opportunistically discover and turn in dead birds.

Podolsky et al. (1998) searched intensively for dead birds in proximity to powerlines in urban and suburban areas, inconspicuously marked all dead individuals, and coordinated with the SOS program to determine if any of these dead birds were subsequently turned in by citizens. Although Podolsky et al. (1998) did not examine the efficacy of SOS in detecting birds, information provided by the findings of these overlapping searches can inform an estimate of the lower limit of detectability.

For the purposes of calculating the efficacy of SOS searchers in locating birds, it was assumed that all the dead birds available to be found by these two concurrent efforts were located by the overlapping intensive surveys and opportunistic observations (an assumption that is uncertain and has not been investigated). In total, 50 dead birds were located, 8 of which were found by citizens and turned into SOS (Podolsky et al. 1998). Based on the assumption that all dead birds were located, this would indicate that SOS had a 16 percent (8 SOS birds/50 total dead birds) discovery rate of dead birds. Given that the detection probabilities reported by Podolsky et al. (1998) only applied to dead birds, this detectability is likely a worst-case scenario for the detectability of live birds because the literature indicates that citizens are more inclined to turn in live birds to SOS. Travers et al. (2012) specifically noted that “residents are extremely unlikely to pick up a dead bird and pass it on to [SOS] thus resulting in an underestimate of this cohort”. Podolsky et al. (1998) reached a similar conclusion regarding residents’ preference to submit live birds to the SOS program. Thus, a minimum detection rate of 16 percent for live birds (as determined using dead birds) was the best conservative estimate that could be empirically derived at this time.

However, it is important to note that there are confounding factors that may interfere with the estimation of detectability of live birds (i.e., their mobility and ability to hide) relative to dead birds, which cannot be quantified based on the information available to date. Thus, we attempted to further adjust the discovery rate downwards as a way of accounting for these additional confounding factors.

To do this, we assumed that the 50 dead birds described in Podolsky et al. (1998) were actually alive and that there were an unknown number of additional dead birds that would remain undiscovered and would never be turned into SOS (equivalent to a detectability of zero percent). The percent of grounded birds that were found dead when trained searchers intensively surveyed for all grounded birds (live or dead) was used to calculate the number of additional dead birds that would go undiscovered. Podolsky et al. (1998) reported that 43 percent of the birds they located when searching for grounded birds were dead and more recent data from Travers et al. (2012) indicated that 35 percent of the grounded birds were dead. In both cases, Travers et al. (2012) noted that these percentages of dead birds were likely an overestimate of the actual proportion of the cohort that was dead versus alive because residents collect live birds prior to searchers arriving.

Knowing the number of documented live birds (50) and the ratio of birds that are alive (100 percent minus 43 percent based on Podolsky et al. 1998, or 100 percent minus 35 percent based on Travers et al. 2012) allows the additional number of grounded birds that are dead and will remain undetected by SOS searcher to be calculated using the following equation:

$$count\ of\ dead\ birds\ = \frac{count\ of\ live\ birds * percent\ of\ birds\ found\ dead}{percent\ of\ birds\ found\ live}$$

Using the percent of dead birds reported by Podolsky et al. (1998), an estimated 37.7 dead birds in addition to the 50 live birds would go undetected by searchers associated with the SOS program.

$$count\ of\ dead\ birds\ = \frac{50\ live\ birds * 43\ percent\ of\ birds\ found\ dead}{57\ percent\ of\ birds\ found\ live} = 37.7$$

In this hypothetical scenario, there would be a total of 87.7 birds (live (50) and dead (37.7)) available to be discovered and submitted to SOS with just 8 ultimately being turned into SOS; thus, the overall detectability rate for SOS at streetlights would be 9.2 percent. If we do the same calculation using the more recent information from Travers et al. (2012), an estimated 26.9 dead birds in addition to the 50 live birds would go undetected by searchers associated with the SOS program.

$$count\ of\ dead\ birds\ = \frac{50\ live\ birds * 35\ percent\ of\ birds\ found\ dead}{65\ percent\ of\ birds\ found\ live} = 26.9$$

In this hypothetical scenario, there would be a total of 76.9 birds (live (50) and dead (26.9)) available to be discovered and submitted to SOS, with just 8 ultimately being turned into SOS; thus, the overall detectability rate for SOS at streetlights would be 10.4 percent (8 found birds divided by 76.9 grounded birds). Given the conservative nature of these calculations, for purposes of correcting the detectability estimate of SOS estimated fallout resulting from KIUC streetlights, the light attraction model used a detectability rate of 10.4 percent as the worst-case estimate for all three covered seabird species.

5C.2.1.7 Sensitivity Analysis

To assess if the output of this assessment was stable across months, separate estimates of the radiance added per streetlight were made for October and November. All other inputs used to estimate the proportional contribution of radiance to streetlights were multiplicative processes and are thus scaled 1:1 input to output at the level of the SOS sector. Thus, on a sector-by-sector basis, a 10 percent change in one input (e.g., streetlight count per sector, detectability correction factor, etc.) would result in a 10 percent change in the output (e.g., estimated fallout per sector).

5C.2.2 Future Streetlights

In addition to quantifying the annual fallout occurring at the existing streetlights, quantifying the anticipated additional fallout associated with the estimated 1,754 future streetlights over the 30-year permit term of the HCP was also necessary. These future streetlights will not be uniformly distributed across the island, but rather are expected to be installed in a manner that is proportional to the growth expected in Kaua'i's Planning Districts (Figure 6, copied from the Kaua'i General Plan; County of Kaua'i 2018). So, for example, if there were 1,050 future streetlights, then 2 percent (or a total of 20 streetlights) would be installed in the North Shore Planning District, 13 percent (or a total of 130 streetlights) would be installed in the East Kauai Planning District, and so on.

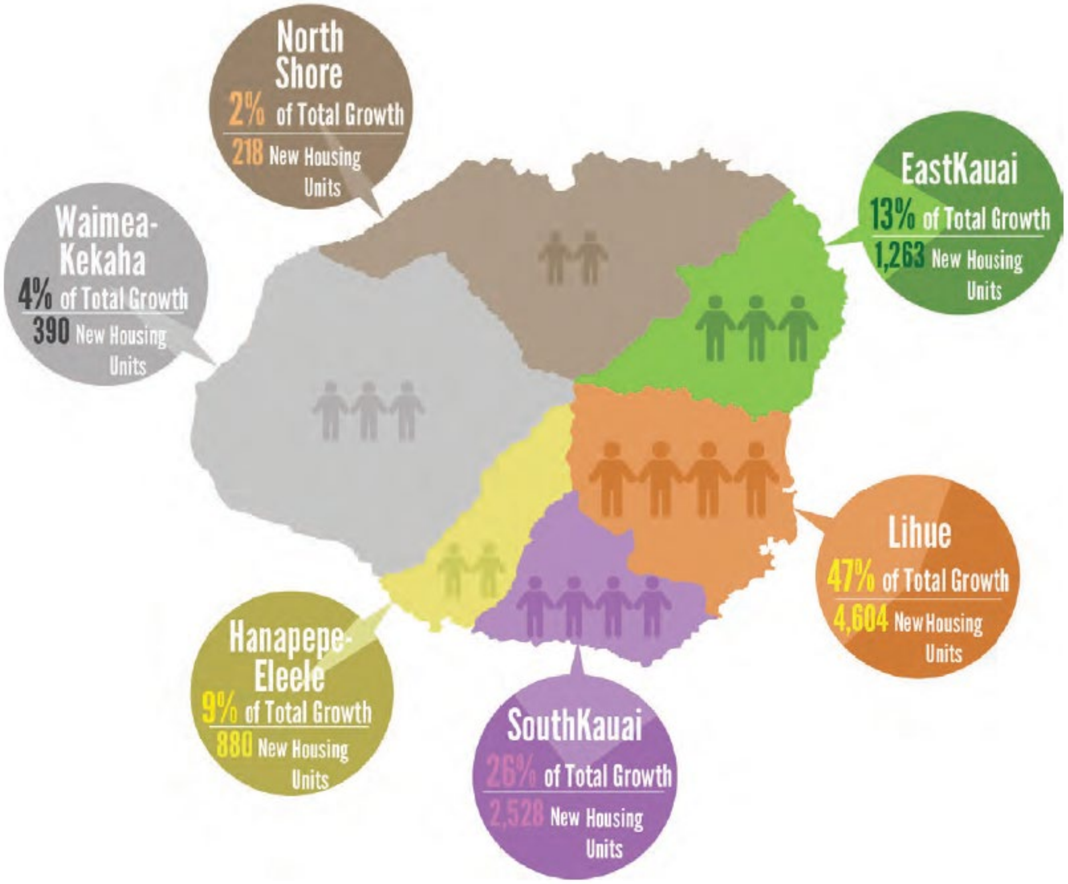


Figure 6. Growth allocations by Planning District from the Kaua'i General Plan (Kaua'i County 2018)

However, these Planning Districts are large and encompass multiple SOS sectors (Figure 2). Thus, for a given Planning District, future streetlights were further partitioned to SOS sectors based on the proportion of streetlights currently present in each SOS sector. So, for example, in the North Shore Planning District there are four SOS sectors that currently have a total of 161 streetlights; 24.8 percent (n=40) of these streetlights are in SOS sector 1, 3.1 percent (n=5) are in SOS sector 2, 64.6 percent (n=104) are in SOS sector 3, and 7.5 percent (n=12) are in SOS sector 32. Thus, of the 20 future streetlights expected in the North Shore Planning District, 24.8 percent were added to SOS sector 1, 3.1 percent were added to SOS sector 2, 64.6 were added to SOS sector 3, and 7.5 percent were added to SOS sector 32. These calculations were repeated for each Planning District on Kaua'i to determine the number of estimated streetlights to be added to each SOS sector in the future.

Once the number of estimated future streetlights to be added to each SOS sector were identified using the method described above, the estimate of radiance generated by a single streetlight could be scaled up to estimate the total radiance added to each SOS sector by the addition of these future streetlights. Similar to the assessment of fallout occurring at existing streetlights, the proportional contribution of future streetlights to SOS sector radiance was used to partition observed fallout into streetlights and non-streetlight and then corrected for detectability using the same logic presented in Section 2.1, *Existing Streetlights* (e.g., assuming a detectability rate of 10.4 percent at streetlights, etc.).

Although we can project the total number and general location of future streetlights with some accuracy based on the existing distribution of streetlights and future growth projections summarized in the Kaua'i General Plan, the same is not true for projecting the magnitude and distribution of future fallout and radiance on the island. It is unknown if and to what extent fallout and overall radiance will change in the future. As such, for purposes of this assessment, we assumed that the current patterns of fallout and radiance will persist into the future.

5C.2.3 Limitations

There were several limitations related to the estimation of fallout occurring at current and future streetlights that should be considered:

- Although the resolution of the radiance data was too coarse to directly measure the radiance added by single streetlight, recently published study (Kyba et al. 2020) successfully measured the proportional contribution of streetlights to nighttime radiance in Tucson, Arizona using the VIIRS DNB radiance data, providing support for validity the approach described here to estimate the proportional contribution of streetlights.
- For purposes of this assessment, it was assumed that the proportional contribution of streetlights to radiance was equal to the proportional contribution of streetlights to the annual rate of fallout. Light intensity and region are the only factors that can be accounted for using the approach presented here and it does not account for other factors known to contribute to patterns in fallout such as differential attraction by different wavelengths or distance from the coastline. It is possible that the intensity of the various light sources on Kaua''i as sensed from space may not match the perceived attractiveness of these light sources to newly fledged seabirds.
- Certain bulb types may be more attractive to shearwaters than others due to the spectrum of wavelengths emitted. Based on preliminary reports, the visual system of Newell's shearwaters (a'o') may be sensitive to violet and ultraviolet wavelengths (Moon et al. 2019), and these attractive wavelengths are more prevalent in "cool" light (e.g., 5000K LED) and less prevalent in "warm" light (e.g., 3000K LED) (Figure 1 in Longcore et al. 2018). There have been two recent studies that specifically characterized the attractiveness of LED lights to shearwaters relative to other light types. Rodríguez et al. (2017c) experimentally attracted shearwaters using unshielded 5000K LED, high pressure sodium, and metal halide bulbs. . They recorded average fallout rates of 1.7 birds per hour at high pressure sodium lights, 2.1 birds per hour at LED lights and 3.3 birds per hour at metal halide lights and concluded that "metal halide multiplied the mortality risk by a factor of 1.6 and 1.9 respectively in comparison with LED and high-pressure sodium lights". Despite having observed fallout of 125 birds in 66 hours at 5000K LED and high pressure sodium lights, the variability in fallout rates at these two light types overlapped enough that it was not possible to conclude that there were differences in the attractiveness of LEDs and high pressure sodium lights (Rodríguez et al. 2017c).. Longcore et al. (2018) created a model that inferred potential attractiveness of a more extensive list of lights based on the visual sensitivity of Newell's shearwater (a'o') reported by an thesis (Reed 1986). Results presented in Longcore et al. (2018) represent predictions rather than actual data on attractiveness of lights to shearwaters, and shortcomings were highlighted in their discussion. Furthermore, the re-analysis of Rodríguez et al. (2017c) by Longcore et al. (2018) showed that using actinic power per lux to predict attraction may overestimate the attractiveness of LED lights based on findings reported by Rodríguez et al. (2017c) (see Figure 5, Longcore et al. 2018). Importantly, the

Longcore et al. (2018) assessment lacked critical information needed to understand if apparent differences presented for various light types were statistically significant.

- The SOS database did not provide sufficient detail regarding fallout location to conclusively link fallout to streetlights. Therefore, the SOS data could not be used to validate the outcome of the analysis. In addition, the surrounding urban lightscape prohibits isolating a single light source as the cause of fallout. Since light attraction likely results from multiple light sources, directly quantifying the true contribution of streetlights to fallout would require an experimental study where various light sources are manipulated and the impact on fallout is measured.
- Data on detectability of seabirds grounded under streetlights does not exist. The 10.4 percent used here is intentionally conservative and lower than what has been documented for other situations. A review of 294 infrastructure-driven mortality studies based on carcass searches found that body mass was the most important variable influencing the detectability of a carcass to searchers (Barrientos et al. 2018); Newell's shearwaters (a'o') range in mass from 342 to 425 grams (Ainley et al. 2020) and the review by Barrientos et al. (2018) suggested that a bird of that size would have an overall detectability rate of about 80 percent for trained observers across the habitat types of interest (fences, powerlines, roads, solar plants, and wind farms).
- The actual distribution of future streetlights may not match what was projected in the Kaua'i General Plan (County of Kaua'i 2018). Further, future fallout and radiance patterns are unknown. If future fallout and radiance patterns are determined to differ from what has been projected by this assessment, differences can be addressed through adaptive management.

5C.3 Assessment of Fallout from Facility Lights

For the two covered facilities in the KIUC HCP, Port Allen Generating Station and the Kapaia Generating Station, take was directly enumerated using the average number of downed birds located at each facility, as documented in KIUC monitoring logs (KIUC 2019) and the SOS database. KIUC staff have monitored and maintained inspection logs for these facilities during the seabird fallout season (September 15 through December 15) since 2011.

The take estimate for KIUC facilities is based on 5-year average (2016-2020) for Newell's shearwater (ʻaʻo) and) a 9-year average (2011-2020) for rarer species (i.e., Hawaiian petrel (ʻuaʻu) and band-rumped storm-petrel (ʻakēʻakē)).. The take estimate that encompassed observations prior to and following full minimization was calculated to be consistent with methods used to estimate facility take elsewhere on the island by participants in the Kaua'i Seabird HCP (DOFAW 2020).

The take estimate for fallout from facility lights used a detectability factor of 50 percent. While this detectability factor is greater than the detectability factor for streetlights, it matches the detectability rate used for facilities covered in the Kaua'i Seabird HCP (DOFAW 2020). Also, KIUC facilities, PAGS and Kapaia, are fenced and monitored for pest. Regular pest control methods such as traps and pest control services are used for rats and mice. Any stray cats that make it into the fenced facilities are captured using live traps and removed from the property. KIUC trains staff to identify and search for covered species and these trained staff conduct searches for downed seabirds during the seabird fallout season twice daily (see Chapter 6, *Monitoring and Adaptive Management*). Searchers are equipped with Oppenheimer Seabird Recovery Kit and recovered birds are transported to an SOS Aid Station.

5C.4 Conclusions

5C.4.1 Summary of Streetlight, Lightscape, and Fallout by Sector

A complete summary of the proportional contribution of 4,150 streetlights, used for this assessment, to radiance and the average annual fallout for Newell's shearwater (ʻaʻo) was summarized on a sector-by-sector basis (Table 3). This is based on radiance data from October 2018.

Table 3. Model output for each SOS sector

Sector ID	Sector Name	Streetlight count (#)	Total streetlight radiance	Sector radiance	Proportional contribution of streetlights	AVE Total NESH[1] fallout (#/year)	AVE Streetlight NESH[1] fallout (#/year)
1	Hanalei	40	1.6	87.5	0.018	10.5	0.20
2	Princeville	5	0.2	83.8	0.002	27.4	0.06
3	Kīlauea	104	4.1	82.7	0.050	2.5	0.13
4	Anahola	91	3.6	69.6	0.052	1.0	0.05
5	Kealia	19	0.7	29.9	0.023	0.0	0.00
6	Kapaʻa	368	14.5	110.2	0.132	3.0	0.40
7	Waipouli	49	1.9	89.9	0.021	3.0	0.06
8	Wailua	115	4.5	61.4	0.073	1.0	0.07
9	Wailua Homesteads	278	10.9	98.6	0.111	1.0	0.11
10	Hanamaulu-Kapaia	180	7.1	94.0	0.076	1.0	0.08
11	Līhuʻe	1000	39.3	473.6	0.083	7.2	0.60
12	Marriott	0	0.0	46.8	0.000	2.5	0.00
13	Nawiliwili	56	2.2	78.5	0.028	4.5	0.13
14	Puhi	290	11.4	99.6	0.115	2.2	0.25
15	Kipu	2	0.1	46.4	0.002	1.0	0.00
16	Poipu	146	5.7	115.6	0.049	8.4	0.41
17	Kukuiula	37	1.5	37.5	0.040	2.0	0.08
18	Kōloa	151	5.9	85.7	0.069	1.5	0.10
19	Lāwaʻi	103	4.0	40.5	0.099	0.0	0.00
20	Kalaheo	266	10.4	71.0	0.147	1.7	0.25
21	Port Allen	43	1.7	44.7	0.038	16.6	0.63
22	ʻEleʻele	211	8.3	81.2	0.102	4.8	0.49
23	Hanapēpē	149	5.9	44.7	0.132	2.2	0.29
24	Salt Ponds	0	0.0	6.6	0.000	0.0	0.00
25	Olokele-Kaumakani	3	0.1	40.9	0.002	0.0	0.00
26	Pakala	1	0.0	45.8	0.000	1.0	0.00
27	Waimea	155	6.1	57.6	0.106	10.2	1.08

Sector ID	Sector Name	Streetlight count (#)	Total streetlight radiance	Sector radiance	Proportional contribution of streetlights	AVE Total NESH[1] fallout (#/year)	AVE Streetlight NESH[1] fallout (#/year)
28	Kekaha	169	6.6	86.0	0.077	5.2	0.40
29	PMRF[2]	5	0.2	84.0	0.002	1.3	0.003
30	Kokeʻe	0	0.0	103.4	0.000	1.0	0.00
31	Omao-Maluhia	57	2.2	39.4	0.056	2.0	0.11
32	Haena-Wainiha	12	0.5	34.4	0.015	4.4	0.07
33	Kipukai, Nā Pali	0	0.0	90.9	0.000	2.0	0.00
34	At sea	0	0.0	0.0	0.000	1.0	0.00
35	Unknown[3]	(124.4)	(4.9)	(80.7)	0.061	15.2	0.93
Total	**--**	**4,105[4]**	**161.2[4]**	**2662.4[4]**	**0.061[5]**	**133.1**	**6.9[6]**

[1] NESH = Newell's shearwater (ʻaʻo)

[2] PMRF = Pacific Missile Range Facility

[3] Sector 35 is called "unknown" and as not all birds turned into SOS are assigned to sector, and the only way to account for birds in this category is to calculate island-wide averages. See Section 2.1.5.1, *Newell's shearwater (ʻaʻo)*, for more information.

[4] Streetlight count, streetlight radiance, and sector radiance totals exclude the numbers in parenthesis from Sector 35 (Unknown) as the values, while they are included in the model and calculations, are in addition to the real island-wide totals.

[5] The proportional contribution of streetlights column cannot be summed because they are proportions and as such, are not additive. Rather the value in the row titled Total represents the island-wide average which is calculated by dividing the streetlight radiance for the entire island by the sector radiance for the entire island (161.2/2662.4)=0.061.

[6] The AVE Streetlight NESH Fallout (#/year) is the summed total of all the rows, including unknown.

5C.4.2 Take Estimates for Covered Seabird Species

5C.4.2.1 Existing Streetlights

Assuming a detectability scenario of 10.4 percent, annual fallout by Newell's shearwater (ʻaʻo), Hawaiian petrel (ʻuaʻu) and band-rumped storm-petrel (ʻakēʻakē) attributed to the 4,150 streetlights used for this assessment are summarized in Table 4. These estimates are based on the proportional contribution of radiance estimated for existing streetlights to the radiance of all night-time lights on Kauaʻi.

Below is the equation used to calculate the total fallout of Newell's shearwater (ʻaʻo) using the total fallout observed per year that is attributable to streetlights. This number is equal to 6.957 without rounding errors and is derived by adding up the annual average of Newell's shearwater (ʻaʻo) fallout at streetlights in each sector (Table 3 – note that the total value of Newell's shearwater (ʻaʻo) fallout at streetlights calculated from sector-specific numbers presented in Table 3 is 6.983 due to compounding rounding errors). This total of Newell's shearwater (ʻaʻo) fallout is then corrected using a detection probability of 10.4%.

$$\frac{6.957\ birds\ found}{0.104\ detectability\ correction\ factor} = 66.9\ birds\ after\ correcting\ for\ detectability$$

The estimates for Hawaiian petrel (ʻuaʻu) and band-rumped storm-petrel (ʻakēʻakē) are then derived from the detectability corrected estimate of Newell's shearwater (ʻaʻo) using the ratios of occurrence in the fallout database averaged over 5 years for Hawaiian petrel (ʻuaʻu) and 10 years for band-rumped storm-petrel (ʻakēʻakē). Per Table 2, for every Newell's shearwater (ʻaʻo) in the SOS database, there has been a long-term average of 0.061 Hawaiian petrel (ʻuaʻu) and 0.01 band-rumped storm-petrel (ʻakēʻakē). Thus, the estimated fallout for Newell's shearwater (ʻaʻo) is multiplied by these ratios resulting in an estimated 4.05 Hawaiian petrel (ʻuaʻu) (=66.9 x 0.061) and 0.669 band-rumped storm-petrel (ʻakēʻakē) (=66.9 x 0.01) fallout at streetlights per year.

Table 4. Estimates of take per year for Newell's shearwater (ʻaʻo), Hawaiian petrel (ʻuaʻu), and Band-rumped storm-petrel (ʻakēʻakē) assuming that the SOS data includes only 10.4 percent of birds that fallout at streetlights.

Species	Estimate	Lower 95% CI	Upper 95% CI
NESH[1]	66.9	51.7	86.8
HAPE[2]	4.0	3.1	5.3
BSTP[3]	0.7	0.5	0.8

[1]NESH = Newell's shearwater (ʻaʻo)

[2]HAPE = Hawaiian petrel (ʻuaʻu)

[3]BSTP = Band-rumped storm-petrel (ʻakēʻakē)

5C.4.2.2 Future Streetlights

Assuming a detectability scenario of 10.4 percent, additional annual fallout anticipated with the addition of 1,754 future streetlights by Newell's shearwater (ʻaʻo), Hawaiian petrel (ʻuaʻu) and band-rumped storm-petrel (ʻakēʻakē) are summarized in Table 5. These estimates are based on the proportional contribution of radiance estimated for existing streetlights to the radiance of all night-time lights on Kauaʻi.

Table 5. Estimates of take per year for Newell's shearwater (ʻaʻo), Hawaiian petrel (ʻuaʻu), Band-rumped storm-petrel (ʻakēʻakē) if the SOS data includes only 10.4 percent of birds that will fallout at future streetlights.

Species	Estimate[1]	Lower 95% CI	Upper 95% CI
NESH[1]	20.5	15.9	26.7
HAPE[2]	1.2	1.0	1.7
BSTP[3]	0.2	0.1	0.3

[1]NESH = Newell's shearwater (ʻaʻo)

[2]HAPE = Hawaiian petrel (ʻuaʻu)

[3]BSTP = Band-rumped storm-petrel (ʻakēʻakē)

[1] These are the additional birds that will be taken each year once all the 1,050 estimated streetlights are added.

5C.4.2.3 Facility Lights

Following a similar approach of the Kaua'i Seabird Habitat Conservation Plan (DOFAW 2020), included in this assessment is the 5-year average for Newell's shearwater ('a'o) and the 9-year average (the extent of the data available) for the rarer Hawaiian petrel ('ua'u) and band-rumped storm-petrel ('akē'akē) (Table 7).

All fallout of covered seabirds reported in Table 7 occurred at the Port Allen Generating Station. After applying the detection correction of 50 percent to the annual average fallout over the full time period the annual take is estimated to be 8.4 Newell's shearwater ('a'o), 0.2 Hawaiian petrel ('ua'u), and 0 band-rumped storm-petrel ('akē'akē).

Table 7. Fallout of covered seabirds documented at covered KIUC facilities. Note that light minimization efforts occurred at the Port Allen Generation Facility prior to the fallout season in 2019 and less birds were found in the two fallout seasons after these measures were implemented.

Year	NESH[1]	HAPE[2]	BSTP[3]
2020[4]	2	0	0
2019[4]	0	0	0
2018	10	0	0
2017	4	0	0
2016	6	0	0
2015	*	0	0
2014	*	0	0
2013	*	0	0
2012	*	1	0
2011	*	0	0
AVE	**4.2**	**0.1**	**0**
50% detectability	**8.4**	**0.2**	**0**

[1] NESH = Newell's shearwater ('a'o)
[2] HAPE = Hawaiian petrel ('ua'u)
[3] BSTP = Band-rumped storm-petrel ('akē'akē)
[4] Light minimization measures were fully implemented in 2019 and 2020

5C.4.2.4 Combined Take Estimate

Combining the take estimates for existing streetlights, future streetlights, and KIUC's covered facilities from Tables 4, 5, and 6, results in an estimated annual take of 95.8 Newell's shearwaters ('a'o) (=66.9+20.5+8.4), 5.4 Hawaiian petrel ('ua'u) (=4.1+1.2+0.2), and 0.9 band-rumped storm-petrel ('akē'akē) (=0.7+0.2+0.0) for the KIUC HCP.

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Appendix 5D

Bayesian Acoustic Strike Model

Underline Monitoring Project
Review Draft- Bayesian Acoustic Strike Model

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Provided June 16, 2020

The Underline Monitoring Project (UMP) is part of the Kauaʻi Endangered Seabird Recovery Project (KESRP), which is a joint project of the Pacific Cooperative Studies Unit of the University of Hawaiʻi and the Division of Forestry and Wildlife (DOFAW)/State of Hawaiʻi Department of Land and Natural Resources.

Estimating rates of power line collisions for seabirds using acoustic monitoring

This document outlines the method and results for a Bayesian model created to assist in the development of the KIUC Long Term Habitat Conservation Plan to estimate rates of power line collisions of two endangered seabirds on the island of Kaua'i – the Newell's Shearwater *Puffinus newelli* and the Hawaiian Petrel *Pterodroma sandwichensis* - using acoustic monitoring. The document has been created with the intention of helping reviewers of the model understand the parameters, decision points and results of the model and accompanies the R code and data for the model. We assume that reviewers already have a high level of understanding of the acoustic monitoring process that has formed the backbone of take monitoring on Kauai since 2011, so have truncated a description of portions of the methodologies – we encourage readers to review any of the Underline Monitoring Project Annual Reports for a full description of field methods and previous key results.

This model was created by KESRP (a project administered by the Research Corporation of the University of Hawaii's Pacific Co-operative Studies Unit) and Tim Tinker of Nhydra and should be considered the intellectual property of its creators. The R code, data, and any other materials will be sent to other parties for the explicit purposes of review only, and the use of this model is bound by the terms of the data sharing agreement, which are that reviewers will not seek to publish the model or aspects of it themselves, nor use it for their own financial gain.

Methods

Study Area

Power lines occur around the perimeter of Kaua'i as well as along inland roads or valleys in several areas. For the purpose of this study we divided the landscape up into 8 regions (*reg*), which we used as a spatial random effect in statistical analyses (Figure 1). We also further divide power lines in into areas within the regions. These regions and areas were delineated based on power line construction type and environment type. Power lines within each region are divided into spans that occur between two sets of adjacent poles, and for this study each span received a unique identifier, or spanID. A span consists of an array of wires, which can be further divided into one or more "levels" of wires (wires within a single level are at the same approximate height above ground, ABG). Birds that fly through an array of wires can potentially strike a wire; however, the likelihood of a bird flying at the same height of the wires depends on several factors, including the presence of "obstacles" (e.g. trees, buildings) which birds must fly above. For example, in a coastal area with tall trees, if the height of the entire wire array is lower than the height of the treetops, birds will in all likelihood fly above the treetop obstacle and thus above the wire array, leading to a near zero likelihood of collision.

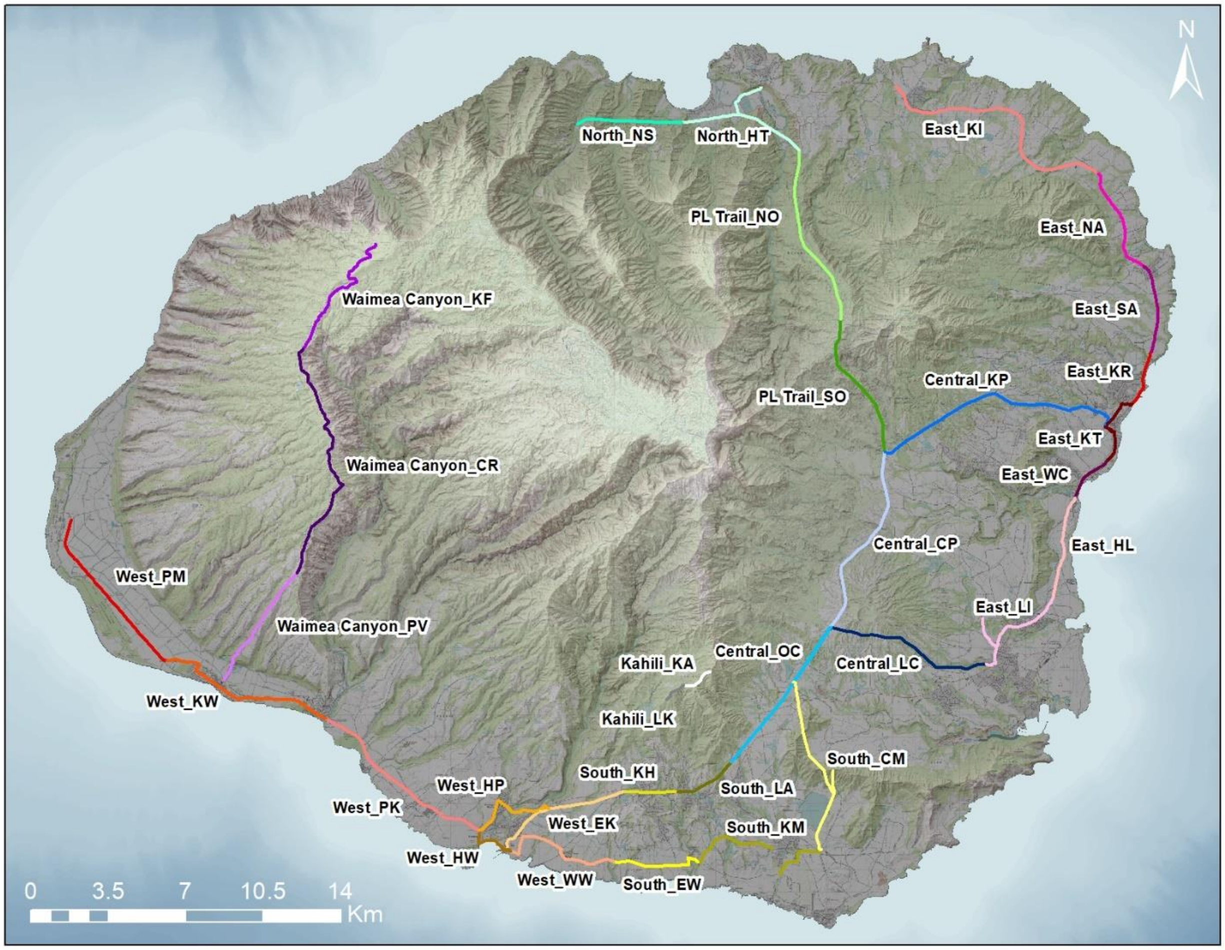

Figure 1. UMP power line regions and areas.

Spans are of varying length, depending on landscape configuration, and have several other defining characteristics or attributes. The structural attributes recorded for a given span include the distance (m) between poles or span length (*Lng*), variance in wire exposure (exsd), percent of span exposed (pcex), space between wire layers (sbwl), and number of wire layers (wlyr).

In addition to structural attributes, each span is associated with several geographic and environmental attributes that can affect bird passage rates or collision likelihood. Geographic and environmental attributes include distance from ocean (*dstoc*) and landscape gradient (grad).

Data Collection

To acoustically record power line strike sounds, Song Meter SM2+ (Wildlife Acoustics, Boston, MA) sensors were deployed at either 1) the base of power poles in quiet soundscapes (typically higher elevation sites) or 2) were mounted on the power pole just below the lowest transmission lines when the pole was near traffic sounds. Units deployed at the base of the poles had two SMX-II microphones positioned on the side of the unit, and the units were placed beneath vegetation to protect the microphone from wind and to reduce the likelihood that units would be tampered with by the public. The pole-mounted units had one Night Flight Microphone mounted on the pole as close to the lowest transmission wire as possible. We had five recording schedules, 1) peak time recording, 2) off-peak recording, 3) check time recording, 4) all3, and 5) every night (see Table 1). These recording schedules were as follows:

- "Peak" time units record acoustic data during two periods, starting at sunset and running for 3.5 hours and then starting again 3.5 hours before sunrise and ending at sunrise, for a total of 7 hours each night. This time period was named "peak" because it includes the peak pulse of passage rates observed at power lines (Travers et al. 2012 and 2013).
- "Off-peak" units record throughout the portion of the night not covered by the peak time units outlined above. They also recorded for 2.5 hours during the day (1 hour before and after sunset and sunrise, respectively, and for one half hour during midday).
- "Check" units recorded all night and thus covered the full nocturnal collision monitoring period (half hour after sunset to half hour before sunrise) every second night. Note to be conservative, the period encompassing the first half hour after sunset and the first half hour before sunrise, was removed from consideration. Although the target seabirds do fly during these periods, their likelihood of colliding with wires during day light is low compared to darker periods.
- "All3" units record every third night for the entire night.
- "Every night" units record every night for the entire night.

These schedules allowed us to deploy each unit type for one month before the batteries and SD cards needed to be changed.

Table 1. UMP Acoustic recording strategy and schedules

Recording Strategy	**Recording Schedule**	**Frequency**	**PM Night Monitoring**	**AM Night Monitoring**	**Day Light Monitoring**
Static (Seasonal)	Peak	Every Night	SS to 3.5 h after	-3.5 to SR	None
Static (Seasonal)	Off-peak	Every Night	SS+3.5 h to 23:59	00:00 to SR-3.5 h	SR to 1 h, 12:00 to 12:30, -1 h to SS
Static (Seasonal) Reduced Cost	All 3	Every 3rd Night	SS to 23:59	00:00 to SR	None
Static (Minimization)	Every	Every Night	SS to 23:59	00:00 to SR	None
Check (Re-sampling)	Check	Every 2nd Night	SS to 23:59	00:00 to SR	None
Rover (Randomized)	Peak	Every Night	SS to 3.5 h after	-3.5 to SR	None

We had three sampling strategies that employed the above recording schedules. First, we had seasonal monitoring which typically covered the full seabird breeding season from March 1 to January 1. In order to reduce costs to KIUC, from 2016 we began reducing some of the seasonal monitoring to April 1-November 1. Seasonal monitoring sites typically had two Song Meter units at each location: one for peak time recording and one for off-peak recording.

The seasonal units were deployed at ‘static’ sites (sites monitored every year) to measure the variation of strikes across the season, which includes identifying the start and end of the strike season and the increase and decrease in the strike rate which coincides with the seasonal variation in passage rates of the target seabirds[1]. The off-peak units were deployed to identify the frequency of strikes in the middle portion of the night and variation across the season. The ratio of off-peak strikes to peak strikes measured at full season monitoring sites is used to develop correction factors or model middle of the night strikes for locations that only had partial night monitoring (i.e. rover peak monitoring described below). For seasonal monitoring locations we deliberately selected sites with the highest known strikes. The consistently elevated strike rates are required to reliably detect the seasonal patterns.

Secondly, we deployed ‘check’ units at sites that recorded strikes in previous seasons (see previous UMP Annual Reports for details) or areas that had high collision risk characteristics. Check units record all night every second night. This schedule was designed to provide data on the full night without the need for increased equipment and analysis time (i.e. to lower monitoring costs). Firstly, these units are used to provide additional information on the variation in strike across the night. Again, this allows for development of correction multipliers for locations that only had partial night monitoring (i.e. rover peak monitoring described below). Secondly, check units being deployed at sites with previously detected strikes allow for measuring strike change across years and at different times of the season.

Thirdly, we employed a random stratified sampling protocol for all other acoustic monitoring (May 15 to September 15). This type of monitoring had one unit recording on the peak schedule per site. Our random stratified protocol, described in detail below, was designed to ensure 1) equal monitoring across the different regions while 2) forcing equal monitoring of varying exposure heights within each region and ensuring 3) that there was equal spread across the existing exposure heights over the entire sampling period. To accomplish equal sampling across regions, we allocated equal monitoring effort (number of units) to a region based on the number of spans present within that region. Within each region, we looked at the range of exposure heights present (height of wires relative to local vegetation; see Travers et al. 2013 & 2014 for details) and classified spans into the categories of low, medium, or high exposure height specific for that region (e.g. the range for low exposure in one region may be different than another region). We then assigned random numbers to each span and selected equal numbers from each exposure category. We conducted this sampling without replacement each month. Thus, every month’s acoustic monitoring was balanced across regions and the exposure heights were balanced within each region.

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[1] Seabird passage rates vary across the season as birds have different burrow visitation rates as they advance through different breeding stages.

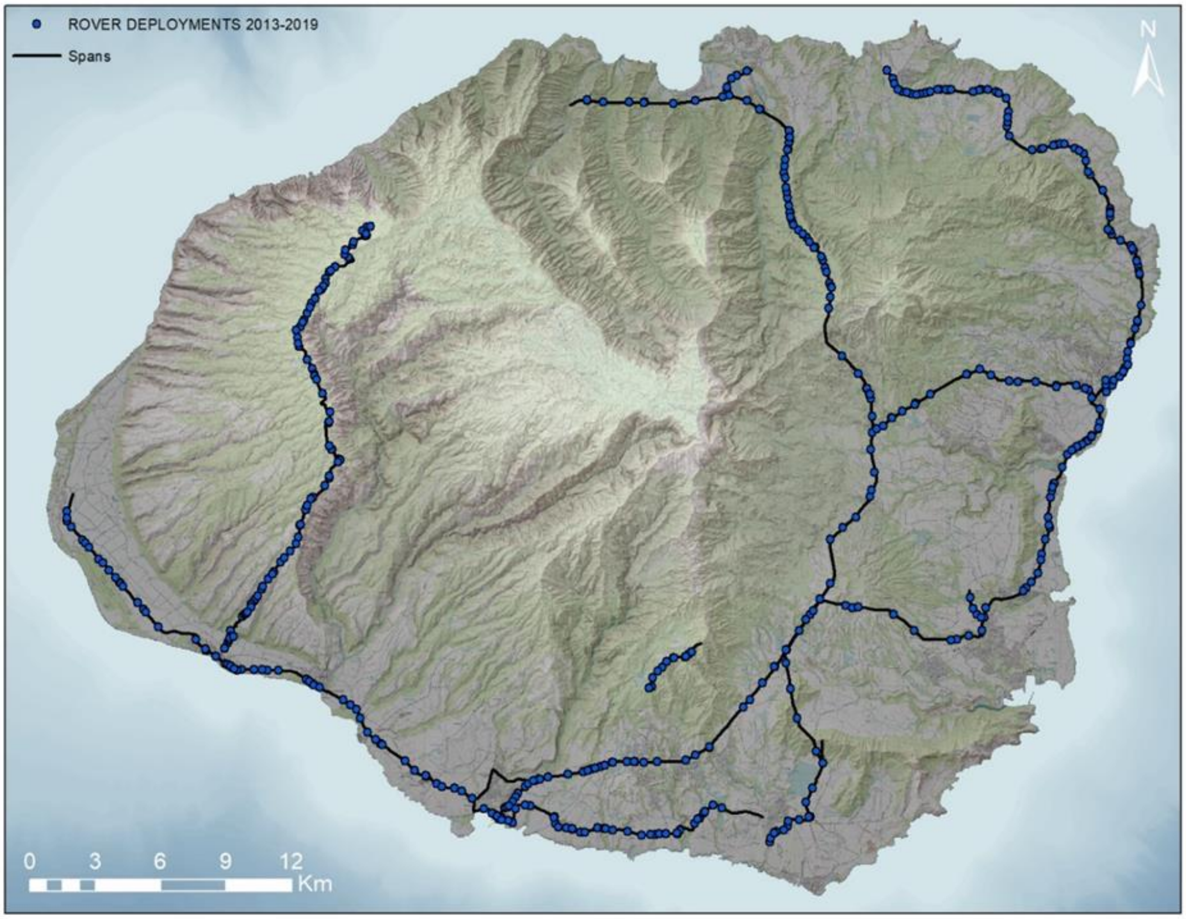

Figure 2. Distribution of rovers monitoring effort 2013-2019 with site selection based on the KESRP simple random stratified sampling design. We have not displayed monitoring effort because rover sites have a uniform effort of one month (20-30 days) on the peak schedule. We have shown that our rover monitoring effort does bias the result towards undercounting strikes. The undercounting of strikes is due the fact that a short window of monitoring effort (20-30 days) has a reduced likely hood of detecting any strikes even if the seasonal strike total is as high as 20 (Travers et al. 2017b). Furthermore, strikes are undercounted when fiberoptic cable is present (because Fiber does not produce a strike sound) and at sites with high ambient noise from vehicle traffic and wind (Travers et al. 2019a).

Conservation Metrics Inc.. Automated detection and classification of acoustic strike sounds

Automated acoustic analysis of all field recordings was carried out with custom detection and classification software developed by Conservation Metrics, Inc. (CMI). We applied a machine learning technique, Deep Neural Networks (DNNs), to detect sounds on field recordings that had spectro-temporal properties similar to those measured from examples of strike sounds. Deep Neural Networks are a powerful tool for detection and classification of events used in many fields such as speech recognition, image recognition, and other pattern recognition tasks (Deng et al. 2013, Schmidhuber 2015, Cichy et al. 2016, Min et al. 2016).

Our workflow splits the stereo acoustic files into two datasets, one for each microphone channel (right and left). Spectro-temporal measurements are extracted from these recordings in discrete time windows (2-seconds long), and discrete frequency bins (256 frequency bins per time step). The Underline Monitoring Project acoustic effort results in the collection of hundreds of millions of discrete 2-second clips every monitoring season, and billions of spectro-temporal measurements.

Feature measurement scores were used to train DNN classification models to detect powerline strikes. Specifically, we developed training and cross-validation datasets with examples of “positive” sound clips containing the sound of interest (i.e. 2-second clips containing powerline strike sounds) and a representative sample of “negative” sound clips (i.e. examples of 2-second clips containing sounds from the soundscapes at all survey sites that are not powerline strikes). The neural networks optimize a combination of spectro-temporal feature values that best differentiates positive sounds from negative sounds in the environment. Trained DNN classification models can then be applied to predict events of interest on acoustic data from future surveys, returning a likelihood that any given 2-second clip contains a sound produced by a powerline strike.

CMI Model performance

There is an inherent trade-off between accuracy (proportion of true positives in the set of possible events identified by the model) and sensitivity (proportion of true positives detected out of total available for detection in the data) in any signal detection problem. An increase in the sensitivity of a detector will usually lead to decrease in accuracy and vice versa. The signal detection challenge for the Underline Monitoring Project is the need to optimize classification model sensitivity for a rare signal, while maintaining accuracy levels that produce a manageable amount of potential events for manual review (*see below*). Collision sounds are rare, in a typical season acoustic surveys collect 60-70,000 hours of acoustic recordings (~7 years in aggregate), and we have typically detected only 1 to 2 hours per season containing collision sounds.

Our current DNN model was developed in 2015. It was trained using example data collected through 2015 and optimized to process large datasets more efficiently than previous detection models. The training data included 1,193 examples of strike sounds and 192,645 randomly selected samples of other background sounds from the soundscape. We evaluated model performance using a standard test dataset developed from KESRP Underline Monitoring Project recordings. Specifically, the test dataset contained recordings from field survey periods when KESRP staff were monitoring for seabird collisions at acoustic monitoring sites in 2013. The test dataset included 216 hours of recordings from 7 sites made on 16 survey nights. Human observers detected a total of 32 strikes during these survey periods. CMI manually reviewed and labeled the test dataset by navigating to each timestamp for a strike observed in the field and finding the strike in the test dataset. There were 9 strikes that could not be located on the sound data, so the test dataset on which we evaluated performance included 23 strike sounds. The DNN model returns a confidence score between 0-1 that a strike is present for each window. Model performance metrics vary based on the confidence threshold selected for an analysis. A receiver operating characteristic (ROC) curve was used to evaluate model performance at different confidence thresholds, and we selected a confidence threshold for our analysis based on a value that balanced the desire for high sensitivity (detection of a high percentage of strike sounds available for detection) and high accuracy (a low number of sounds incorrectly identified as strike sounds). At the chosen threshold of 0.006, the DNN model detected 16 of 23 (sensitivity: 69.6%, accuracy: 0.6%) collisions in the test data. At that threshold, the model classifies 99.29% of the test dataset (over 386,000 2-second clips) as not containing a collision sound, with an accuracy of 99.998%. If the performance of the acoustic method was evaluated as a whole (DNN Detections/Total Observed Strikes) the survey method identifies 16 of 32 strikes (sensitivity: 50%).

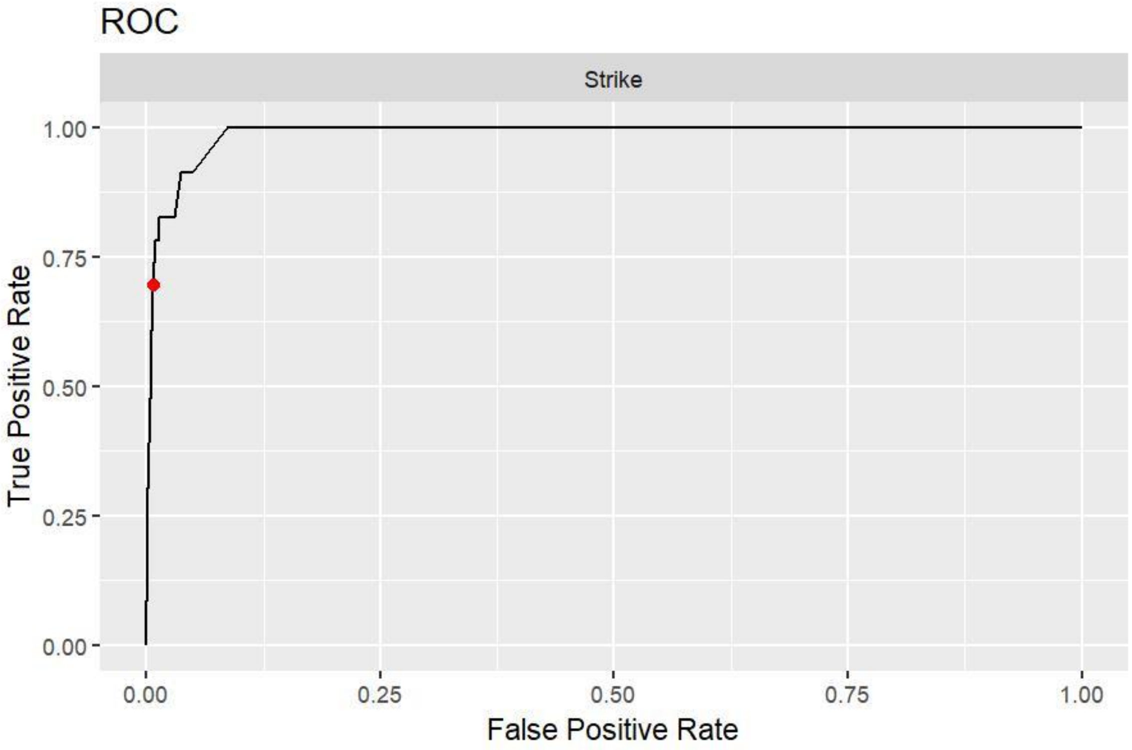

Figure 1:ROC curve for Strike classification model. The red dot represents the DNN confidence threshold selected for our analysis.

CMI Channel selection

Song meter sensors are equipped with two microphones (left and right) that record acoustic data in stereo. During our initial data ingestion process, we split those stereo files into their component channels (*See above*). We then chose only one channel from each recording to analyze for collision sounds. This decision was sometimes based on UMP's guidance (i.e. when UMP utilized two different microphone types for the purposes of a specific equipment test or if there was a clear problem with one microphone). When channel selection wasn't specified by UMP (which was the majority of recordings) we conducted our own assessment of recording quality; using long-form spectrograms and metrics of microphone sensitivity to select the channel with the best quality data.

CMI Auditing - manual review of events of interest

We applied our DNN classification model to all acoustic data received to predict clips containing potential strike sounds, or “events of interest”. We then manually reviewed all events that are assigned confidence score above our threshold (0.006). All acoustic “events of interest” occurring in the sensor channel selected for analysis are then reviewed by a human analyst. We call this quality assurance/quality control (QA/QC) review process “auditing”. A 16-panel browser screen in CMI’s Auditor software enables the analyst to rapidly assess presence/absence of strike sounds in spectrograms of each event of interest – both visually and by listening to the sound (either the 2-second clip, or a longer section of recordings where context is needed). All potential strike sounds were labeled as either strikes or not-strikes by the analyst. As a final QA/QC step, all strike sounds tagged by the analyst were reviewed by a senior CMI staff member to confirm the classification. This two-step process removes all false positive detections predicted as possible events by the DNN. The end result is that all collision sounds positively identified through this process have been manually reviewed by two people to confirm that they meet the criteria of a strike sound - as identified and recorded by UMP field staff.

Data Exclusions

For this analysis, we removed acoustic data from experimental monitoring methods (e.g. SM4, Vibration sensors), and field experiments such as LASER nights, white Light nights, and diverters. We excluded acoustic data collected outside of the night period and for the first half hour after dark and the first half hour before dawn. Removal of the first and last half-hours is a conservative approach, as seabirds do fly with risk in these time windows and the strike patterns detected in these windows match that of seabirds and not other species. However, there is elevated risk that other species could also hit wires during this time period. To reduce the concerns of some reviewers we have removed these collisions. We also removed all acoustic data from areas where we have discerned through years of research that acoustic sensors were not functioning and predicted strikes within these areas using the model parameter estimates. Using BRS data, we determined that there is a 0% chance of detecting a strike sound in the areas KR, KT, WC on the east side, and in area HW on the west side. These areas had ambient noise levels that resulted in a detection rate of zero BRS strike sounds. These are areas we have highlighted in past years as having zero strikes but have dead seabirds under wires (see previous UMP Annual Reports). Removing these data specifically from the Kealia area, also address the issue of the fiber-optic cable. Fiber-opitic cable does not produce a strike sound and thus results in underestimating of strike acoustically. We have not made any adjustment for the fiber-optic cable in the lines running from Ele’ele to Kapaia power plant, which will result in an underestimate for these lines. Lastly, for the current model run, we have elected to be conservative and exclude Waimea Canyon acoustic data because we determined there was a discrepancy with this data when compared to the observational data. In this region, the acoustic data indicated a higher strike rate than did the observation results and to date we have no studies to determine why this would be the case. Since 2017, UMPKESRP has recommended multiple methods to examine the strike rate more closely for this region but due to funding decisions we could not undertake these studies.

Data Analyses Overview

We used a Bayesian hierarchical modeling framework to estimate the annual rate of bird–powerline collisions based on data from acoustic sensors. To accommodate the large volume of data collected from acoustic sensors deployed over many spans and sample periods, we used a tiered analytical approach consisting of 4 steps: 1) We use a sub-sample of data from representative spans for each region to estimate generalized patterns of temporal variation in strike rates. We account for two temporal scales of variation, seasonal (variation across weeks) and diel (variation across 15-minute time steps), and we allow for temporal autocorrelation at both scales; 2) We use a sub-set of data from well-sampled spans to estimate the effect of acoustic signal quality on the likelihood of strike detection; 3) We sequentially step through each sampled site (i.e. an acoustic sensor deployed at the intersection of two adjacent spans) and use all available data to estimate the mean annual number of strikes, accounting for the effects of temporal variation (using the generalized temporal effect estimate from step 1 as a prior for local temporal effects), lunar illumination and fluctuations in acoustic signal quality; and 4) Using the mean annual strike rate estimates for sampled spans as a dependent variable, we use MCMC methods to fit a generalized linear mixed effect model (GLMM) estimating annual strike rate as a function of environmental, geographic and structural covariates, while allowing for random effects (unexplained variation) among regions and spans. We then apply this model to predict annual strike rates for all spans on Kauai, as well as associated estimation uncertainty. We explain each of these analytical steps in the following sections.

Step 1: Generalized Patterns of Temporal Variation

The rate of powerline strikes by seabirds at any given span is not expected to be constant, but rather to vary temporally as a function of changes in the relative abundance and behavior of birds. For example, more birds are likely present at some points of the year and/or times of night, potentially resulting in more strikes, and the strike rate can also change depending on behavioral attributes such as relative flight height with respect to wire spans. Accounting for this temporal variability is necessary to allow for meaningful comparisons of strike rates among spans, or extrapolation of rates across an entire season, while controlling for confounding effects of seasonal and diel variation. We note that it would be less critical to account for temporal variability if all spans were sampled evenly across all days of the year and all times of night, but such uniform sampling is rarely possible.

For analytical tractability we identified two distinct time scales for evaluating temporal variation in strike rates. Specifically, we discretized time into intervals of one week (w = 1, 2… W) for evaluating seasonal effects, and intervals of 15 minutes (q = 1,2… Q) for evaluating diel effects. Exploratory analysis of pilot data suggested that these intervals were appropriate for capturing meaningful patterns of variation at the relevant scales, while still ensuring that time steps were functionally independent. In the case of diel effects, we recognized that biologically meaningful patterns of variation in bird behavior are best described with respect to solar time (sunset and sunrise) rather than a fixed 24-hour clock. In particular, for the first half of the night it is convenient to describe variation in bird activity (and thus strike frequency) with respect to the time elapsed since sunset, while for the second half of the night we can describe variation in bird activity with respect to the number of minutes before sunrise. Assuming that we are interested in describing behavior (and thus powerline strikes) from 30 minutes after sunset to 30 minutes before sunrise, then for nights around summer solstice there are Q = 38 timesteps (9.5 hours) of interest. We can describe q = 1–19 in terms of minutes after sunset (with q = 1 starting at 30 minutes after sunset) and q = 20–38 in terms of minutes before sunrise (with q = 38 ending at 30 minutes before sunrise). However, as one moves backward and forward in the season away from solstice the total night duration increases: we allow for this by having an extendable "middle-of-night" period, and classify all 15-minute intervals in the middle of the night as q = 19 (recognizing that this results in a disproportionally larger number of records for q = 19) This adjustment is reasonable because there tends to be less bird activity (and thus less variability) in the middle of the night. We keep track of the number of additional minutes of q=19 to account for each week and incorporate this adjustment into our calculations of total seasonal strike rates (see below).

In addition to discretization of time at multiple scales, there are several challenges inherent in measuring and describing temporal variation: these include autocorrelation of strike rates between time-steps, non-linear patterns of variation, and interactions between the seasonal and diel time scales (i.e. the functional form of diel effects can vary over the course of the season). Conditional Autoregressive (CAR) models have become a widely used approach for describing complex patterns of variation in a parameter of interest that is autocorrelated across time or space (Besag 1974, Banerjee et al. 2003, Gelfand and Vounatsou 2003). CAR models are an effective means of incorporating temporal correlations into an analysis, particularly in Bayesian models where they require estimation of only a few additional parameters (Lee 2011), and they can be adapted for univariate or multivariate non-linear effects. For our model we wished to describe patterns of variation and autocorrelation in relative strike rates across two temporal dimensions, corresponding to the seasonal and diel timescales. Our specific objective was to estimate a temporal effects matrix, **T**, having dimensions W (number of weeks) and Q (number of quarter-hour timesteps), whose cell values $\gamma_{w,q}$ describe the log ratio of the mean strike rate in week w and timestep q relative to the average rate over all weeks and timesteps. To accomplish this we utilized a CAR model designed to estimate correlated variation in a variable of interest over two dimensions, following the specific formulation described by Liu et al. (2017) based on a generalized multi-dimensional CAR model (Stern and Cressie 1999). We model variation in $\gamma_{w,\mathbf{v}}$, where **v** represents vector [q(1), q(2)… q(Q)], using the following autoregressive structures:

$$\gamma_{1,\mathbf{v}} = \phi_{1,\mathbf{v}} \tag{1}$$

$$\gamma_{w,\mathbf{v}} \mid \gamma_{w-1,\mathbf{v}}, \rho_w = \rho_w\left(\gamma_{w-1,\mathbf{v}}\right) + \phi_{w,\mathbf{v}}, \quad for\ w = 2,3\ldots W \tag{2}$$

$$\phi_{w,\mathbf{v}} \sim multivariate\ normal\left(0, \Sigma\right) \tag{3}$$

$$\mathbf{\Sigma} = \sigma_\gamma^2 \cdot inverse\left(\mathbf{D} - \rho_q \mathbf{G}\right) \tag{4}$$

Equation (2) describes the temporal autocorrelation component for seasonal effects, and follows a standard "AR(1)" autoregressive model formulation (Brockwell and Davis 2016). The value of $\gamma_{w,\mathbf{v}}$ depends (in part) on the value of $\gamma_{w-1,\mathbf{v}}$, with the strength of the correlation determined by fitted parameter ρ_w.

Equation (3) describes the temporal autocorrelation component for diel effects, and follows a conditional autoregressive distribution (Besag 1974): $\phi_{w,\mathbf{v}}$ is a random vector ($\phi_{w,1}$, $\phi_{w,2}$ … $\phi_{w,Q}$), the joint distribution of which is multivariate normal with mean 0 and variance-covariance matrix $\mathbf{\Sigma}$. Equation (4) describes the computation of the variance-covariance matrix, $\mathbf{\Sigma}$: the magnitude (scale) of variation is determined by the fitted parameter σ_γ, while the degree of correlation across timesteps is determined by correlation coefficient ρ_q. The remaining variables in equation (4), **D** and **G**, represent square matrices with dimension Q: the elements of **G** ($g_{q,q'}$) are equal to 1 if timestep q occurs immediately before or after timestep q' (i.e. they are sequential) and 0 otherwise, while the elements of **D** ($d_{q,q'}$) are equal to 0 for all elements except the diagonal and the q^{th} diagonal element gives the number of sequential timesteps for q (1 for q = 1 and $q = Q$, 2 for all other time steps).

To estimate generalized patterns of temporal variation in strike rate (for use as a prior for temporal effects at individual spans), we selected a sub-set of representative sites for which there were abundant data collected across the entire season over multiple years. To ensure even geographic representation, we selected from each of 7 regions the two sites having the largest sample size of acoustic records from multiple years and for all weeks between Apr 1 - Nov 30 (an acoustic record is defined as a 15 minute time step in which the number of detected strikes has been recorded). For each unique combination of site (i = 1, 2… S), week (w) and timestep (q), we tallied the number of acoustic records available ($R_{i,w,q}$) and the total number strikes detected in those records ($H_{i,w,q}$). The mean expected number of strikes at site i in week w and timestep q is calculated as:

$$\lambda_{i,w,q} = \exp\left(\zeta + \psi_i + \gamma_{w,q}\right) \cdot R_{i,w,q} \tag{5}$$

Where ζ gives the overall mean log strike rate (for these 14 sites), ψ_i is the log proportional deviation from the overall mean associated with site i (estimated as a hierarchical random effect drawn from a normal distribution with mean of 0 and standard deviation σ_i) and $\gamma_{w,q}$ is the average temporal effect for week w and timestep q (estimated using CAR methods as described above). We note that other fixed effects are expected to affect strike rate (including lunar illumination and fluctuations in signal quality), but while these effects are included in site-specific models (see below) we exclude them from this generalized model because, for this data-rich sub-set of sites, the large number of samples over multiple years for each week-timestep combination means that those other effects are effectively “averaged out”.

We treat $H_{i,w,q}$, the number of detected strikes, as our observed variable, assumed to be described by a negative binomial distribution that is related probabilistically to the mean expected number of strikes:

$$H_{i,w,q} \sim \textit{negative binomial}\left(\textit{mean} = \lambda_{i,w,q}, \nu\right) \tag{6}$$

where the inverse scale parameter υ determines the degree of over-dispersion in the recorded number of strikes per sample.

The observed variable $H_{i,w,q}$ constrains the possible values of unknown parameters in equations (1) – (5), allowing us to estimate posterior distributions for these parameters using standard Markov Chain Monte Carlo (MCMC) methods. We used vague prior distributions for all parameters (i.e., weakly informed based on biological feasibility but having no information specific to the analysis): a Cauchy prior (scale = 2.5) for ζ, half-Cauchy priors (scale = 2.5) for 0-bounded parameters σ_γ, σ_i and υ, and flat beta priors for 0-1 bounded parameters ρ_w and ρ_q (Gelman 2006, Gelman et al. 2008). We used R (R.Core.Team 2014) and Stan software (Carpenter et al. 2017) to code and fit the model, saving 20,000 samples after a burn-in of 5,000 samples. We evaluated model convergence by graphical examination of trace plots from 20 independent chains and by ensuring that Gelman-Rubin convergence diagnostic (Rhat) was ≤1.1 for all fitted model parameters. We conducted posterior predictive checking (PPC) to evaluate model goodness of fit, both by graphical comparison of the frequency distributions of empirical data vs. out-of-sample ("new") estimates, and by using the χ^2 statistic (sum of squared Pearson residuals for observed counts vs expected values) to compare fit of observed data and out-of-sample estimates (Gelman et al. 2000). We examined scatter plots of the posterior distribution of χ^2 scores for new vs observed data (in the case of well-fitting models, points in such a plot should be distributed around a line with slope 1) and we computed the associated "Bayesian-P" value (the proportion of new observations more extreme than existing observations; Gelman 2005, Ghosh et al. 2007), which should fall within the range 0.2< Bayesian-P <0.8 for a well-fit model. We summarized results graphically and by reporting the mean and 95% CI of parameter posterior distributions.

Step 2: Effect of Acoustic Signal Quality on Strike Detection

Acoustic recordings, combined with machine learning algorithms for detecting a signal of interest (in this case the sound of a bird-sized object striking a powerline), have been shown to be an effective and scalable method for monitoring the abundance and/or behavior of seabirds (Buxton and Jones 2012, Borker et al. 2014). One challenge inherent with acoustic detection of signals is that the quality of the acoustic recording is sometimes impaired (often as a function of environmental conditions such as wind and rain), such that the probability of signal detection declines as signal quality decreases. This can potentially lead to a bias, with lower levels of detection during times when the signal quality is impaired. Fortunately, there are several metrics of acoustic signal quality that together can be used as an index of relative signal quality, and thereby provide the ability to correct biases associated with poor signal quality. Signal quality metrics show predictable patterns under certain conditions (e.g. microphone failure, rain or water-logged microphones) that are associated with reduced probability of signal detection. The challenge for a given data set is thus to determine the relationship between signal quality metrics and detection probability.

To estimate the effect of acoustic signal quality on the likelihood of powerline strike detection, we first sub-sampled data from those sites that were recorded during the peak period of strike activity ($3<w<19$ and $26<q<32$, as determined from the generalized temporal matrix **T** described in the previous section) and for which at least one strike was detected. We then developed a conditional logistic regression model to estimate the effects of signal quality variables on the probability of strike detection. Specifically, for each detected strike we randomly selected 4 "matching" non-strike records from the same site during the same peak period (and having the same lunar illumination and set of environmental conditions): for H detected strikes, this resulted in a data set of $N = 5H$ records, with a mean expected strike probability of 0.2. These data were analyzed as a series of Bernoulli trials, in which the outcome of each record (Y = 1 for a strike, Y = 0 for no strike) was estimated as:

$$y_n \sim bernoulli\left(\theta_n\right) \tag{7}$$

where θ_n is the probability of that a strike occurs and is detected in record *n*, calculated as:

$$logit(\theta_n) = \kappa + \sum \alpha_j \cdot X_{n,j} \tag{8}$$

where κ determines the baseline strike probability for the sample and α_j is a vector of parameters associated with predictor variables X_j that potentially affect the likelihood that a strike is detected.

We next added a second observed data set to the model: for a sub-set of acoustic records that overlapped with visual surveys it was possible to compare observed strikes with their corresponding acoustic records to evaluate a) the average probability that visually-confirmed strikes were detected by the acoustic algorithm and b) the effect of signal quality metrics on this probability. For each of *c* = 1, 2… *C* visually confirmed strikes, we define z_c as a binary variable with value of 1 if the strike was detected by the acoustic recording and a value of 0 otherwise. These data were analyzed as a series of Bernoulli trials, in which the outcome of each record was estimated as:

$$z_c \sim bernoulli(\varphi_c) \tag{9}$$

and φ_n is the probability that a visually confirmed strike is detected in acoustic record *c*, calculated as:

$$logit(\varphi_c) = \alpha_0 + \sum \alpha_j \cdot X_{c,j} \tag{10}$$

where α_0 is a parameter specifying the baseline strike detection probability, α_j is the same vector of parameters defined for equation (8) and X_j are predictor variables that potentially affect the likelihood that a strike is detected.

There were 6 signal attribute metrics that we expected *a priori* to potentially provide information on the likelihood of a strike being successfully detected by an acoustic record: flux, flux sensitive, level, level absolute, click and burst. Unfortunately, the raw metrics were colinear to a certain degree and thus not fully independent. Moreover, the relationship between metrics and detection probability was not necessarily linear and there were potential interactions between metrics. To address the problem of collinearity we used principal components analysis (PVA) to collapse variation and obtain a smaller number of orthogonal variables (factors) that were linear transformations of the original signal attribute metrics. We used function "prcomp" in the stats library of R (R.Core.Team 2014), which utilizes singular value decomposition of the centered and re-scaled data matrix to produce orthogonal factors that were rotated functions of the original variables, centered on zero and with unit variance. The first 4 factors explained 96% of the variation in the raw signal attribute metrics, so we used these as predictor variables for equation (8). We also evaluated quadratic terms for each of the PCA factors as well as first-order interactions.

We used standard MCMC techniques to fit equations (7) - (10) to the observed data, with model fitting and evaluation methods identical to those described for the temporal effects model (see step 1, above). We evaluated alternative combinations of predictor variables, retaining those terms where the 90% credible intervals of the posterior distributions did not overlap 0, and we used the "Leave-out-one Information Criterion" (LooIC) to compare models with different combinations of predictor variables and select the best-supported model (Vehtari et al. 2017). With the best-supported model we drew from posterior predictive distributions of model parameters and calculated the predicted signal detection probability (SDP) associated with each 15-minute acoustic record (*a*) in the full data set:

$$SDP_a = logit^{-1}\left(\alpha_0 + \sum \alpha_j \cdot X_{a,j}\right) \tag{11}$$

We summarize graphically the distribution of SDP values and report the mean, standard error, and upper and lower 95% quantiles.

Step 3: Estimating Site-specific Strike Rates

The generalized temporal matrix (**T**) and the SDP estimates generated from step 1 and step 2 models were used as inputs for a site-specific model to estimate annual strike rates. The structure of the site-specific model is similar to the generalized temporal model of step 1, with the mean expected number of detected strikes at site *i* in week *w* and timestep *q* ($\Lambda_{i,w,q}$) calculated as:

$$\Lambda_{i,w,q} = \exp\left(\zeta + \psi_i + \overline{\gamma}_{w,q} + \gamma^*_{w,q}\right) \cdot R_{i,w,t} \cdot \overline{SDC}_{i,w,q} \cdot \Omega_{i,w,q} \tag{12}$$

where ζ is the overall mean log strike rate (as estimated in model step 1) and ψ_i is the log proportional deviation from the overall mean associated with site *i* (estimated as a hierarchical random effect drawn from a normal distribution with mean of 0 and standard deviation σ_i). Unlike equation (5), the temporal effect in equation (12) is divided into two components: $\overline{\gamma}_{w,q}$, which represents the generalized temporal effect common to all sites (as estimated in model step 1), and $\gamma^*_{w,q}$, which represents deviations from the generalized temporal effect that are specific to site *i* and is estimated using the CAR methods described in equations (1) - (4). By using this split formulation, we effectively treat the generalized temporal effect matrix as a prior, providing a reasonable baseline for those sites having low sample sizes or missing data from portions of the season. For sites having larger sample sizes and complete seasonal coverage, the sum of $\overline{\gamma}_{w,q}$ and $\gamma^*_{w,q}$ produces a locally-specific temporal effects matrix. The last 3 terms in equation (12) represent sample-specific adjustment factors: $R_{i,w,q}$ is a multiplier that adjusts the per-capita strike rate for the number of observed records, $\overline{SDC}_{i,w,q}$ is the signal detection probability statistic (as estimated in model step 2) averaged over the sample of acoustic records for site *i* in week *w* and timestep *q*, and $\Omega_{i,w,q}$ adjusts for the effects of lunar illumination in week *w* and timestep *q*. This last term was included based on *a priori* knowledge that moon illumination can affect bird behavior and thus the frequency of wire strikes. To account for the effects of lunar illumination, the relative degree of moon illumination for each record was specified as the proportion of moon face illuminated (and forced to 0 when the moon was below the horizon). We then re-centered this variable such that the mean value across all timesteps within a single season was 0, and we define *MI* as the re-scaled moon illumination associated with a single acoustic record. We then computed the mean and standard deviation of *MI* for all records recorded at site *i* in week *w* and timestep *q* (designated as $\overline{MI}_{i,w,q}$ and $sMI_{i,w,q}$, respectively). Finally, we calculate the moon illumination adjustment factor as:

$$\Omega_{i,w,q} = \exp\left(\overline{MI}_{i,w,q} \cdot \omega + 0.5 \cdot (sMI_{i,w,q} \cdot \omega)^2\right) \tag{13}$$

Where ω is a fitted parameter that accounts for the effects of moon illumination on strike rate.

For each site, *i*, and for each unique value of week and timestep, we tallied the number of acoustic records available ($R_{i,w,q}$) and the total number strikes detected in those records ($H_{i,w,q}$). For some sites a modification of the wire array (e.g. removal of the top wire) occurred part way through the sampling period: in these cases we partitioned the data into before and after the modification event (treatment), and consider each of these data sets as separate “sites” for the purpose of estimating strike rates before vs. after the treatment. We treat $H_{i,w,q}$, the number of detected strikes, as our observed variable, and we assumed it was described by a negative binomial distribution related probabilistically to the mean expected number of strikes:

$$H_{i,w,q} \sim negative\ binomial\left(mean = \Lambda_{i,w,q}, \nu\right) \tag{14}$$

where the inverse scale parameter υ determines the degree of over-dispersion in the recorded number of strikes per sample. The observed variable $H_{i,w,q}$ constrains the possible values of unknown parameters in equations (12) - (13), allowing us to estimate posterior distributions for these parameters using standard Markov Chain Monte Carlo (MCMC) methods. Model fitting and evaluation methods were identical to those described for the generalized temporal effects model (see step 1, above).

The posterior predictive distributions of fitted parameters were then used to estimate annual strike rates for each site, Y_i. We first created an index vector *t* representing all combinations of *w* and *q*, iterated so as to create a complete and ordered temporal sequence for all days over all weeks of a season from Apr 1 - Nov 30 (and accounting for variation in night duration via the extendable “middle-of-night” period, as described in step 1). We used this index vector to estimate the expected sum of strikes over an entire season:

$$Y_i = \exp\left(\zeta + \psi_i\right) \cdot \sum_{t}^{T} \exp(\bar{\gamma}_t + \gamma_t^*) \tag{15}$$

In comparing equation (15) to equation (12), we note that the terms adjusting for signal quality and number of records have dropped out, as we are now interested in “true” number of strikes rather than detectable strikes, and we assume just one record per unique value of *t*. Similarly, the term for moon illumination effect is dropped from equation (15) because the re-centered moon illumination variable *MI* results in an average seasonal moon effect value of 0. The posterior distribution for Y_i therefore represents our expectations (and associated uncertainty) about the average annual number of strikes at a given site and wire-array configuration. We use this posterior distribution as the “observed data” input for the final model step.

Step 4: Predictors of Strike Rate and Island-wide Estimate

We can express the expected annual number of strikes at a given span as a generalized linear mixed-effects model (GLMM), whereby the log of the mean expected value is an additive linear function of several fixed effects (corresponding to geographic, environmental and/or structural covariates) as well as a random effects that account for unexplained variation among regions and spans-within-regions. Specifically, if we define $Yexp_s$ as the expected mean annual number of strikes at span *i*, then:

$$\log(Yexp_s) = \xi + \sum_k X_{k,s} \cdot \beta_k + \log(Lng_s) + \eta_{region|s} + \varepsilon_s \tag{16}$$

where the intercept parameter ξ represents the log mean value, X_k is a matrix whose columns consist of *k* predictor variables (normalized and re-centered to have mean of 0 and standard deviation of 1) and β_k is a vector of *k* fitted parameters that describe the effect of the predictor variables, Lng_s is the total length of span *s* (in units of 100m), η represents unexplained variance (random effects) associated with region (estimated as a hierarchical random effect drawn from a normal distribution with mean of 0 and standard deviation σ_r) and ε represents unexplained variance (random effects) associated with a given span (estimated as a hierarchical random effect drawn from a normal distribution with mean of 0 and standard deviation σ_s). We evaluated a variety of potential predictor variables, using an information theoretic approach to determine which fixed effects to include in the final model. Potential geographic predictor variables included distance from ocean (*dstoc*), distance to nearest known nesting colony (*dstcol*), mean angle or slope of the landscape between adjacent poles (*slp*), mean gradient of the landscape in the area surrounding the span (*grad*), and topographical position index (*tpi*, a neighborhood-based measure of local variability in elevation). Potential environmental variables included mean annual wind shear (*wshr*), mean annual windspeed (m/sec.) within 100m of the span (wnd^{100}) and mean annual windspeed within 30m of the span (wnd^{30}). Potential structural predictor variables included the number of wire layers (*wlyr*) mean height (m) above ground (*abgh*) for the top wire level within the array, mean exposure (*exmn*, where exposure is defined as the height difference between the top wire level in the array and the top of the tallest obstacle to flight), standard deviation in exposure (*exsd*), maximum exposure (*exmx*), the percent of the wire layer exposed (*pcex*), and the total height of the array (i.e. the height between the top and bottom wire layer) divided by the number of layers, which provides a measure of the space between wire layers (*sbwl*).

To estimate the parameters in equation (16) we summed the values of $Yexp_s$ for the two spans comprising each site to obtain a site-specific value ($Yexp_i$), which we could then compare to “observed” values represented by the posterior predictive estimates of annual strike rate by site (Y_i) based on acoustic monitoring data (model step 3). Because the posterior distributions of Y_i were well-fit by gamma distributions, we were able to use a limited vector of quantiles to capture the distribution of uncertainty in the estimated value of Y_i for a given span. Specifically, for each span we computed 11 evenly spaced quantiles between 0.05 and 0.95 from the posterior distribution of Y_i. We confirmed that the original posterior distribution could be well-approximated by fitting a gamma distribution to the vector of quantiles. The combined array of quantile values for all spans (designated as $y_{i(u)}$) was then treated as an observed data variable, assumed to be described by a gamma distribution that was related probabilistically to the expected strike rate

$$y_{i(u)} \sim gamma\left(shape_i = \left(Yexp_i \cdot \tau_i\right), \tau_i\right) \tag{17}$$

where the inverse scale parameter τ_i was estimated separately for each site to account for differing degrees of precision in estimates of Y_i. In this way, sites having greater sample sizes (and thus more precise estimates of Y_i) contributed more to the estimation of fixed effect parameters in equation (16).

We used standard MCMC techniques to fit equations (16) - (17) to the observed data, with model fitting and evaluation methods identical to those described for the temporal effects model (see step 1, above). We set vague priors for all parameters, including Cauchy priors for ξ and β parameters and half-Cauchy priors for σ parameters (scale parameter = 2.5 in both cases). The prior distribution for τ_i was a half-Cauchy distribution with scale parameter ι itself a fitted parameter with a vague normal prior. We evaluated all combinations of predictor variables, retaining those effects where the 90% credible intervals of the posterior distributions did not overlap 0, and we used the "Leave-out-one Information Criterion" (LooIC) to compare models with different combinations of predictor variables and select the best-supported model (Vehtari et al. 2017). We present goodness of fit statistics and credible intervals for parameters included in the final model.

Finally, drawing from the posterior predictive distributions of fixed effect parameters and random effects, we generated predictive distributions of $Yexp_s$ (mean expected annual strike rate) for all spans around the island. We noted that the site-specific estimates for sampled spans in Waimea Canyon appeared anonymously high relative to visual surveys. Accordingly, we relied on posterior predictive estimates of strike rates for all spans in the Waimea Canyon region, which resulted in lower, more conservative estimates for sampled spans.

Results

Acoustic data on powerline strikes were collected over 7 years, from 2013 – 2019, with sample sizes of 500 or more 15-minute recordings analyzed from each of 441 sites (882 spans) for a total of 902,520 data records. There were 7,339 bird strikes positively identified from these records, for an average strike rate across the entire power grid of 0.008 per 15-minute recording.

Step 1: Generalized Patterns of Temporal Variation

The model to estimate generalized patterns of temporal variation in strike rate converged well, with Rhat <1.1 for all parameters (Table 1). Posterior predictive distribution plots indicated excellent goodness of fit (Figure 3), with a Bayesian-P value of 0.42. While there was considerable variation in mean log strike rate among sites (see ψ random effect values, Table 1), seasonal and diel trends in the relative frequency of strikes exhibited clear patterns when averaged across sites (Figure 4). The average period where strike rates were generally highest was 30-90 minutes before sunrise between April 20 and September 20, although it should be noted that the highest strike rate period is very site specific and can vary dramatically across different portions of the power line grid.

Step 2: Effect of Acoustic Signal Quality on Strike Detection

Results from a principal component analysis (PCA) indicated that 4 orthogonal PCA factors captured 96% of the combined variation in 6 signal quality metrics (Figure 5a). Loadings plots indicated that level, level absolute and burst loaded heaviest on PC1, flux and flux sensitive loaded heaviest on PC2, click loaded heaviest on PC3, and burst loaded heaviest on PC4 (Figure 5b-d). These 4 PCA factors were included as predictor variables in a model estimating the probability of signal detection. This model converged well, with Rhat <1.1 for all parameters (Table 2). Posterior predictive distribution plots indicated excellent goodness of fit (Figure 6), with a Bayesian-P value of 0.48. The best-supported model included 6 predictor variables that had significant effects on signal detection (Figure 7): PC1 and PC2 were positively related to the likelihood of signal detection, PC3 and PC4 had negative effects on signal detection, and significant quadratic effects included $PC2^2$ and $PC3^2$ (which had negative and positive effects, respectively, on the probability of signal detection). Applying the fitted model to all data records produced an estimated average strike detection rate of ~60%, although the distribution of signal detection probabilities was highly skewed (Figure 8). The most common detection probability rate was in the range of 60-85%, but there was a long "left tail" of records having detection probabilities of 0-60%, reflecting poorer signal quality.

Step 3: Site-specific Strike Rates

We fit separate models estimating annual strike rates to data from 441 sites, representing 882 spans. Models converged well, with Rhat values <1.1 for all parameters estimated for all spans, and provided excellent goodness of fit: sample posterior predictive plots from representative spans (Figure 9) show a close match between observed and out-of-sample predictive distributions, with Bayesian-P values from posterior predictive checks close to 0.5 (Figure 10). The temporal matrices for individual sites were broadly similar, although there were some site-specific differences in the seasonal and diel timing of peaks in strike activity (Figure 11). Sites also varied in terms of the effect of moon illumination on strike rates (Figure 12), although most sites exhibited a negative relationship between moon illumination and strike rates. PL Trail was an exception, with more sites in this region exhibiting a positive relationship between moon illumination and strike rates (Figure 12).

The estimated annual strike rates differed considerably among sites, and the precision of estimates was generally greater for sites having more robust sample sizes (Figure 13). The overall distribution of estimated annual strike rates was skewed, with most sites having low estimated numbers (<10) but a few sites having relatively high numbers of strikes (100 or more; Figure 14). The estimated mean annual number of strikes per site (corresponding to current wire configurations) was 31.6, with a standard deviation of 76.5, a median value of 4.9 and a 95% CI of 1.96 – 247.5.

Step 4: Predictors of Strike Rate and Island-wide Estimate

The model analyzing predictors of annual strike rate converged well, with Rhat <1.1 for all parameters (Table 3). Posterior predictive distribution plots indicated excellent goodness of fit (Figure 15), with a Bayesian-P value of 0.496. The best-supported model included 6 fixed-effect predictor variables (Figure

16): strike rates tended to increase with distance to ocean (*dstoc*) and decrease with increasing gradient of the landscape (*grad*); there were more strikes for arrays having more wire layers (*wlyr*) although arrays having greater space between wire layers (*sbwl*) had fewer strikes; and strike rate was higher for arrays having a greater percent of the wire span exposed (*pcex*) and lower for spans having more variance in exposure height (*exsd*).

In addition to the above-described fixed effects, there was a substantial degree of variance in strike rate attributable to unexplained differences (random effects) among regions and among sites within regions, with site differences accounting for a larger component of variation (Figure 17). The region having the highest strike rates was the PL Trail. Applying a posterior predictive approach, we estimated annual strike rates for all spans: the cumulative mean annual number of strikes across all spans prior to wire modification was estimated as **18,956 (95% CI = 4,417– 56,903**)[2]. A map of the strike rate estimates shows that most areas have less than 20 strikes per year, with a few clear hot spots of strike activity occurring in PL TRAIL and CENTRAL regions (Figure 18).

Step 5- Estimating immediately grounded seabirds and species ratios

When seabirds collide with power lines the minimum immediate grounding rate has been calculated as 13.0%, while the upper bound is 22.8% (Travers et al. 2020). When these immediate grounding rates are applied to the 18,956 acoustic strikes the minimum and upper bound of immediately grounded birds is **2,464-4,321 per year**.

The seabird passage rate was used in the past to identify the species-specific ratio of collisions and mortalities. If we apply the 70/30 Newell's Shearwaters to Hawaiian Petrel passage rate ratio used in the past, the immediate grounding rate by species is **1,725-3,025 immediately grounded Newell's Shearwaters and 739-1,296 immediately grounded Hawaiian Petrels**. However, separate to the Bayesian model it should be noted that we are actively working on updating the species specific collision rate and will present those updated results when the updated analysis is complete.

Step 6- Minimizing seabird power line collisions

Given the very large numbers of seabird power line collisions illustrated by this model update, which is in line with previous KESRP take models (see previous Briefing Documents), mitigation alone is clearly not practicable for offsetting this level of take. This is true for the current minimum grounding estimate of 2,462 seabirds annually but was also true for all previous model estimates. The previous estimates

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[2] Note this number was created using all data prior to any minimization. The number presented does not include reductions for Kahili Undergrounding and the static wire removal in the coffee fields. Furthermore, in the 2020 seabird breeding season, KIUC has started implementing larger scale minimization efforts than prior to 2020, by removing the static wire across multiple larger sections of wires.– see discussion below. With new measures in place, take estimates for 2020 will be lower.

(UMPKESRP 3 model amalgamation and the 3 versions of the FWS acoustic strike models from 2014, 2015, and 2016) considered fewer power line sections and had lower totals collisions, but each estimate also exceeded the available practicable mitigation options. As has been outlined in previous UMP Annual Reports and Briefing Documents, to mitigate for seabird power line collisions, power line minimization needs to be implemented in a manner that dramatically lowers the current level of collisions.

We have previously recommended several minimization actions that will help reduce seabird power line collisions to a level that can be mitigated. Before examining those options, we should first consider ideal minimization efficacy levels and the remaining mortalities for mitigation. If power line minimization targets of 80 or 90% reductions are achieved the required mitigation offset would be reduced to 492 or 246 seabirds annually, respectively. Certainly, the target goal of 90% minimization would reduce mitigation requirements (246 seabirds) to a level that is both practicable and financially feasible for KIUC. Minimization can be achieved through the following actions.

Static wire removal- We have previously reported estimates for several minimization actions. Static wire removal resulted in an estimated reduction of 36-72% depending on the terrain. Recent unreported observation work indicates that static wire removal could reduce strikes by as much as 78% on steel towers in flat terrain. Static wires are present in nearly all high strike locations and are geographically widespread and are therefore an ideal starting point for large scale geographic minimization[3].

LED Diverters- In discussion with researchers tackling powerline collisions in South Africa in early 2016, we were provided with unpublished information that LED diverters used in their work reduced avian collision rates at their study sites by more than 90%. If diverters were studied thoroughly on Kauai, diverters could also be implemented at a large geographic scale.

Power line reconfiguration- We have previously reported that wire modification plans put forward by KIUC in their first draft HCP produced in 2016, would lower collisions by 72-96% depending on the plan and the terrain. In the most challenging terrain, we have recommended that combining reconfiguration with the addition of static wire removal and or diverters would achieve significantly better reductions. Lastly, KIUC's new seabird team has put forth a wire design called spacer cable. This construction uses insulated wires, which increases the diameter of the wires, and allows wires to be closer together and much lower on the poles. We have not yet been asked to estimate the benefit of this method, but our opinion is that any method that maximizes the lowering of wires will greatly reduce collisions. If the spacer cable is lowered to the level currently being discussed, we believe that spacer cable could also achieve greater the 90% collision reductions.

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[3] In 2020 the new KIUC seabird team began large scale static wire removals at multiple high collision areas. At the time of writing, static wires have been removed in Kilauea, CP central region (previously in Ele'ele). Preparations are completed and static wire removal is about to begin in LC Central region. Once the third minimization action is complete KIUC will have partially minimization of 29.3 Kilometers of power lines in the beginning half of 2020. Prior to 2020, 8.4 Kilometers of power lines had been minimized. Lastly, the new KIUC team is developing plans for removing the static wire on the northern section of power line trail.

Maintenance of existing trees or promoting tree growth in a wire safe manner- In most areas trees that are taller than wires force bird to fly over wires, which would thus achieve 100% reduction when fully shielding wires.

Conclusion- As discussed above, achieving a 90% or greater seabird collision reduction should be achievable at power line sections on Kauai that are modified. High collision areas need to be modified immediately to minimize powerline collisions and bring the strike rate down to a level that can then be offset through mitigation actions such as predator control in colonies and the creation of fully protected areas surrounded by predator proof fences. Minimization needs to be implemented at a geographic scale that will reduce island-wide take to levels where mitigation will realistically offset take. While the modeled strike rates produced in this briefing document (and through previous models) are high, we believe that it is entirely possible and financially feasible to do this.

Tables

Table 1. Parameter estimates from model step 1. Hierarchical random effect values of ψ are shown for 14 representative sites (2 from each of 7 regions) selected for analysis of generalized temporal trends.

Parameter	***mean***	***sd***	***2.5%***	***50%***	***97.5%***	***Rhat***
ζ	0.193	0.606	-1.083	0.212	1.339	1.013
σ_γ	0.180	0.050	0.083	0.181	0.275	0.999
σ_i	2.162	0.565	1.336	2.072	3.516	1.002
υ	3.150	0.705	2.094	3.045	4.828	1.001
ρ_w	0.649	0.051	0.543	0.652	0.742	1.012
ρ_q	0.853	0.038	0.765	0.857	0.914	1.014
$\psi[1]$	1.972	0.593	0.854	1.951	3.233	1.012
$\psi [2]$	1.373	0.603	0.244	1.352	2.657	1.012
$\psi [3]$	1.323	0.600	0.185	1.296	2.594	1.012
$\psi [4]$	-0.018	0.653	-1.245	-0.034	1.345	1.010
$\psi [5]$	-1.950	1.005	-4.163	-1.881	-0.147	1.003
$\psi [6]$	-2.916	1.447	-6.268	-2.726	-0.673	1.003
$\psi [7]$	2.113	0.591	1.008	2.089	3.387	1.012
$\psi [8]$	2.449	0.591	1.334	2.426	3.716	1.013
$\psi [9]$	-2.546	0.983	-4.680	-2.488	-0.781	1.004
$\psi [10]$	-2.461	1.486	-5.946	-2.267	-0.145	1.001
$\psi [11]$	2.010	0.609	0.858	1.986	3.304	1.011
$\psi [12]$	0.520	0.637	-0.706	0.503	1.849	1.011
$\psi [13]$	-1.521	0.739	-3.001	-1.513	-0.063	1.008
$\psi [14]$	0.005	0.632	-1.194	-0.013	1.329	1.011

Table 2. Parameter estimates from model step 2. The fixed effect parameters affecting signal detection probability (α_j for J = 1:6) correspond to linear and quadratic effects of 4 PCA factors: PC1, PC2, PC3, PC4, PC2^2, PC3^2.

Parameter	*mean*	*sd*	*2.5%*	*50%*	*97.5%*	*Rhat*
κ	-1.969	0.087	-2.140	-1.970	-1.801	1.001
α_0	-0.632	0.190	-1.008	-0.632	-0.261	1.000
α_1	0.426	0.053	0.323	0.426	0.532	1.002
α_2	0.669	0.070	0.534	0.668	0.809	1.002
α_3	-0.392	0.126	-0.647	-0.389	-0.146	1.000
α_4	-0.722	0.107	-0.932	-0.722	-0.512	1.001
α_5	-0.042	0.027	-0.096	-0.041	0.009	1.001
α_6	0.057	0.024	0.009	0.058	0.101	1.000

Table 3. Parameter estimates from model step 4. The fixed effect parameters affecting signal detection probability (β_j for J = 1:6) correspond to predictor variables *dstoc*, *grad*, *wlyr*, *sbwl*, *pcex*, and *exsd*

Parameter	*mean*	*sd*	*2.5%*	*50%*	*97.5%*	*Rhat*
ξ	-0.341	0.476	-1.302	-0.337	0.524	1.005
σ_r	0.897	0.337	0.461	0.829	1.723	1.001
σ_s	1.169	0.044	1.087	1.169	1.256	1
ι	0.089	0.006	0.079	0.089	0.1	1
β_1	0.643	0.132	0.389	0.641	0.904	1.006
β_2	-0.096	0.094	-0.276	-0.094	0.09	1.009
β_3	0.179	0.06	0.06	0.179	0.296	1.01
β_4	-0.396	0.141	-0.675	-0.395	-0.12	1.009
β_5	1.205	0.342	0.533	1.207	1.878	1.013
β_6	-0.125	0.083	-0.288	-0.124	0.037	1.01

Figures

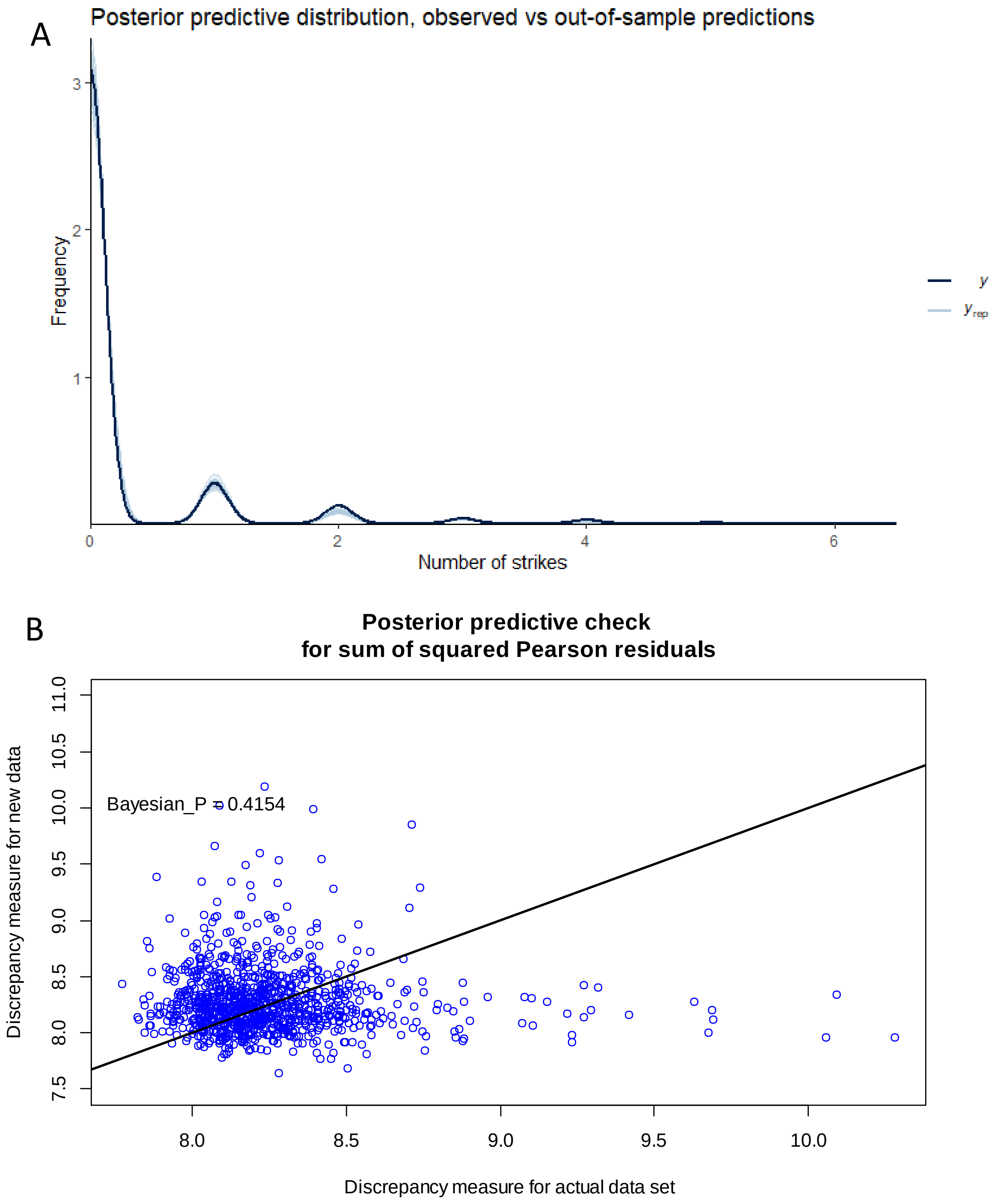


Figure 3. Posterior predictive plots for Bayesian model of temporal variation in strike rate. A) frequency distribution of observed number of strikes per sample (y = black line) and out-of-sample predictions (y_{rep} = grey lines), with the degree of concordance between distributions indicating goodness of fit ; and B) scatter plot of a discrepancy measure (squared Pearson residuals) for observed data vs "new data" (out-of-sample predictions) generated by model: clustering of values around a 1:1 relationship (solid black line) indicates a well-fit model, as quantified by a Bayesian-P value near 0.5.

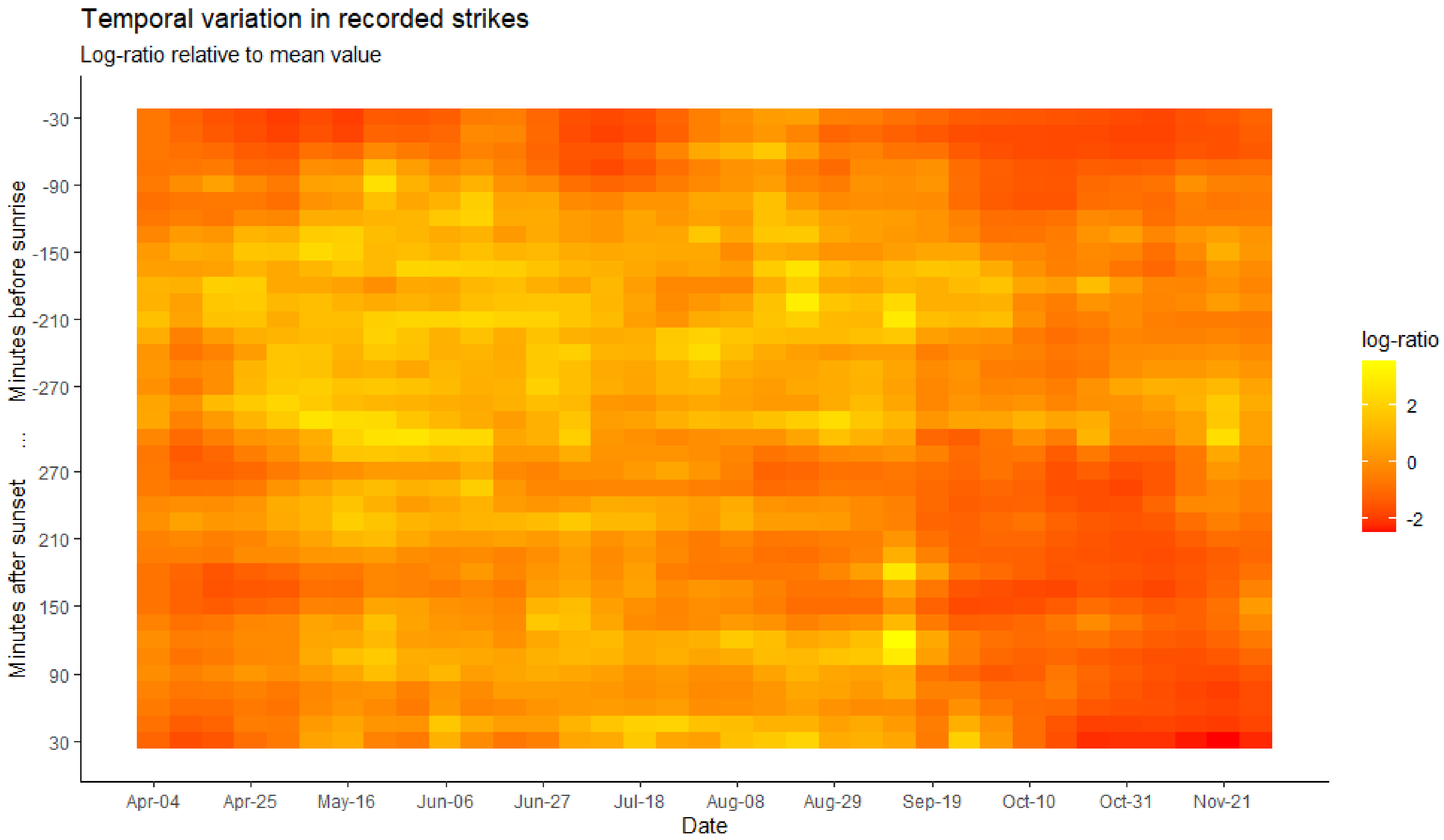


Figure 4. Heatmap plot of a temporal matrix (**T**) of the relative rate of bird strikes as a function of date of the season (x-axis) and time of night (y-axis). Colors show variaiton in the log-ratio relative to the overall mean, such that a value of 0 corresponds to the mean.

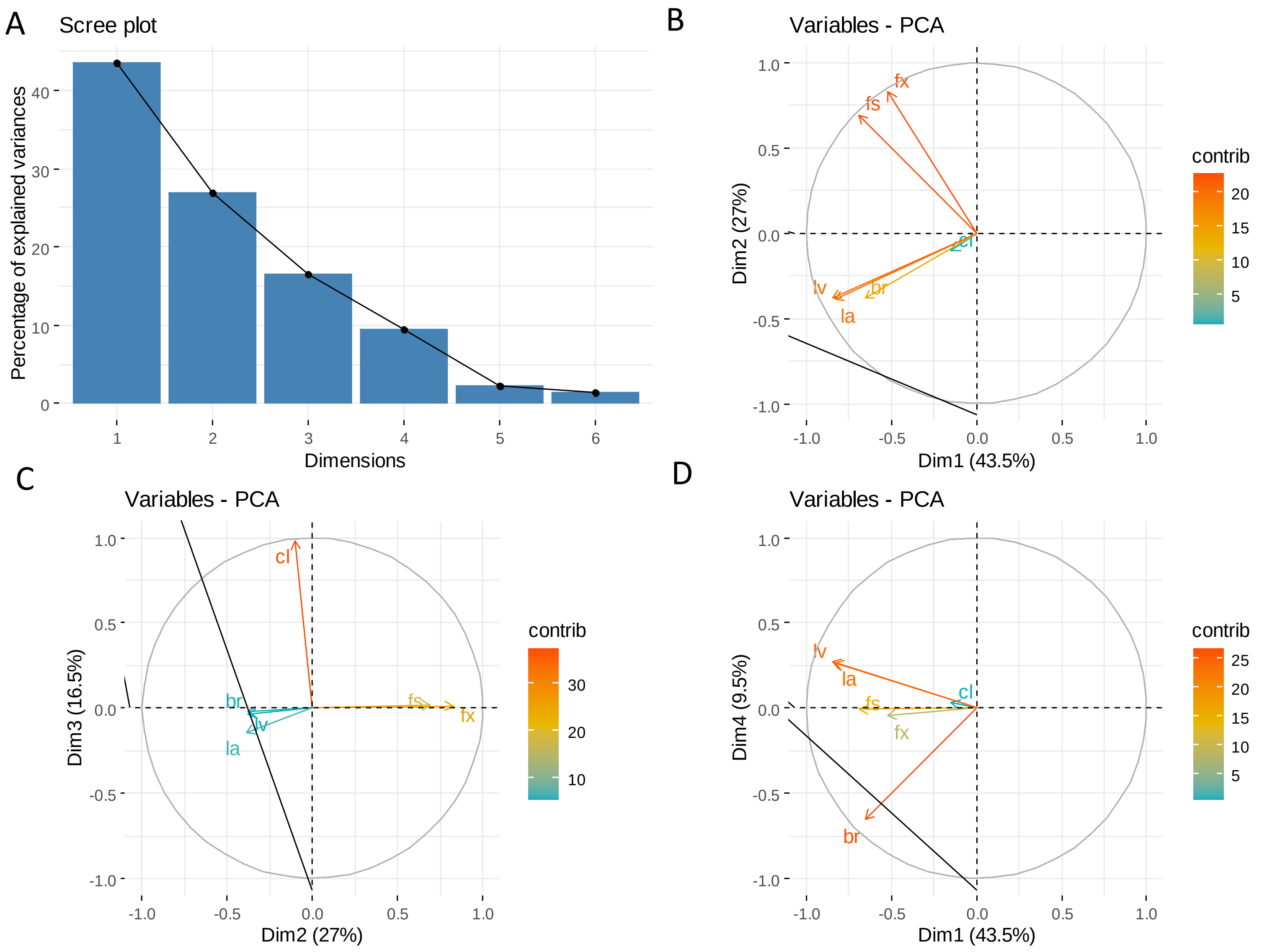


Figure 5. Graphical results from a principal components analysis (PCA) of 6 signal quality metrics: flux (fx), flux sensitive (fs), level (lv), level absolute (la), burst (br) and click (cl) . A) Scree plot showing the reletive amount of variation in the original 6 variables explained by each of the PCA factors (ordered). B) radial loadings plot showing the relationship betweeen the original variables (loadings vectors) and PCA factors 1 (x-axis) and 2 (y-axis); C) radial loadings plot showing the relationship betweeen the original variables and PCA factors 2 (x-axis) and 3 (y-axis); D) radial loadings plot showing the relationship betweeen the original variables and PCA factors 1 (x-axis) and 4 (y-axis). In plots B-D, the color of loadings vectors indicates their relative contribution to the PCA factors in the respective ordination.

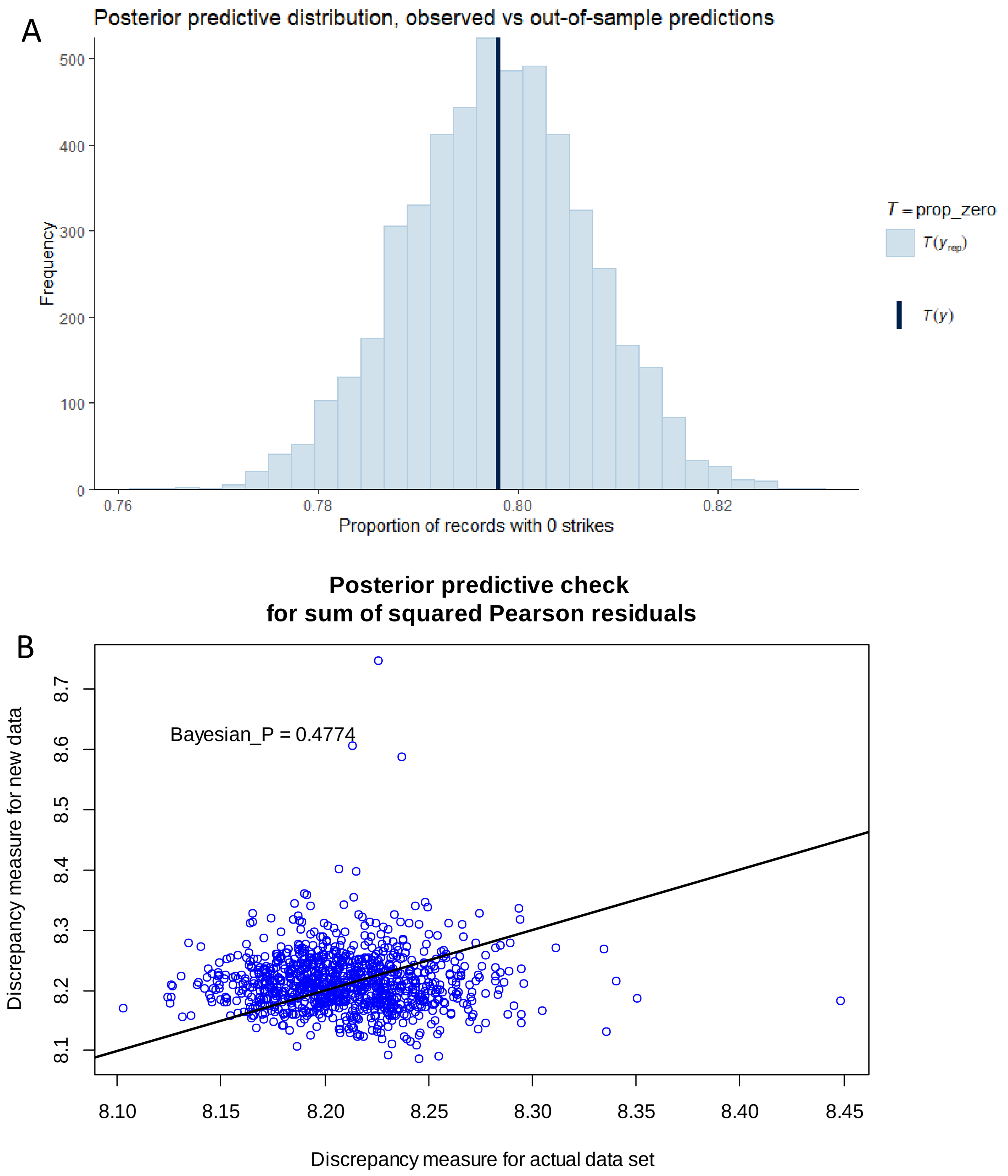


Figure 6. Posterior predictive plots for Bayesian model of signal quality effects on strike detection probability. A) frequency distribution of the proportion of out-of-sample model predictions where 0 strikes were detected (grey bars) as compared to the actual proportion of 0-detections in the observed data set (y = black line); and B) scatter plot of a discrepancy measure (squared Pearson residuals) for observed data vs "new data" (out-of-sample predictions) generated by the model: clustering of values around a 1:1 relationship (solid black line) indicates a well-fit model, as quantified by a Bayesian-P value near 0.5.

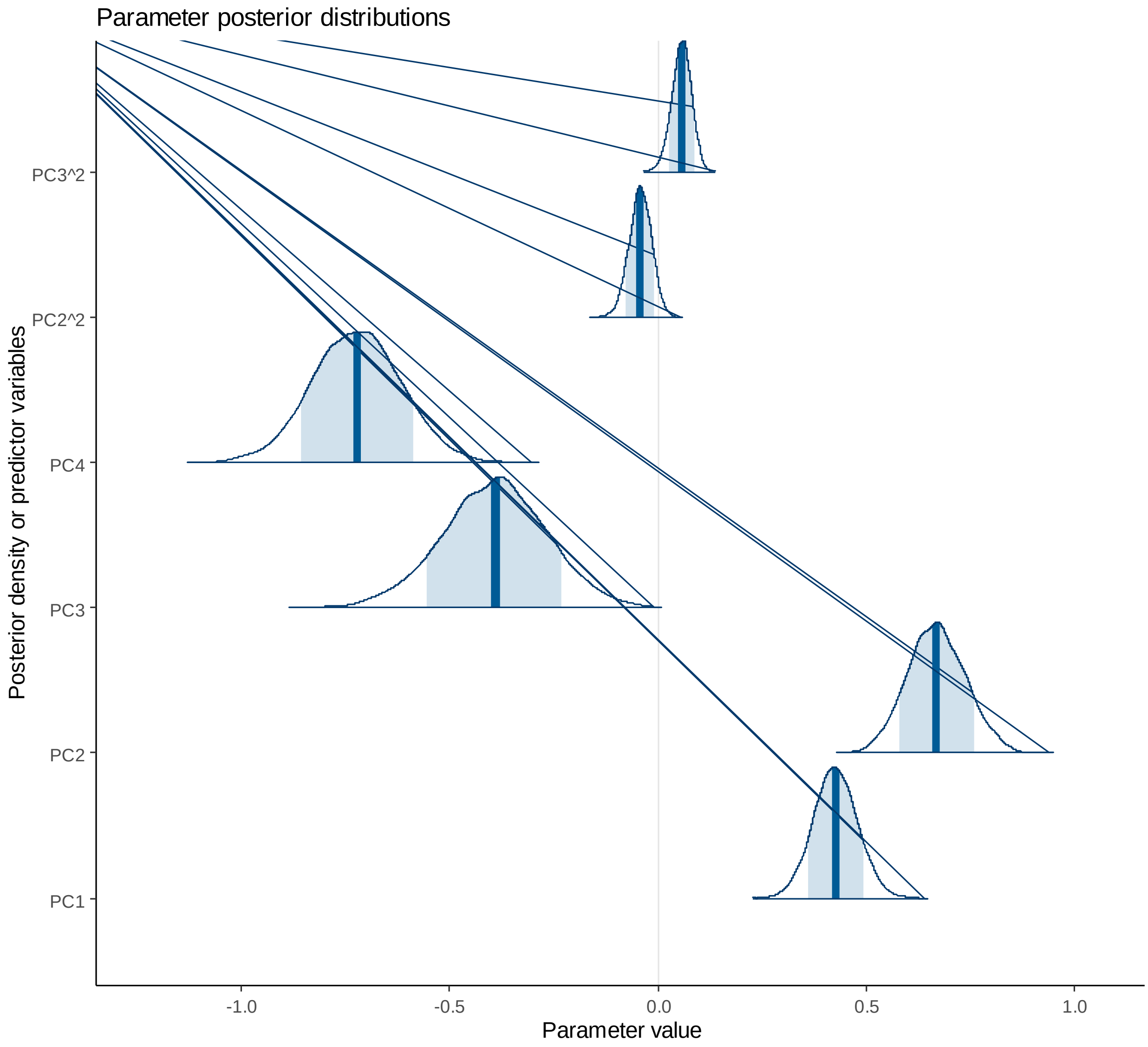


Figure 7. Posterior distribution plots for the parameters in a model predicting strike detection probability as a funciton of signal quality metrics. A PCA was used to collapse variaiton of raw signal quality metrics into 4 orthogonal PCA factors, and the parameters of the model correspond to linear and/or quadratic effects of these factors. Shaded area of each density distribution indicates the 90% CI, and the solid vertical line indicates the mean parameter estimate.

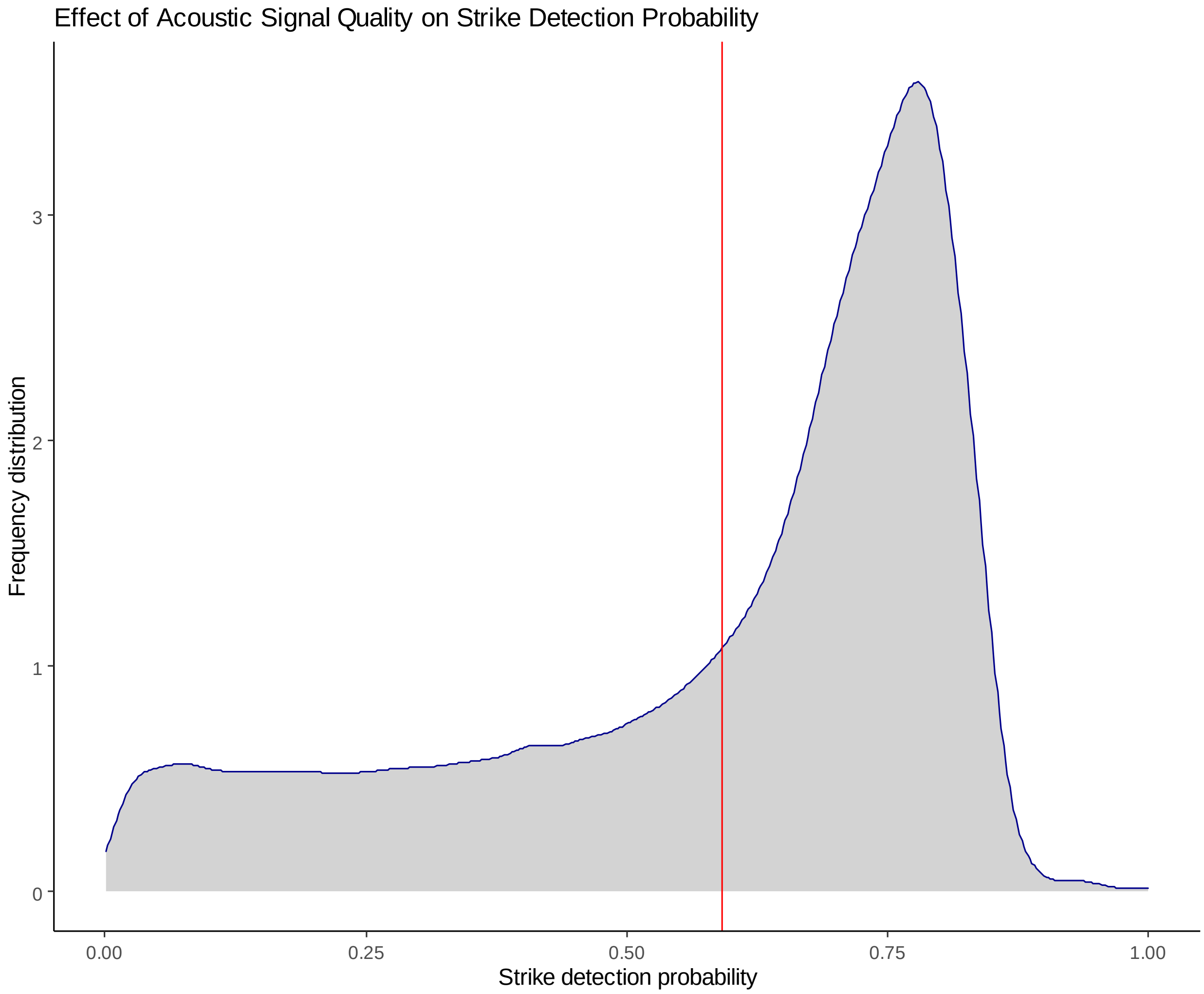
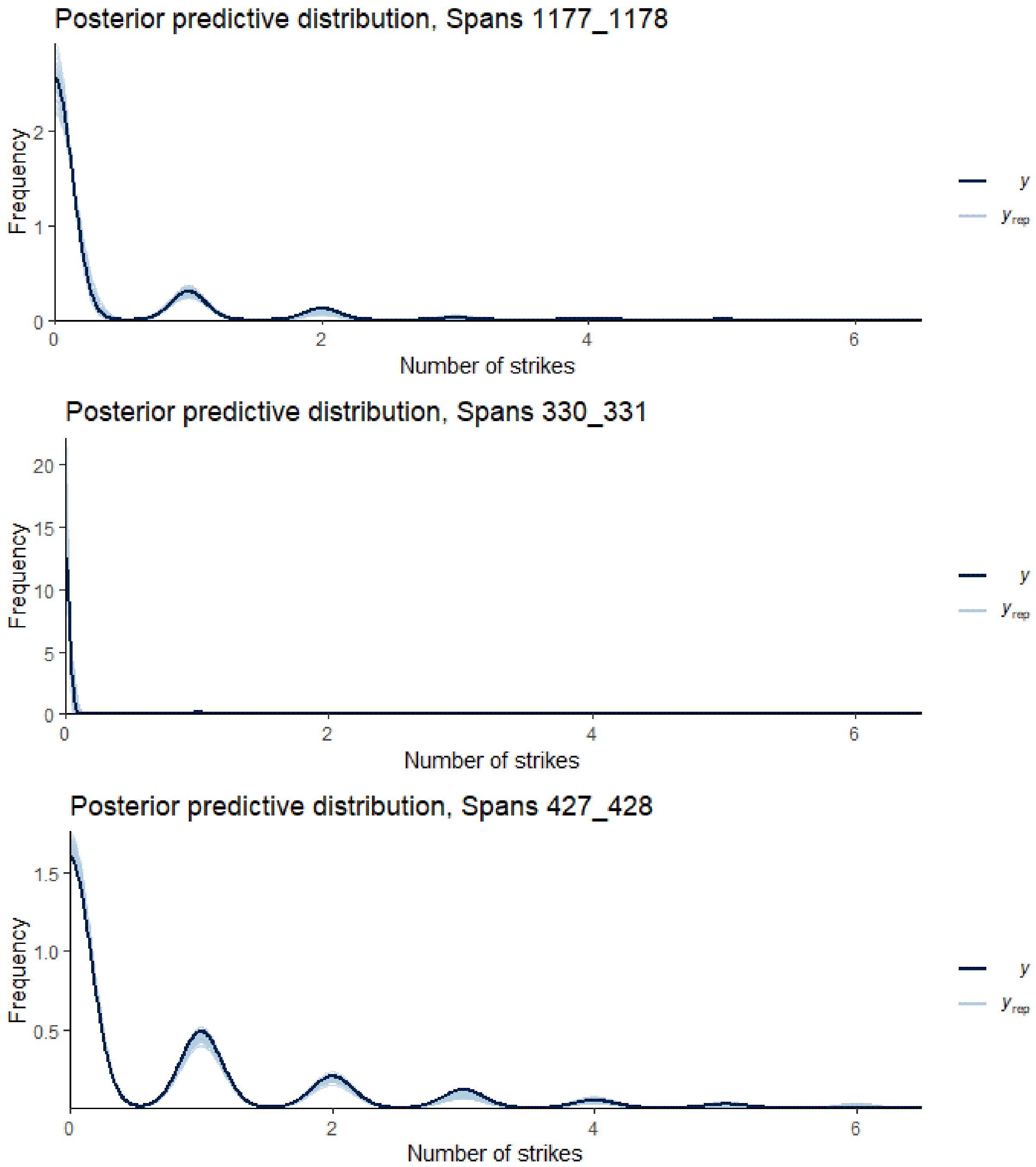


Figure 8. Density-distribution of the estimated strike detection probability for all acoustic records included in the analyses (N=902,520).



Posterior predictive distribution, Spans 1177_1178

Posterior predictive distribution, Spans 330_331

Posterior predictive distribution, Spans 427_428

Figure 9. Posterior predictive plots for Bayesian model of site-specific annual strike rates, with each panel representing the results from an analysis of one site (2 spans) selected haphazardly. Plots show the frequency distribution of observed number of strikes per sample (y = black line) and out-of-sample predictions (y_{rep} = grey lines), with the degree of concordance between distributions indicating goodness of fit.

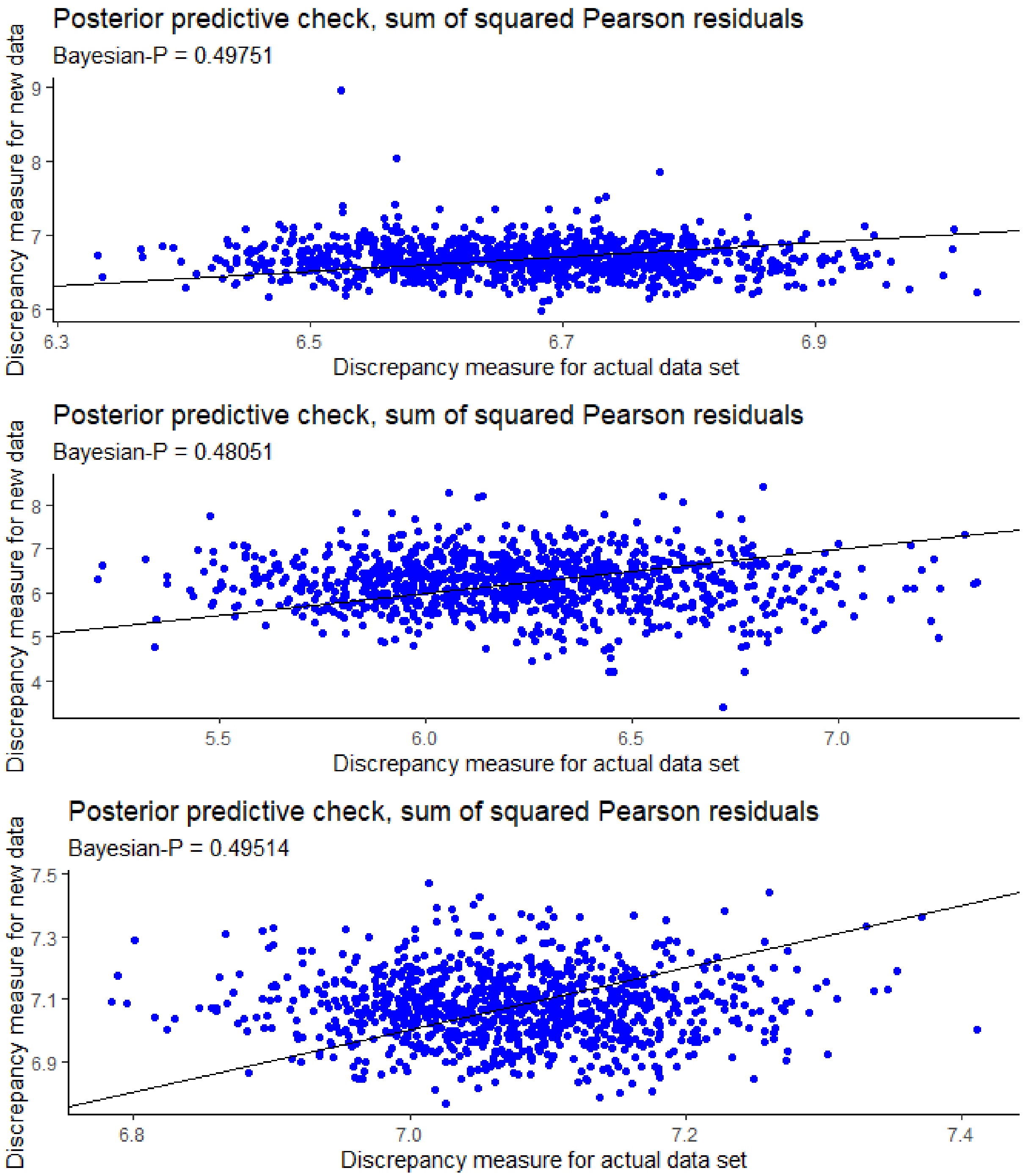


Figure 10. Posterior predictive plots for Bayesian model of site-specific annual strike rates, with each panel representing the results from an analysis of one site (2 spans) selected haphazardly. Scatter plots represent an ordination of a discrepancy measure (squared Pearson residuals) for observed data vs "new data" (out-of-sample predictions) generated by model: clustering of values around a 1:1 relationship (solid black line) indicates a well-fit model, as quantified by a Bayesian-P value near 0.5.

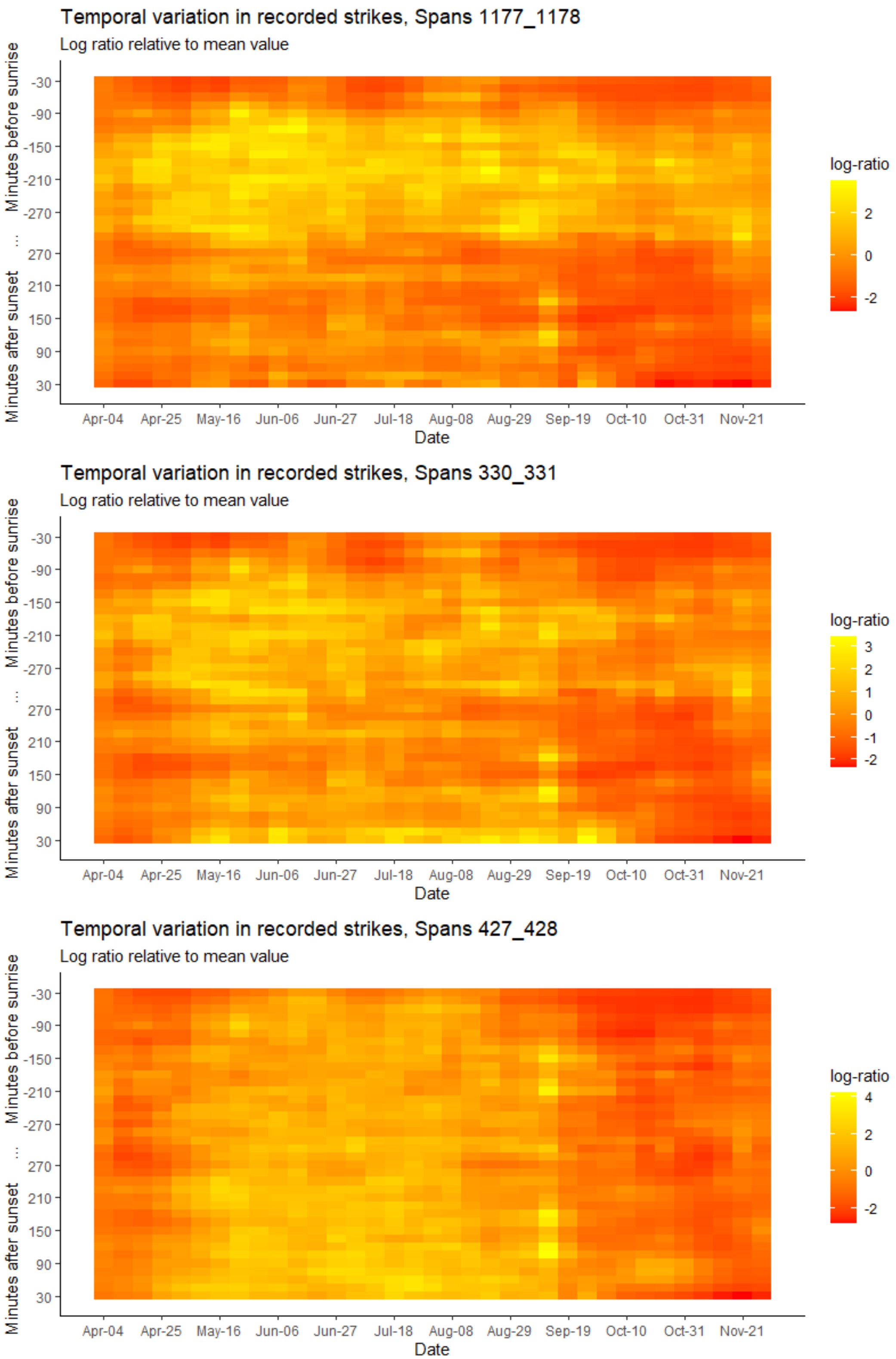


Figure 11. *Representative heatmap plots for 3 arbitrarily selected sites, showing variability among sites in the temporal matrix (***T***) of relative rate of bird strikes as a function of date of the season (x-axis) and time of night (y-axis). Colors show variaiton in the log-ratio relative to the overall mean, such that a value of 0 corresponds to the mean.*

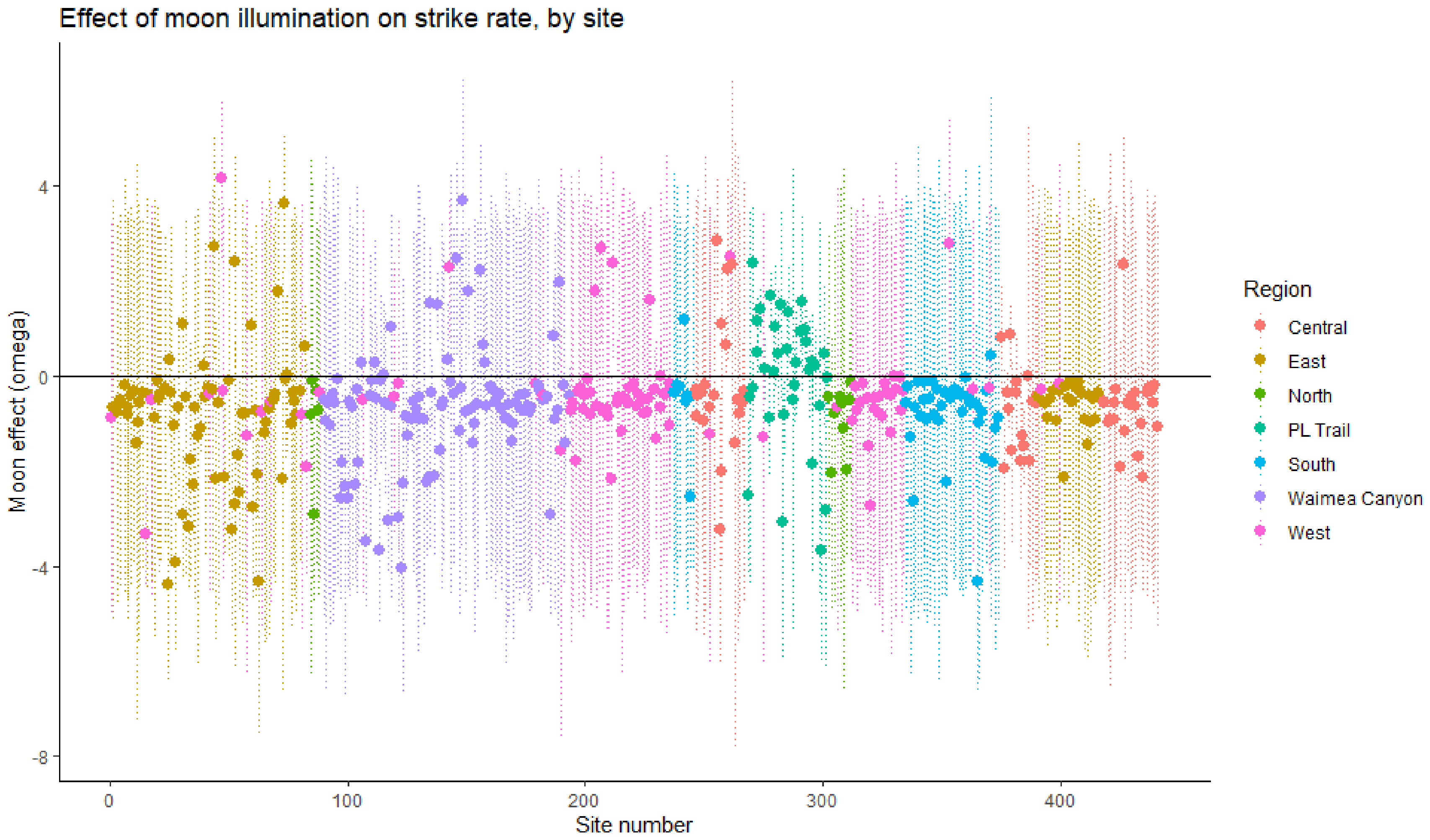


Figure 12. Plot of the estimated values of parameter ω, the effect of moon illumination of strike rate, for each of the 441 sites analyzed, color-coded by region. Points represent the mean estimate of ω for each site (values <0 correspond to a negative relationship between moon illumination and strike rate) and dotted error bar lines show parameter uncertainty (± 1 standard deviation of posterior samples).

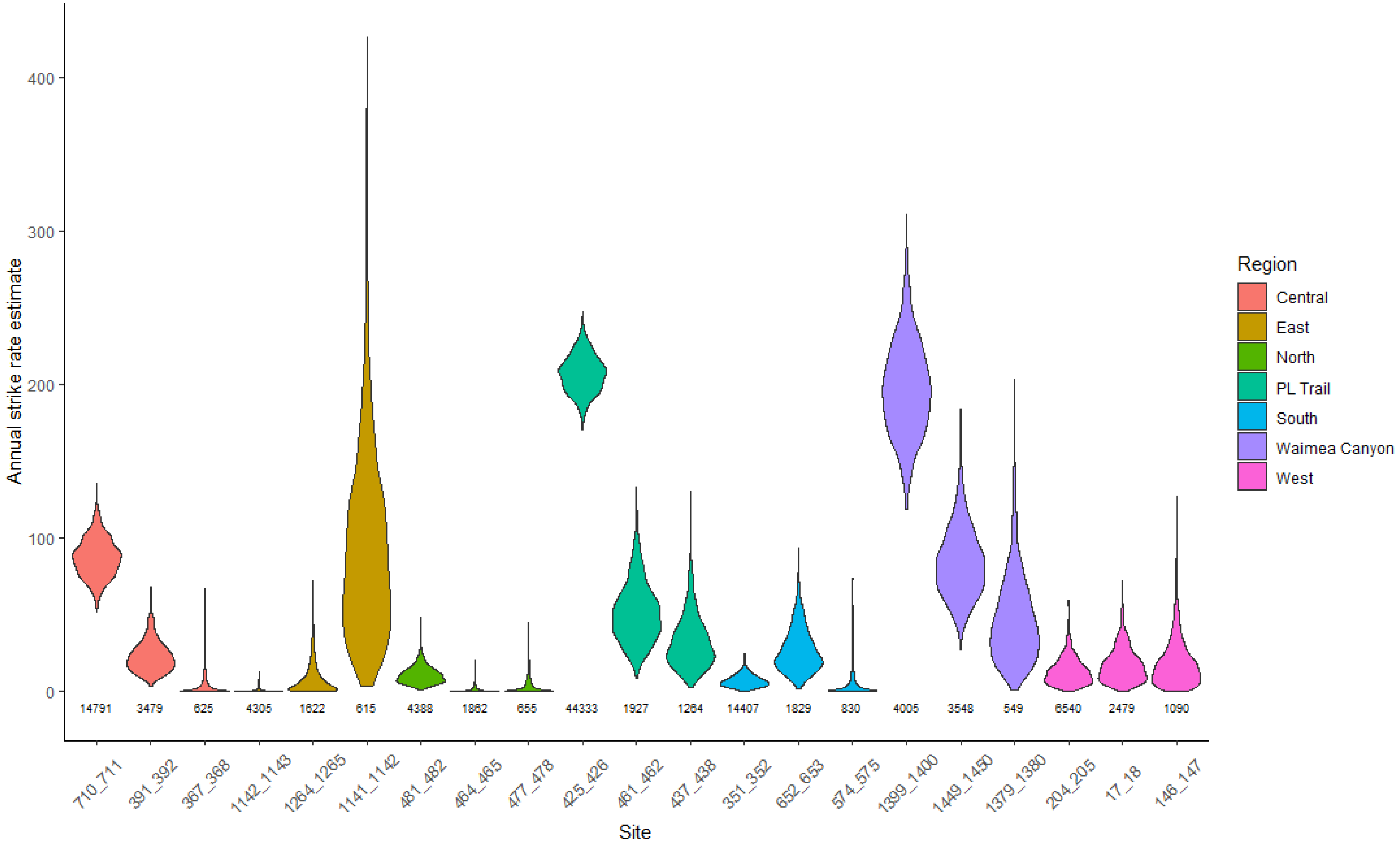


Figure 13. Violin plot of the posterior distributions of estimated annual strike rates for 21 randomly selected sites (3 from each of 7 regions). Site labels show the ID numbers of the two spans at each site, and the numbers below each violin are the sample sizes (number of 15-minute acoustic records) for each site.

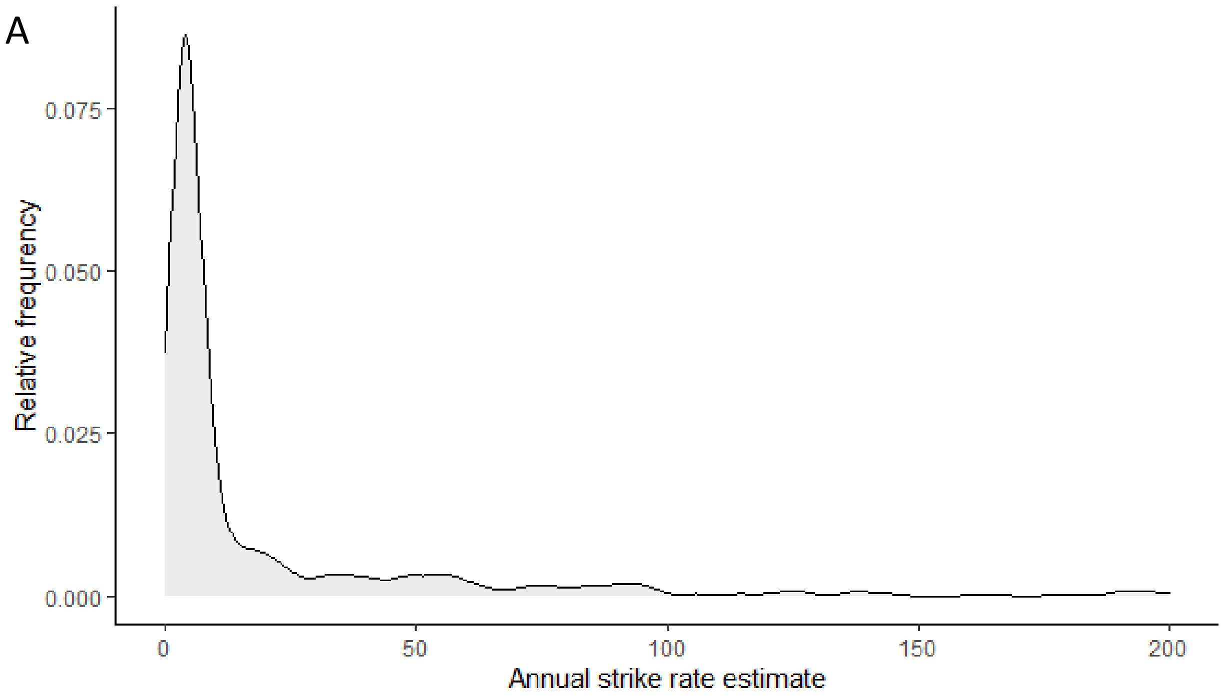


Figure 14. Results from site-specific analyses of annual strike rate. Density distribution of annual strike rate estimates across all 441 sampled sites.

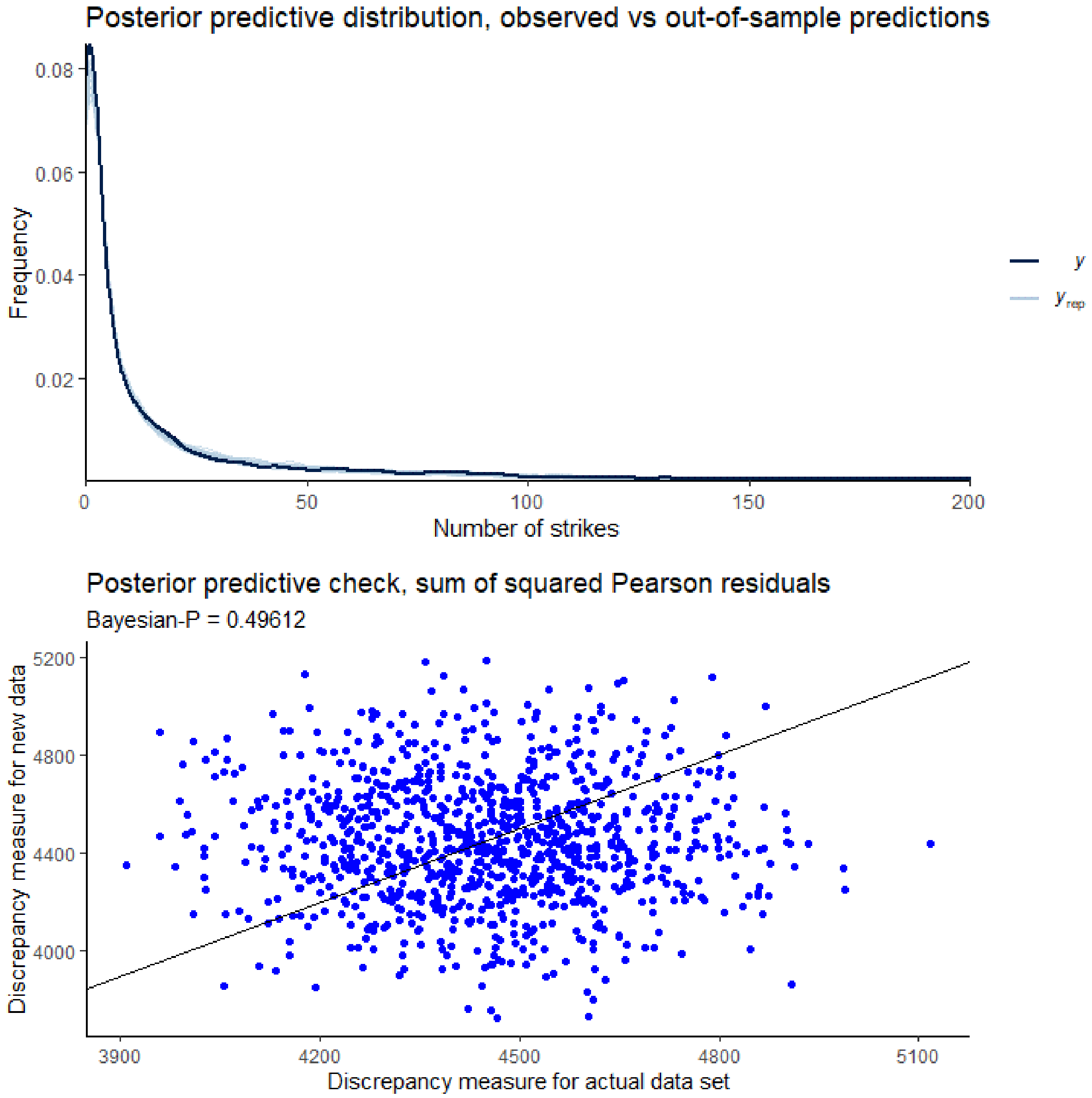


Figure 15. Posterior predictive plots for Bayesian model of the factors explaining variation in annual strike rate. A) frequency distribution of observed number of strikes per sample (y = black line) and out-of-sample predictions (y_{rep} = grey lines), with the degree of concordance between distributions indicating goodness of fit ; and B) scatter plot of a discrepancy measure (squared Pearson residuals) for observed data vs “new data” (out-of-sample predictions) generated by model: clustering of values around a 1:1 relationship (solid black line) indicates a well-fit model, as quantified by a Bayesian-P value near 0.5.

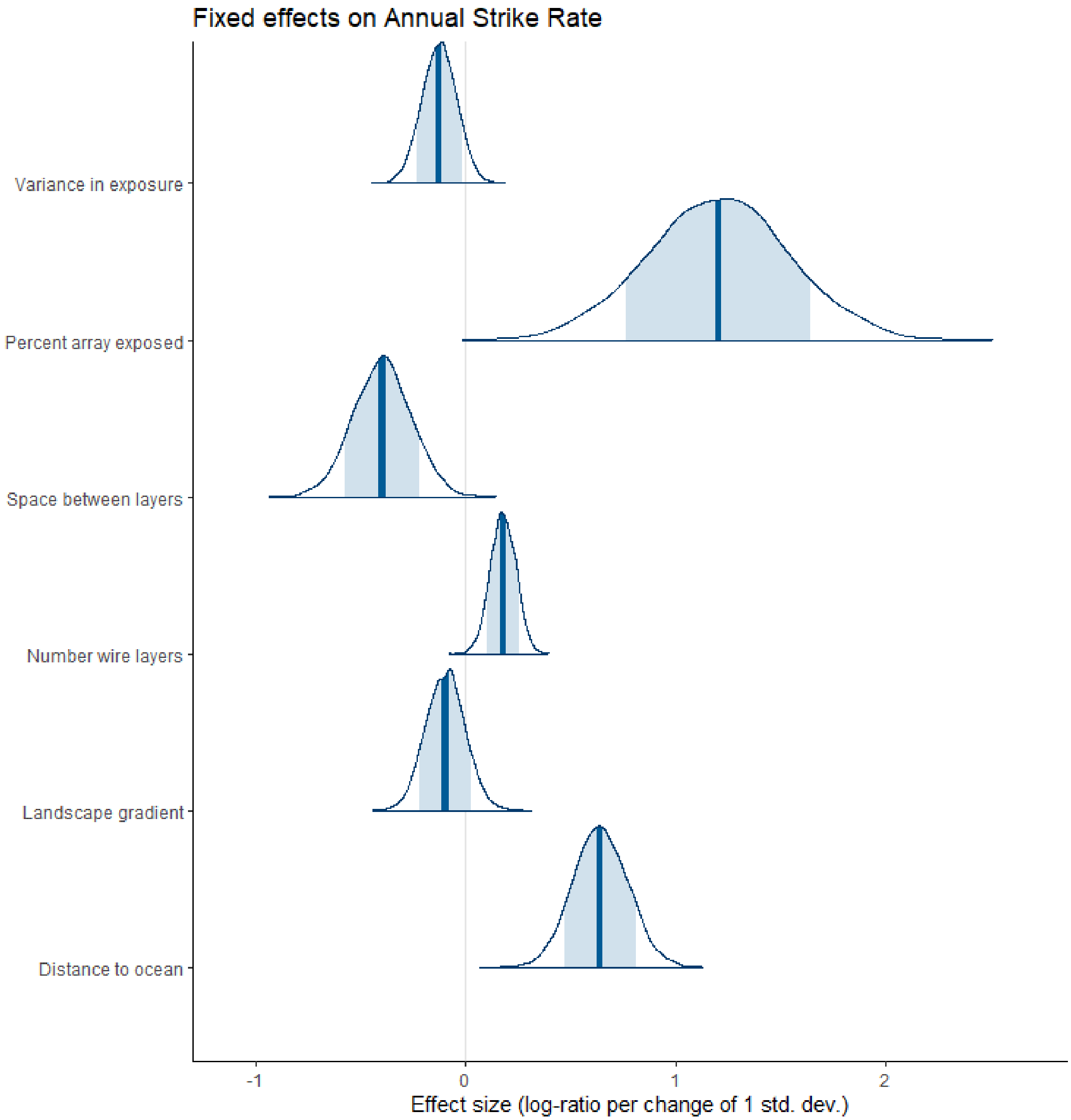


Figure 16. Posterior distributions for fixed-effect parameter estimates (β) from a Bayesian model examining the predictors of annual strike rate. The shaded area of each density distribution indicates the 90% CI, and the solid vertical line indicates the mean parameter estimate. An effect value of 0 indicates no effect of the predictor variable on annual strike rate, while values >0 indicate a positive relationship between the variable and strike rate.

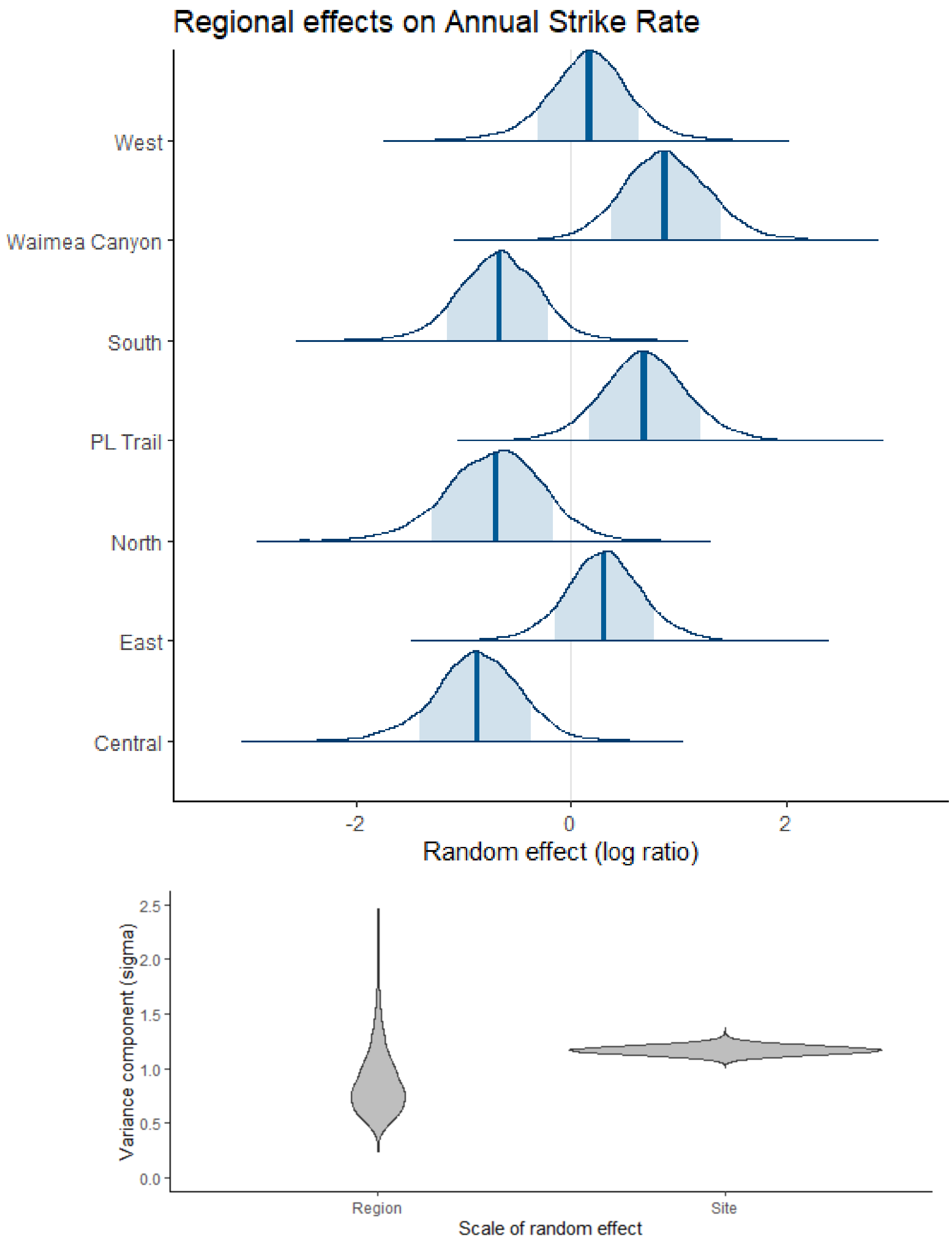


Figure 17. A) Posterior distributions of regional effects from a Bayesian model examining the predictors of annual strike rate. The shaded area of each density distribution indicates the 90% CI, and the solid vertical line indicates the mean parameter estimate. The vertical line (0) represents the average across all regions, while values >0 indicate a higher-than-average strike rate values for the indicated region. B) Violin plots showing the posterior distribution of estimated variance components (σ parameters) associated with unexplained differences among regions and unexplained differences among sites within regions.

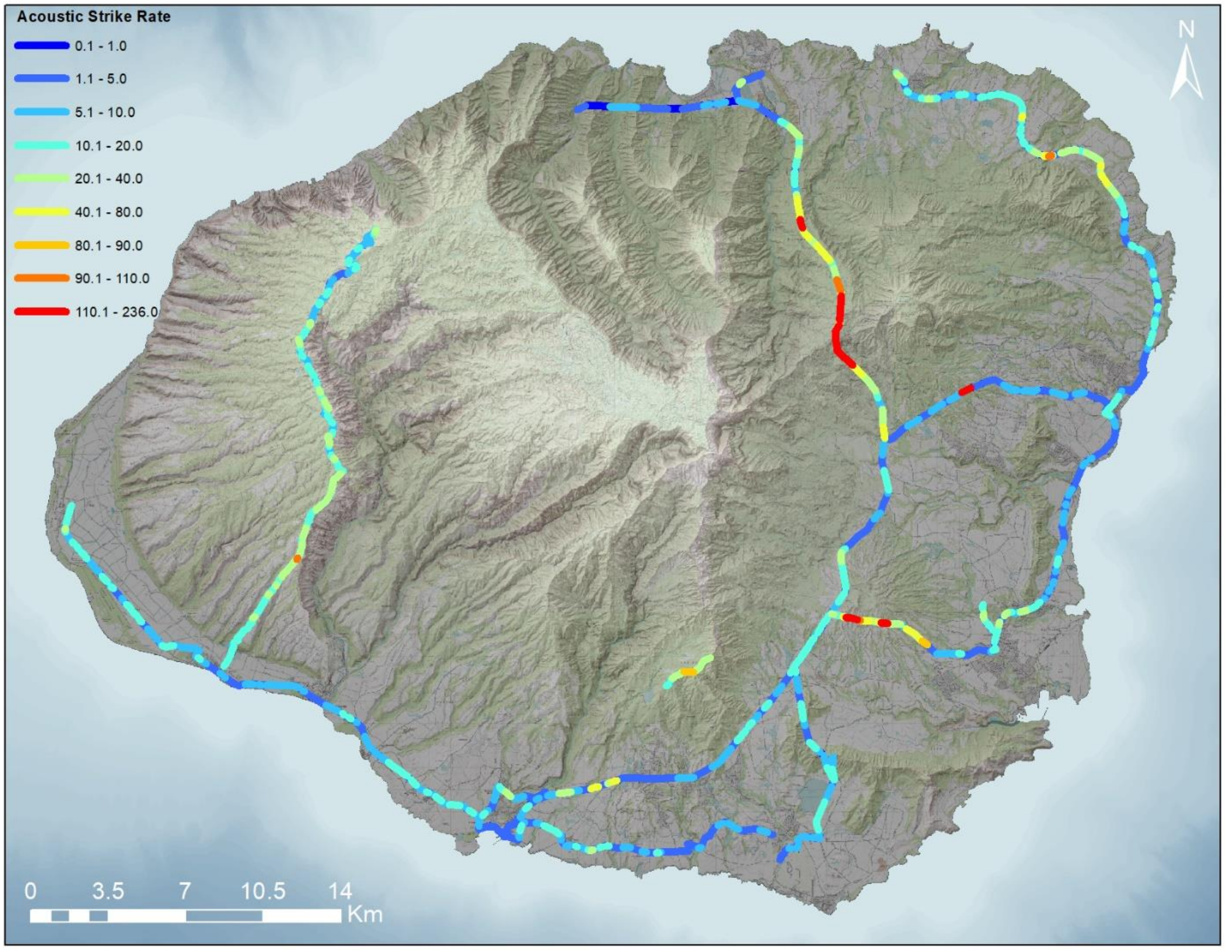


Figure 18. Map of Kauai showing the locations of all wire spans, color-coded to indicate the estimated annual number of bird strikes for each span.

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Appendix 5E

Population Dynamics Model for Newell’s Shearwater (‘a‘o) on Kaua‘i

The purpose of this appendix is to describe the population dynamics models developed by KIUC for Newell's shearwater (ʻaʻo). The population dynamics model for Hawaiian petrel (ʻuaʻu) is presented in Appendix 5F, *Population Dynamics Model for Hawaiian Petrel (ʻuaʻu) on Kauaʻi*.

A population dynamics model was not developed for band-rumped storm-petrel (ʻakēʻakē) because of the lack of data on this species.

The population dynamics models for Newell's shearwater (ʻaʻo) was developed for the following specific uses in the HCP:

1. To evaluate the effects of the requested take authorization of the species from KIUC's covered activities (described in Chapter 5, *Effects*) in the absence of any mitigation.
2. To quantify the benefits of the conservation measures proposed in Chapter 4, *Conservation Strategy*, to the Kauaʻi metapopulations of these species.
3. To determine the net effects of the HCP covered activities and conservation measures on the Kauaʻi metapopulation of this species and to quantify the net benefit provided by the HCP.
4. To track population trends during HCP implementation over the 50-year permit term.

This appendix is divided into four sections: (1) Overview of the model, including methods, initial conditions, technical specifications, and tables with model input values, (2) Model results, (3) A discussion of model limitations, uncertainties, and assumptions, and (4) References cited.

The appendix and population dynamics models were developed by John R. Brandon, PhD, Senior Biometrician at ICF with extensive review by David Zippin, PhD, Senior Conservation Biologist. Dr. Brandon designed the mathematics and code for the modeling framework. Model inputs were developed in close collaboration with André F. Raine, PhD, Science Director for Archipelago Research and Conservation (ARC) and Marc Travers, MS, Senior Scientist at ARC, both of whom are experts on seabird biology and lead scientists on multiple studies of endangered seabirds on Kauaʻi. Dr. Raine and Mr. Travers provided input and data for many of the model parameters as cited throughout the appendix.

5E.1 Overview of the Population Dynamics Models

The model for Newell's shearwater (ʻaʻo) is composed of 14 distinct subpopulations.[1] Each subpopulation corresponds to one of the 10 conservation sites proposed in the HCP, including four social attraction sites that are located within the HCP conservation sites at Honopū, Pōhākea, Upper Limahuli Preserve, and Site 10.[2] The 14 subpopulations are listed in Table 5E-1 and their locations illustrated in Figure 5E-1 (see Chapter 4, *Conservation Strategy*, and Appendix 4A, *Conservation Site Selection*, for a map and details of the 10 conservation sites).

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[1] The term *subpopulation* is used here to distinguish between groups of individuals associated with breeding colonies located in different geographic areas of the island. Together, these subpopulations make up the Kauaʻi metapopulation.

[2] KIUC will select a tenth conservation site ("Site 10") but the final location of this site is still under evaluation. See Figure 4-6 for the general location of the site. The conservation benefits of Site 10 are based on the previously selected site that proved infeasible (Upper Mānoa Valley). KIUC will ensure that Site 10 will provide equal or greater benefits than the Upper Mānoa Valley site it is replacing.

Outside of the 10 conservation sites, the rest of Kauaʻi was subdivided into four regions that correspond to the known metapopulation distribution of the species (see Figure 1 in Appendix 3A, *Species Accounts*). Each area in the model encompasses a geographic portion of the island which has similar conservation threats and management efforts for the species, as well as similar available data sources for estimating the abundance and trend of breeding pairs which nest there (Table 5E-2).

The modeling framework allows each subpopulation to have its own set of vital rate values and therefore different trends in abundance through time. This reflects the fact that pressures such as powerline collisions and predation vary depending on region and topography. For example, the remote areas in the northwestern region of the island do not have powerlines (see Figure 5E-1). Available tagging data is consistent with the flyways of breeding colonies in those areas resulting in little to no vulnerability to powerline collisions (e.g., Raine et al. 2017a). For breeding colonies in northwestern Kauaʻi (including the conservation sites), where powerline collision vulnerability is low and predator control efforts have been effective, acoustic monitoring data has demonstrated increases in abundance since 2014–2015 (Raine et al. 2022a). The opposite is true in other areas of the island where breeding colonies are particularly vulnerable to powerline collisions and light attraction. Examples include those sites that have flyways crossing the Powerline Trail in the middle of the island, where collisions are known to be highest (Travers et al. 2020; also see Chapter 5, Figure 5-1 estimated relative rates of bird strikes per wire span).

Furthermore, available monitoring data also differs by each area. For example, radar survey data, which is the longest running systematic monitoring study for trends in relative abundance for this species, are only available from areas with road access (the radar system is mounted on a vehicle).

The spatially explicit model developed here serves to account for these differences and complexities in the overall metapopulation dynamics and allows for monitoring data (e.g., trends) from different areas to be incorporated in the model. The vital rates for each subpopulation are also modeled to change through time as future management efforts are implemented, corresponding to the timeline of these measures described in Chapter 4, *Conservation Strategy*. For example, increases in estimated powerline strike minimization efficacy are modeled through time to reduce powerline strike mortality rates. Similarly, the timing of installation of predator exclusion fencing around particular management sites are modeled to reduce predation mortality rates for the corresponding subpopulations at those sites in future years.

Island-based estimates of abundance for each subpopulation are used to initialize population trajectories, which are then projected forward in time through the 50-year permit term. For simplicity, the model does not assume any dispersal among the Kauaʻi subpopulations, except for immigration into the four social attraction sites (see Section 1.3, *Social Attraction Site Dynamics and Dispersal*, for details), which is reasonable because shearwaters and petrels exhibit strong natal philopatry[3] (e.g., Harris 1966; Perrins et al. 1973; Warham 1980) and established breeding pairs typically return to the same nesting burrow year after year. The model also does not assume any dispersal between Kauaʻi and other islands in Hawaiʻi.

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[3] *Natal philopatry* is the tendency of an animal to return to breed in the place of its birth.

Table 5E-1. Modeled Subpopulations, HCP Status, and Associated HCP Management Actions.

Modeled Subpopulation	HCP Status	HCP Management Actions (see Chapter 4 for details)
Pihea[a]	Conservation site	Predator control[b] and partial pig fence
North Bog[a]	Conservation site	Predator control and partial pig fence
Pōhākea[a]	Conservation site	Predator control and partial pig fence (site excludes Pōhākea PF)
Pōhākea PF[c]	Conservation site with social attraction	Predator control, predator exclusion fence completed in 2022, encircling this subarea of the Pōhākea conservation site; social attraction
Hanakāpiʻai	Conservation site	Predator control
Hanakoa	Conservation site	Predator control
Upper Limahuli Preserve[a]	Conservation site	Predator control and ungulate exclusion fencing, predator exclusion fence to be completed for a portion of the site in 2025; social attraction introduced in the same year
Conservation Site 10	Conservation site	Predator control, predator exclusion fence to be completed for a portion of the site in 2025; social attraction introduced in the same year
Honopū[a]	Conservation site	Predator control and ungulate fencing (site excludes Honopū PF)
Honopū PF	Conservation site with social attraction	Predator control, predator exclusion fenced completed in 2022, encircling this subarea of the Honopū conservation site, social attraction
Hanalei to Kekaha	N/A	None
Wainiha and Lumahaʻi Valleys	N/A	None
Kalalau east to Upper Mānoa (excluding conservation sites)	N/A	None
Nā Pali Coast	N/A	None
Waimea Canyon	N/A	None

[a] Ungulate (deer, pig and goat) exclusion or partial pig exclusion fence is already in place. Partial pig exclusion fences block pigs from accessible portions of a site's perimeter.

[b] Predator control involves species specific efforts for ungulates, cats, rodents and barn owls.

[c] PF stands for predator exclusion fence. Construction of the predator exclusion fence at Honopū was completed in 2022.

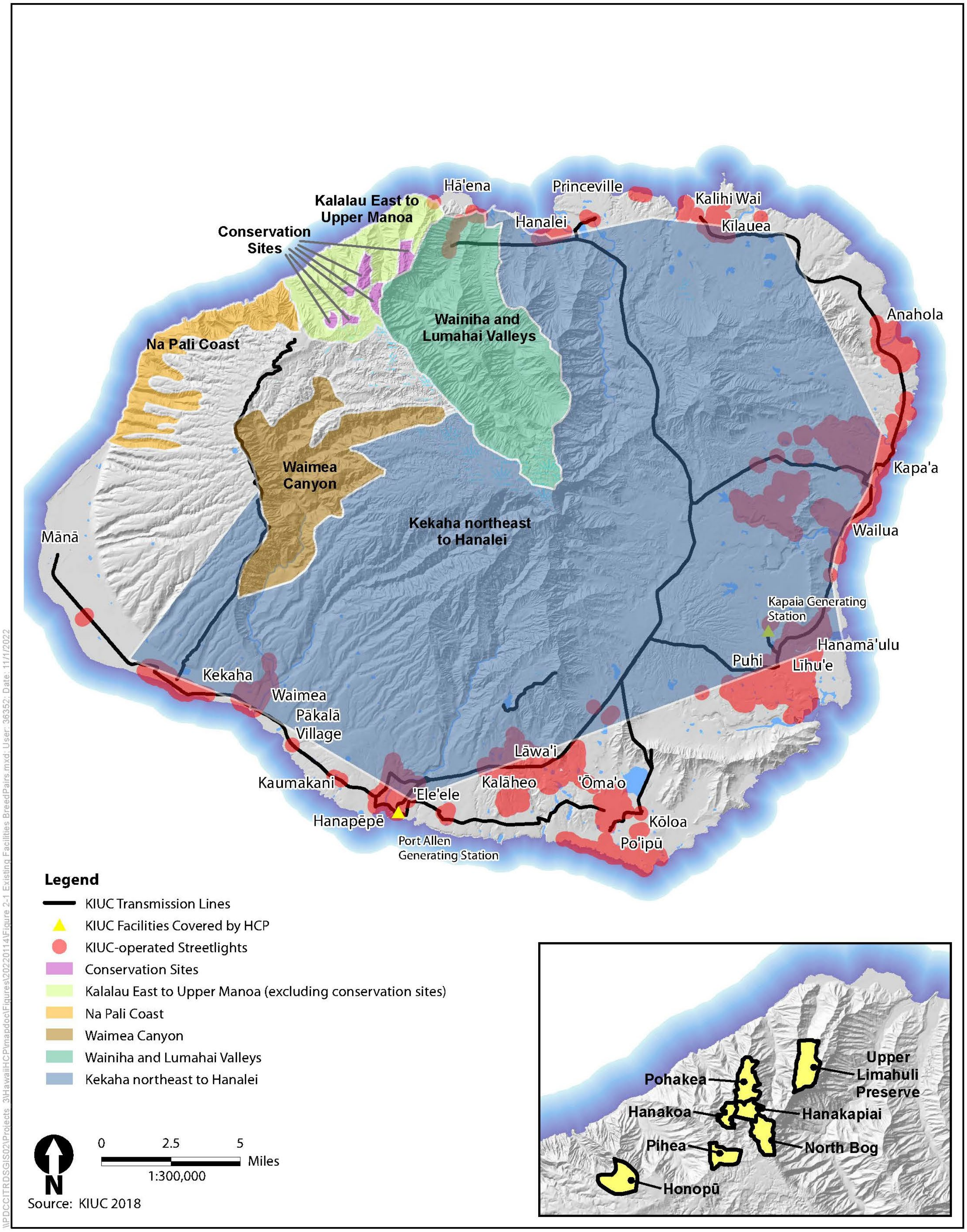

Figure 5E-1. Locations of Regional Subpopulations in Population Dynamics Models for Newell's Shearwater (ʻaʻo) and Location of KIUC's Covered Facilities

5E.1.1 Initial Conditions

The initial conditions for the model were set in 2019, before projections forward in time from that year were carried out. Modeled reductions in powerline line mortality rates due to minimization efforts that are accounted for in the model start in 2020. Population trajectories for Newell's shearwater (ʻaʻo) were based on the following parameter categories, each of which is described below:

1. Estimates of **abundance** on Kauaʻi.
2. **Vital rates** by age class under optimal conditions (i.e., natural mortality and fertility rates in the absence of introduced predators and powerlines).
3. Estimates of **powerline injury and mortality**, prior to 2020 minimization efforts.
4. Estimates of **predation rates** with and without predator control measures.

5E.1.1.1 Estimates of Abundance on Kauaʻi

All population dynamics models must begin with an estimate of initial population size to forecast future abundance levels. The only published estimates of abundance of Newell's shearwater (ʻaʻo) come from transect surveys conducted on ships at sea. Because of the use of these estimates in previous studies, these at-sea population estimates and their limitations are summarized in the following subsection. This summary is followed by an explanation of the methods used for this HCP to develop a spatially explicit population estimate of Newell's shearwater (ʻaʻo) on Kauaʻi.

At-Sea Abundance Estimates

Seabird populations are often estimated using counts of birds observed at sea and calculations of what proportion of the total population may have been sampled. This technique is used because (1) a substantial fraction of seabirds remains at sea prior to reaching breeding age, and (2) at-sea surveys can enumerate populations which may have breeding colonies spread over different islands or geographic locations, and which can otherwise be difficult to locate and count on land during the breeding season. This is the case for Newell's shearwater (ʻaʻo), where nesting adults are nocturnal, and nests are located underground in densely vegetated and rugged, remote montane environments.

Neither of the available at-sea estimates were adopted for the HCP population dynamics models because they include serious spatial deficiencies in geographical survey coverage, leading to uncorrected sources of statistical bias. Further, at-sea estimates alone, even if they could be corrected for these biases, provide only a single population estimate for the entire island of Kauaʻi. An important innovation of the HCP population dynamics model is that it considers important spatial differences in mortality risk in different areas of Kauaʻi, as discussed below. The at-sea abundance estimates are briefly described here for context, however, because they have been used in previous population modeling studies.

The modeling studies of Ainley et al. (2001) and Griesemer and Holmes (2011) incorporated the at-sea abundance estimate of Newell's shearwater (ʻaʻo) from Spear et al. (1995) to form the basis for estimating mortality rates from light fallout. These earlier modeling studies did not project trajectories of absolute abundance based on the at-sea survey estimates. Rather, the modeled trajectories were based on a hypothetical relative abundance level of 1,000 Newell's shearwater

(ʻaʻo) in the first year of the population trajectories (e.g., Ainley et al. 2001:120; Griesemer and Holmes 2011:30).

Spear et al. (1995) estimated a total population size of 84,000 Newell's shearwater (ʻaʻo) based on shipboard observations between 1984 and 1993. Subsequently, Joyce (2016) analyzed shipboard observations from more recent surveys during 1998–2011 and calculated an at-sea total abundance estimate of 27,011. Vorsino (2016) adopted the Joyce (2016) at-sea estimate of abundance to forecast model trajectories of absolute abundance for Newell's shearwater (ʻaʻo) on Kauaʻi. In all three modeling studies that incorporated available at-sea abundance estimates (Ainley et al. 2001; Griesemer and Holmes 2011; Vorsino 2016), 90 percent of the total population of Newell's shearwaters (ʻaʻo) was assumed to be from Kauaʻi.

The authors of the at-sea estimates of abundance explicitly acknowledge that the resulting estimates of abundance are not comprehensive because available survey data does not encompass the entire at-sea range of either species (e.g., Joyce 2016:183). As Griesemer and Holmes (2011:16) note, "Repeating at-sea surveys or determining another method of population estimation is critical to recovery planning." Available estimates from at-sea surveys have limitations for several reasons.

- The at-sea range of Newell's shearwater (ʻaʻo) is incredibly large, and dedicated survey coverage of their at-sea range has not been undertaken in any systematic way. For example, the available at-sea data analyzed by Joyce (2016) comes from surveys with spatial coverage designed to estimate the abundance and distribution of cetaceans (whales and dolphins), and which did not survey areas north of the United States Exclusive Economic Zone around Hawaiʻi (an area from the shoreline to 200 nautical miles [370.4 kilometers] outside the islands), where chick provisioning (breeding adult) Newell's shearwater (ʻaʻo) have been observed through tagging (Joyce 2016:230). Likewise, more recent tagging data for this species are also consistent with the available at-sea survey effort covering only a fraction of the at-sea range of this species (Raine et al. 2020; ARC unpublished tagging data). Therefore, the at-sea estimates of abundance represent a fraction of total abundance.
- In order to take into account the spatial complexities of different pressures and conservation benefits in different areas of Kauaʻi, the at-sea abundance estimates would need to be partioned such that a proportion of the at-sea estimates (which represent the total at-sea population) could be assigned to each area of the island. In other words, what proportion of the at-sea estimates of abundance represents those birds associated with the conservation sites? Such assumptions would have a high degree of uncertainty, so it is preferable to use available survey data from the conservation sites themselves. Survey data at the conservation sites provide a more current and defensible estimate of covered seabird abundance than older at-sea estimates.
- At-sea estimates are compiled from survey data collected during different times of year, which further complicates interpretation because the at-sea range of Newell's shearwater (ʻaʻo) changes according to life stage and season (see Joyce 2016:230, which shows tag locations of chick provisioning adults generally north of Kauaʻi during the summer nesting season, and Raine et al. 2020:45, which shows at-sea locations of fledglings south of Kauaʻi, including south of the equator, during the late fall and early winter).
- There are no available correction factors to scale the at-sea abundance estimates to total abundance on Kauaʻi, which is necessary to incorporate estimates of powerline strike numbers, and the effects of powerline strike minimization on total abundance for the HCP population dynamics model. This is important because using an abundance estimate that only represents a

fraction of total population size would lead to negatively biased results in terms of forecasting future abundance levels given estimated strike numbers or trends from radar data.

- For example, if the abundance estimate from Joyce (2016) is assumed to pertain to the year 2004 (the approximate mid-year of the corresponding 1998–2011 at-sea survey period), where the number of Newell's shearwater (ʻaʻo) on Kauaʻi represent 90 percent of the estimated at-sea abundance, and a -13 percent annual rate of population decline is assumed (e.g., from Raine et al. 2017b), the forecasted abundance would be 4,571 total Newell's shearwater (ʻaʻo) on Kauaʻi in the year 2016. Given the assumptions made here about the mortality level associated with estimated powerline collisions (e.g., the proportion of powerline collisions resulting in mortality is 28.8%; Travers et al. 2021), the annual average number of Newell's shearwater (ʻaʻo) mortalities resulting from powerline collisions during 2013 to 2019 was 3,196. Applying this level of mortality to the projected 2016 abundance level based on the uncorrected at-sea survey estimate would result in an approximate -70% annual decline, which is inconsistent with long-term monitoring data.
- If a -6.9 percent rate of decline were assumed instead, from an updated analysis of trends including more recent years of radar survey data (Raine and Rossiter 2020), the model forecasted total population size on Kauaʻi from this at-sea abundance estimate would be 7,744 Newell's shearwater (ʻaʻo) in the year 2020. In either case, recent population sizes this low are not consistent with concurrent observational data from multiple sources, including: (1) Estimates of breeding pairs in the conservation sites (Raine et al. 2022a); (2) Estimated collisions and resulting mortality levels (Travers et al. 2020, 2021); and (3) Trends in relative abundance from the radar surveys, which would be expected to exhibit much more drastic rates of decline if the at-sea abundance estimates were not biased low due to incomplete survey coverage of the species at-sea range, and instead represented an accurate measure of true abundance, rather than an estimate of minimum abundance.

For all of these reasons we chose not to utilize at-sea population estimates. Instead, the population estimates used to initialize the model are based on different Kauaʻi-specific data sets, as described below.

Breeding Pair Population Estimates on Kauaʻi

Given the serious limitations of the at-sea abundance estimates, which miss a significant (but as of yet unquantified) proportion of the island's breeding population—and breeding colonies in different areas of Kauaʻi are not uniformly vulnerable to threats such as introduced predators, light fallout, or powerline strike mortalities—staff at ARC developed spatially explicit estimates of Newell's shearwater (ʻaʻo) breeding pair abundance on Kauaʻi for this HCP.

These estimates were adopted as the basis for calculating the initial model population size in the HCP population dynamics model. They also allow for a modeling approach that can help to address the fundamental question of whether localized conservation efforts (e.g., predator control, predator-proof fencing, or social attraction sites) in targeted breeding areas on Kauaʻi can result in a sufficient net benefit to offset future minimized powerline strike mortalities for the island-wide population (metapopulation) on Kauaʻi.

Breeding pair abundance in 2021 was estimated for each of the modeled subpopulations (Table 5E-2, Figure 5E-1). The approach used to estimate the number of breeding pairs differed between areas, dictated in part by the extent to which various data sources are available (or lacking) for each area.

In general, however, the breeding pair estimates developed by ARC are informed by acoustic call rate and nesting burrow monitoring studies, which have demonstrated a significant relationship between call rates and estimated densities of active nesting burrows (e.g., Raine et al. 2019). These acoustic call rates are used in combination with published habitat suitability models (Troy et al. 2014, 2017). To the extent possible, the most recently analyzed study data from 2021 have been used to inform the resulting breeding pair estimates.

For the two modeled areas of Kauaʻi that have the highest level of collisions (Hanalei to Kekaha and Waimea Canyon), preliminary model results indicated that ARC's estimates of breeding pairs for these areas were, in combination with the biological assumptions in the model, incompatible with the observed trends from the radar survey and the level of mortality from the average annual unminimized strike estimate during 2013–2019. In other words, preliminary model results for these two areas, when based on ARC's breeding pair estimates and the low modeled maximum population growth rate (i.e., resiliency) produced modeled subpopulation trends from unminimized powerline strike mortality rates that were much more negative (i.e., much greater projected declines) than any trends estimated from the radar survey since that systematic survey began collecting data in 1993.

Therefore, an alternative approach was used to calculate the breeding pair abundance necessary to sustain the rate of decline observed in the radar data (Raine et al. 2017b; Raine and Rossiter 2020), given the estimated average annual number of unminimized powerline collisions during 2013–2019 for these two areas (Travers et al. 2020). This approach to initialize the breeding pair abundance in the model for the Hanalei to Kekaha and Waimea Canyon areas is described in more detail under the area-specific descriptions of breeding pair abundance estimation process and background considerations for each modeled subpopulation below. Using estimated trends from radar data to initialize the model also integrates the effects of powerline collisions and light fallout prior to the HCP, to the extent available data allow, because the trend estimate is based on radar survey data starting in 1993.

Table 5E-2 provides a summary of the approach used for each modeled subpopulation as well as a relative comparison of mortality sources (the differences in mortality help explain why each subpopulation was modeled) and uncertainty in the estimate of abundance. Where certainty in abundance was moderate and habitat suitability modeling was used (i.e., Kalalau east to Upper Mānoa), nesting densities were extrapolated from other areas with available data, and expert opinion was used to derive density correction factors to account for lower expected nest densities in areas with higher levels of mortality (i.e., due to unmanaged predation outside the conservation sites).

Table 5E-2. Summary of Approach to Initial Population Estimate, Relative Mortality Levels by Source, and Data Availability by Modeled Subpopulation of Newell's Shearwater (ʻaʻo)

Modeled Subpopulation	Data Sources Used for Initial Population Estimate	Relative Population-Level Mortality by Source			Certainty in Abundance Estimate
		Powerlines	Light Attraction	Predation	
Conservation Sites (7)[a]	Habitat Suitability Model and auditory survey polygons (based on annual surveys)	Low	Low	Low	High

Modeled Subpopulation	Data Sources Used for Initial Population Estimate	Relative Population-Level Mortality by Source			Certainty in Abundance Estimate
		Powerlines	**Light Attraction**	**Predation**	
Nā Pali Coast	Song meters/regression analysis	Low	Low	Low	Moderate
Wainiha and Lumahaʻi Valleys	Habitat suitability model and auditory survey polygons	Low	Low	Moderate	Moderate
Kalalau east to Upper Mānoa	Habitat suitability model and cover ratios[b] calculated from auditory survey polygons in Wainiha and Lumahaʻi Valleys	Low	Low	Moderate	Moderate
Hanalei to Kekaha	Radar trend and strike estimate	**High**	Moderate	**High**	Low
Waimea Canyon	Radar trend and strike estimate	**High**	Moderate	Low	Low

[a] There are six existing conservation sites: (1) Upper Limahuli Preserve; (2) Pihea; (3) North Bog; (4) Pōhākea; (5) Hanakāpīʻai; and (6) Hanakoa. Conservation Site 10 is discussed in Section 1 above.

[b] Cover ratios were used to extrapolate the fraction of suitable habitat used by nesting seabirds detected through acoustic surveys to areas without available acoustic survey data, before applying density correction factors to account for lower nesting densities in areas that have been more greatly affected by powerline strike, light attraction, and predation mortalities (Raine et al. 2019; Raine et al. 2022a.).

Hanalei to Kekaha

This area is most affected by powerline collisions, light attraction, and predation (e.g., Troy et al. 2014 and see Figure 5E-1). It is also the area of the island for which trends in relative abundance have been estimated through the long-term systematic radar survey since 1993 (e.g., Day and Cooper 1995; Raine et al. 2017b). Thirteen radar sites have been surveyed since 1993 in the Hanalei to Kekaha area. Two additional radar sites have also been surveyed in Wainiha and Lumahaʻi Valleys starting in 2006, where trends have been stable (Raine and Rossiter 2020; see below for details).

The radar survey on Kauaʻi represents the longest systematic monitoring study of trends in abundance for this species anywhere. Raine et al. (2017b) estimated the average rate of decline in Newell's shearwater (ʻaʻo) abundance, between 1993 and 2013, across all radar sites in the Hanalei to Kekaha area at approximately -13 percent per year. Since that study, Raine and Rossiter (2020) present the most recent estimates for the long-term subpopulation trend for this area. When averaged across all radar sites in this area, the more recent estimate of the average annual rate of decline is -6.9 percent per year during 1993–2020. During those three decades, the most extreme rate of decline for any of the 13 individual radar sites in this area has been estimated at the Hanalei radar site. The trend in relative abundance from that radar site is -10.7 percent per year during 1993–2020.

As noted above, the total breeding pair estimates developed by ARC for Hanalei to Kekaha were found through preliminary modeling results to be incompatible with the estimated number of powerline collisions, associated mortalities, and the most negative trend estimated from radar survey data. Given the biological assumptions in the model, this combination of factors, as initially explored (i.e., relatively small abundance relative to the magnitude of powerline collision mortalities for a species with low maximum rates of modeled population growth) led to resulting modeled rates of decline that were much greater than any trends that have been observed through the radar surveys in this area, or elsewhere on Kauaʻi.

To correct this inconsistency, an alternative approach to initializing abundance for the Hanalei to Kekaha area was developed so that the model would match both the magnitude of powerline collisions estimated from acoustic monitoring and trends in abundance estimated from the long-term systematic radar surveys. This approach was also applied to the Waimea Canyon area, which ran into similar compatibility issues between estimates, given the relatively large number of unminimized collisions in that area.

The initialization approach for Hanalei to Kekaha and for Waimea Canyon involved solving for the combination of (1) abundance at age, and (2) the subadult and adult powerline mortality rates that result in the estimated number of collision mortalities, while matching the -10.7 percent rate of decline estimated from the radar survey at the Hanalei radar site (a worst-case recent trend). The solutions for abundance and powerline mortality rates at age were found using non-linear numerical optimization (a penalized maximum likelihood approach) as implemented in the Stan programming language using the *cmdstanr* package (Stan Development Team 2022; Gabry and Češnovar 2022). The specific penalties used to fit the model were as follows.

1. The Bayes acoustic estimate of powerline strikes was assumed to follow a log-normal distribution with a mean in log-space corresponding to the strike allocation for this area (described below), and a coefficient of variation assumed to be 0.001, which ensures the resulting modeled number of strikes matches the mean of the reported estimate.
2. The trend from the radar data was modeled as a normally distributed random variable with a coefficient of variation of 0.01, which again ensured the resulting modeled trend matched the point estimate for the rate of decline.
3. The proportion of powerline collision mortalities that were subadult was assumed to follow a *Beta*(11, 3) probability distribution, which corresponds to the sample of 14 downed Newell's shearwater (ʻaʻo) examined and categorized as 11 subadults and 3 adults by Cooper and Day (1998), i.e., the expected proportional age-class split for powerline collision mortalities was 79 percent subadult and 21 percent adult.

The estimate of powerline collisions is an annual average during 2013–2019. It was assumed that this estimate pertained to 2016, the midpoint year of the acoustic monitoring data analyzed by Travers et al. (2020). In an analogous example, this approach to estimating abundance is the same as solving a problem where one wants to calculate the amount of money in a stock market account 1 year earlier. If one knows the rate of decline in the market from one year to the next was -10 percent, and the account lost $10 last year, there must have been $100 in the account before the loss.

The resulting abundance at age from this approach was then projected forward from 2016, under the assumption of a stable age distribution at the -10.7 percent rate of decline, through 2019, after which time the initial unminimized powerline mortality rates at age were reduced each year according to the modeled minimization schedule under the HCP.

Estimates for the number of annual powerline collisions are not available prior to 2013. However, incorporating estimated trends from radar data to initialize the model integrates the effects of powerline collisions and other sources of mortality prior to 2013, to the extent available data allow, because the radar trend is based on observations starting in 1993.

Upper Limahuli Preserve, Conservation Site 10, Pihea, North Bog, Pōhākea, Honopū, Hanakāpiʻai, and Hanakoa)

This conservation sites have the highest level of management (mainly predator control) and are in northwest Kauaʻi away from most powerlines and light sources (Figure 5E-1). The Upper Limahuli Preserve, Conservation Site 10, and North Bog conservation sites are close to the towns of Hāʻena and Wainiha and thus closer to powerlines and light sources. There is one streetlight at Hāʻena Beach Park that is approximately 0.4 mile north of the Upper Limahuli Preserve; however, all lights and powerlines are located over 1 mile to the east. The remaining four conservation sites in the Hono O Nā Pali Natural Area Reserve are west of the Upper Limahuli Preserve, Conservation Site 10, and North Bog conservation sites, over 3 miles from the nearest powerlines or light sources to the east.

The covered seabirds in this area are expected to be affected the least of any area by all stressors (Table 5E-2). This area also has the best available data (e.g., annual auditory surveys, extensive burrow searches) for abundance estimates based on annual surveys (e.g., Raine et al. 2019, 2022a). Breeding pair estimates have been conducted on an individual basis for the conservation sites and have been presented previously in annual seabird monitoring reports (e.g., Archipelago Research and Conservation 2021; Raine et al. 2022b).

In 2017, the first estimates of breeding pair abundance were produced at all monitored management areas using two independent methods: (1) a habitat suitability model, which utilized the peer-reviewed models presented in Troy et al. (2014, 2017) where suitable habitat ranked 7+ and an average nearest neighbor distance was used from known burrows at monitored colonies to model nesting density; and (2) a regression analysis of acoustic monitoring data, which provides an estimate of active burrows (i.e., breeding pairs) as a function of call detections, given previous studies comparing paired visual and acoustic data in the same nesting areas. Based on the outputs of the two models, it was decided that the habitat suitability model was the most appropriate way of providing population estimates and that the acoustic method would need to be further refined before it could be used for this metric (e.g., Raine et al. 2019). For these sites, habitat suitability modeling (Troy et al. 2014, 2017) is also employed for portions of the conservation sites outside the acoustic arrays, using the estimated nearest neighbor distances between active burrows (i.e., burrow densities) to predict breeding pair numbers outside the acoustic array footprint.

The habitat suitability model was updated in 2021 by including new polygons from auditory surveys undertaken in 2021 and total surface area to take into account vertical space such as drainages and cliff walls. Two population estimates were then created for each site: (i) a low population estimate using only polygons related to "hot spot heavy" or "ground calling activity," and (ii) a high population estimate using *all polygons* collected during auditory surveys. In areas where suitable nesting habitat overlapped between Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) (i.e., where the habitat is suitable for nesting for either species), the habitat was partitioned between species to prevent double counting of available nesting habitat.

The breeding pair abundance in 2021 in the population dynamics model is equal to the lower of the two estimated values for all areas except for Hanalei to Kekaha and Waimea Canyon, where the approach to estimating initial abundance is described in the respective area descriptions.

Kalalau East to Upper Mānoa

This area is in the northwest of Kauaʻi away from most powerlines and light attraction issues. However, this area is unmanaged and thus more heavily affected by predators than adjacent conservation sites. Like Hanalei to Kekaha, the Troy et al. (2014, 2017) habitat suitability model was used to estimate breeding pairs in this area, but only included suitable habitat ranked at 8+ (i.e., suitable habitat ranked lower than 8 was assumed to contain zero breeding pairs). The modeled suitable habitat was also further reduced by an elevation cut-off, such that suitable habitat below 1,922 feet (585.9 meters) above sea level for Newell's shearwater (ʻaʻo) was assumed to contain zero breeding pairs. As this area is largely unsurveyed, a cover ratio was applied. The cover ratio used was the same ratio calculated for Lumahaʻi (see *Wainiha and Lumahaʻi Valleys*). To calculate estimated densities of active nests, the average nearest neighbor distance from burrows in Upper Limahuli Preserve was multiplied by 1.5, to account for active nests being more dispersed in unmanaged areas.

Nā Pali Coast

This area is in northwest Kauaʻi far from powerlines and light attraction sources. The entire subpopulation is within steep, north-trending valleys. As a result, foraging breeding adults and fledglings are expected to exit and enter the region almost entirely towards the ocean. While this area is largely unmanaged, the seabirds breeding here nest on nearly vertical cliffs several thousand feet high and are thus assumed to be much less affected by predators than other unmanaged sites. The current breeding pair estimate for the Nā Pali Coast is based on call rate data collected from 15 song meters deployed in this area in 2020, and a regression fit between call rates and active nests, to predict the number of breeding pairs (Raine et al. 2019). There is a strong statistically significant relationship between call rate and the number of active burrows located around acoustic sensors (Raine et al. 2019).

Waimea Canyon

This area is in the center of Kauaʻi, but it is affected by powerline collisions and light attraction. While this area is largely unmanaged, like the Nā Pali Coast area the birds breeding here nest on near-vertical cliff walls and are thus assumed to be less affected by predators than other unmanaged sites. Initial modeled abundance for this area was calculated using the same approach described above for the Hanalei to Kekaha area, except that the modeled rate of decline was assumed equal to the average estimated across all radar sites in the Hanalei to Kekaha area (-6.9 percent per year).

Wainiha and Lumahaʻi Valleys

This area encompasses two of the largest valleys on Kauaʻi with breeding Newell's shearwater (ʻaʻo). While affected to some degree by powerlines and light attraction, radar data has shown no trend since monitoring began in 2006 (e.g., Raine and Rossiter 2020) and tracking data shows that birds transiting over this area are predominantly higher than powerlines (Raine et al. 2017a). There is no predator management in this area, but in order to match the stable radar trend since 2006, it was assumed that predation rates were equal to those modeled in the Waimea Canyon and Nā Pali Coast areas (i.e., that birds in these valleys have been confined to very steep and less accessible habitat and have reduced predation rates).

Auditory surveys were conducted in portions of Lumahaʻi Valley in 2020, and the corresponding call rate data was combined with survey data in both valleys in 2012–2014 and used after filtering out any call rates that did not meet the "heavy" and "ground calling" criteria (e.g., Raine et al. 2020). This approach excluded any breeding pairs associated with low-density nesting areas. Like other areas, habitat suitability modeling was also incorporated, and the breeding pair estimate for Wainiha and Lumahaʻi Valleys only included suitable habitat ranked at 8+ (i.e., suitable habitat ranked lower than 8 was assumed to contain zero breeding pairs). For areas within each valley that were not surveyed a cover ratio was applied. This was created by considering all areas within each site where auditory surveys were undertaken, drawing an 0.6-mile (1-kilometer) radius around each survey point, and creating a cover ratio within that survey radius of seabird activity polygons (heavy and ground calling) to suitable habitat. The cover ratio was then extrapolated to unsurveyed areas. The modeled suitable habitat was also further reduced by an elevation cut-off, such that suitable habitat below 1,922 feet (585.9 meters) above sea level for Newell's shearwater (ʻaʻo) was assumed to contain zero breeding pairs. The estimated densities of active nests were multiplied by 1.5, which reduced the breeding pair estimate, to account for active nests being more dispersed in unmanaged areas.

Social Attraction Sites

Several social attraction sites are also included in the population dynamics model, including at: Pōhākea, Conservation Site 10, Upper Limahuli, Honopū, and Kahuamaʻa. These sites are assumed to start from zero birds in the first year of operation and are mentioned here for completeness in terms of listing modeled subpopulations. The modeling assumptions for social attraction sites are described in detail under Section 1.3, *Social Attraction Site Dynamics and Dispersal*.

Table 5E-3. Abundance Estimates (males and females combined) of Newell's Shearwater (ʻaʻo) on Kauaʻi in 2021 by Subpopulation and Age Class

Subpopulation (see Figure 5E-1 for locations)	2021 Breeding Adults (ages 6+)[a]	2021 Subadults (ages 1–5)[b]	2021 Total Abundance (ages 1+)	Fraction of Total Powerline Strikes[c]	2016 Powerline Mortalities (all ages) per 100 breeding adults in 2020
Pihead	< 2	< 1	< 2	2×10^{-6}	0.5
North Bog	133	76	209	0.0013	2.5
Pōhākea[e]	579	330	909	0.0015	1.0
Hanakāpiʻai	152	87	239	0.0007	1.0
Hanakoa	89	51	140	0.0001	0.5
Upper Limahuli Preserve[e]	996	568	1,564	0.0077	2.5
Conservation Site 10[e]	397	226	623	0.0024	2.5
Honopū[e]	180	103	283	0.0003	0.5
Wainiha and Lumahaʻi Valleys	4,698	2,677	7,375	0.0221	1.5
Hanalei to Kekaha	13,538	8,368	21,906	0.8604	20.3
Kalalau east to Upper Mānoa[f]	1,642	936	2,578	0.0077	1.5
Nā Pali Coast	818	466	1,284	0.0013	0.5
Waimea Canyon	1,971	1,426	3,343	0.0945	15.3
Total Kauaʻi abundance	**25,140**	**15,314**	**40,454**		

[a] Values for breeding adults correspond with the minimum theoretical estimate of abundance based on several alternative data sources, methods for estimation, including a partioning of suitable nesting habitat between Newell's

shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu), and expert opinion (e.g. Raine et al. 2019; Raine et al. 2022a). Estimates for all conservation sites with established subpopulations (first 8 rows) were derived in 2021. Estimates of unmanaged subpopulations (last 4 rows) are derived from the habitat suitability analysis of Troy et al. (2014) restricted to 1,922 feet (585.6 meters) above sea level and above (the lowest elevation in managed colonies with a known burrow) correcting for the more dispersed nature of unmanaged colonies as compared to managed colonies.

[b] Except for the Hanalei to Kekaha and Waimea areas, the initial number of subadults was derived under the assumption that subadults comprise 36.3 percent of the age 1+ (non-chick) component of the population (Ainley et al. 2001). This assumption is quite close to the numerical solution for the proportion in a stable age distribution for the first two areas, which is a function of the high fledgling natural mortality rate assumed, as well as the high proportion of powerline mortalities that are assumed to be subadults in the model.

[c] Spatial patterns in the acoustic collision detection data from powerline collision monitoring and rationale for the modeled strike allocation is described in more detail below.

[d] The Pihea conservation site is aimed at protecting Hawaiian petrel (ʻuaʻu). The amount of suitable nesting habitat for Newell's shearwater (ʻaʻo) is more limited there than at other sites. Due to the limited amount of suitable nesting habitat, the estimated number of existing breeding pairs is between zero and one.

[e] The social attraction sites at Pōhākea, Upper Limahuli Preserve, Conservation Site 10, and Honopū have initial starting populations of zero so are not listed (see Table 5E-7).

[f] The area from Kalalau east to Upper Mānoa Valley excluding conservation sites.

5E.1.1.2 Vital Rates under Optimal Conditions

A critical set of assumptions used in the KIUC HCP population dynamics model relate to the vital rates of the target species. *Vital rates* for any population dynamics model dictate population trajectories in the absence of any external factors, also referred to here as *optimal conditions*. Estimated reductions in vital rates relative to optimal conditions allow the modeling of expected impacts on population dynamics from combined threats (e.g., mortalities due to introduced predators and powerline collisions). Likewise, the estimated effects of conservation measures on vital rates allow the modeling of expected benefits of mitigation and minimization measures. Vital rates for this model include the following.

- Survival from one age class to the next age class
- The age at first reproduction (also termed the "adult" age)
- The annual breeding probability for adults (expressed as a fraction of adult birds that breed each year)
- The reproductive success rate (i.e., the fraction of eggs laid by adults that survive to emerge from the nest as fledglings)

During the last decade, burrow monitoring and other studies have led to a substantial increase in available species-specific estimates of endangered seabird vital rates on Kauaʻi (e.g., Raine et al. 2020, 2022a; Archipelago Research and Conservation 2021). Likewise, advances in powerline monitoring methods have resulted in estimates of powerline strike numbers, resulting mortalities, and locations (e.g., Travers et al. 2020, 2021). In addition to recent estimates of vital rates related to reproduction and recruitment from burrow monitoring studies, acoustic monitoring of call rates and satellite tagging studies also provide information on trends in abundance and relative vulnerability to powerline collisions for breeding colonies in conservation sites in northwestern Kauaʻi. These newly available estimates serve to inform the biological assumptions of the KIUC HCP population dynamics model.

However, even with the improved estimates of vital rates and additional information on trends in abundance that recent monitoring efforts provide, there remains a high level of uncertainty for many of the biological assumptions that are input parameters for the population dynamics model. For example, the most recently reported estimate of the number of seabird powerline strikes from the Bayesian analysis of acoustic strike monitoring data collected between 2013 and 2019 has a 95 percent posterior predictive probability interval of 4,417–56,903 strikes per year (Travers et al. 2020). Moreover, in some instances, the parameter values adopted for this set of biological assumptions may be based wholly, or in part, upon expert opinion, and therefore confidence intervals cannot be calculated. Despite these limitations, the biological assumptions described in this appendix represent the best available scientific data, which is the regulatory standard for HCPs under the federal Endangered Species Act and Hawai'i Endangered Species Act.

The optimal rate of population growth is related to (but might be less than) the intrinsic rate of growth of the population, which is the maximum expected exponential growth rate that populations can achieve in the absence of density dependent competition for resources, and decreases in vital rates through anthropogenic effects and invasive predators (e.g., Caughley 1977). The optimal rate of population growth is a key parameter in conservation risk assessments and management strategy evaluations (e.g., Niel and Leberton 2005). However, the optimal population growth rate is also a difficult parameter to estimate, especially for species without long-term surveys of abundance to monitor the rate of recovery from low population levels. At present, no empirical estimate exists for the optimal rate of population growth for Newell's shearwater ('a'o).

Given the biological assumptions for the vital rates of this model, the resulting optimal rate of modeled population growth (i.e., in the absence of introduced predators, powerline strike or light fallout mortality) is 2.36 percent per year. This is similar to the optimal rate of population growth modeled by Griesemer and Holmes (2011:30), which was 2.3 percent per year.

In practice, however, the optimal rate of population growth is never achieved in the KIUC model, because even for those sites with predator-proof fences, birds are still assumed to be vulnerable to powerline strike mortalities (E-15at relatively low levels, given these sites are in northwestern Kaua'i) as well as aerial predation by introduced barn owls. The highest rate of modeled population growth in the KIUC model is achieved at the Honopū PF site. This site has a relatively low powerline strike mortality rate in the model (0.5 unminimized powerline mortalities per 100 breeding adults), due to its remote geographic location on the Nā Pali Coast, and predation rates other than barn owls are assumed to be zero. Ignoring immigration of existing birds from other areas due to social attraction at this site, the underlying modeled population growth rate is 2.03 percent per year at Honopū PF.

The optimal rate of population growth in a population dynamics model is a function of the optimal input values for the vital rates. All else being equal, higher optimal input values for survival or reproductive rates (or lower age at reproduction) result in higher values of optimal population growth rates and vice versa (e.g., Caswell 2001). The biological assumptions for the individual component life history values in the model are as follows.

Fledgling Survival Rates

Fledgling (age 1) survival rates and subsequent survival rates to breeding age were derived from the satellite tagging study reported by Raine et al. (2020). In that study, 12 Newell's shearwater ('a'o) fledglings were tracked at sea. From the tag signals it was possible to estimate if a fledgling died at sea (i.e., the tag stopped reporting movements in a manner that indicated it had not simply fallen off). Based on the observations of tagged fledglings, only 25 percent of tagged fledglings survived their first month at sea, suggesting that this percentage or lower would reach breeding age (Raine et al. 2020). Therefore, the fledgling survival rate assumed in the model was set such that, in combination with the assumed subadult survival rate, 25 percent of fledglings in the model (under near optimal conditions) would reach breeding age. Combined with the subadult survival rates at age described below, this assumption yields a fledgling survival rate of 0.371 (i.e., survival from age 1 to age 2). Accounting for fallout from light attraction further reduces the fledgling survival rate in the Hanalei to Kekaha area of the model (Section 3.1, *Conservative Assumptions*). The estimated level of fallout includes correction factors for the proportion of grounded seabirds that go undetected, e.g., for KIUC streetlights, 89.6% of grounded Newellʻs shearwater (ʻaʻo) are assumed to go undetected (Appendix 5C: *Light Attraction Modeling*). Fallout, whether detected or not, is assumed to result in 100% mortality in the model.

Subadult and Adult Survival Rates

There are no available empirical estimates of adult survival rates for Newell's shearwater (ʻaʻo). Instead, adult survival rates were based on multiple studies undertaken on the similar Manx shearwater (Harris 1966; Perrins et al. 1973; Brooke 1977) and were set to 0.924. Subadult survival rates (ages 2–5 years) were set equal to the adult survival rate, which is consistent with a life history punctuated by very high first year at-sea mortality rates for fledglings, followed by relatively low natural mortality rates for subadults and adults. The exact values for subadult survival rates at age are uncertain, in part because subadults may spend several years at sea, making conventional approaches for estimating survival rates, like mark-recapture, impracticable. The values for subadult survival rates at age assumed in the model are consistent with the Raine et al. (2020) satellite tagging study on Kauaʻi described above in *Fledgling Survival Rates* and result in 25 percent of modeled fledglings reaching breeding age (age 6) under near optimal conditions.

Age at First Breeding

Like previous modeling studies, the age at first breeding was assumed to occur at 6 years (Ainley et al. 2001; Griesemer and Holmes 2011; Vorsino 2016).

Reproductive Success Rate

The reproductive success rate (RS) in the model measures the fraction of eggs that develop into a chick that survives to fledge. This is consistent with how reproductive success rates have been defined in the burrow monitoring study data. Reproductive success rates have been estimated from burrow monitoring studies at the conservation sites, both before (RS = 0.558) and after (RS = 0.872) dedicated predator mitigation measures. The RS rate at the conservation sites is taken from 3-year average value estimated across sites during 2019–2021 (e.g., Archipelago Research and Conservation 2021; Raine et al. 2022a). As a conservative assumption, this observed value was further reduced to account for observations of seabird bycatch in predator traps (n = 34 since 2016; Hallux unpublished data). Dividing the number caught in predator traps by estimated breeding age abundance at the conservation sites, the observed RS was reduced to 0.867. For areas in the model without predator mitigation, the reproductive success rate is assumed to be equal to that estimated at the conservation sites prior to dedicated mitigation measures. An adjustment was made for the Nā Pali Coast and Waimea areas, given that nests in these areas are confined to very steep and inaccessible cliff sides. Following the assumption that predation mortality rates in these two areas are 25 percent of those in unmanaged areas, due to the nests in these areas being confined to vertical high cliffsides largely inaccessible to mammalian predators (see also *Predation Rates*), it was also assumed that the reproductive success rate in these two areas is 25 percent greater than in unmanaged areas (RS = 0.698).

The RS rates in areas with predator-proof fences were based on the estimated RS rates at the conservation sites following dedicated predator mitigation, with an upward percentage adjustment corresponding to observed predation rates on nests without predator proof fences, which were 0.0023 for adults and 0.02 for chicks (Raine et al. 2022a; Raine unpublished data). This resulted in a modeled RS rate inside predator-proof fences of 0.891, or a 2.2 percent increase compared to the estimated RS rate from burrow monitoring studies at the conservation sites.

An additional area-specific adjustment was made to the RS values to account for powerline collisions that result in injury but not mortality and might cause breeding individuals to be unable to fledge a chick successfully (e.g., due to an inability to forage effectively that season). Following the observations of Travers et al. (2021), 24.5 percent of powerline collisions were assumed to result in non-lethal injury. These were individuals with post-collision elevation loss that were not assigned to immediate grounding mortality or short-term grounding mortality (within 3,609 feet [1,100 meters] of wires). The observed elevation loss of these birds not assigned as grounded/mortality, was used as a proxy for injury. The elevation loss indicates the collision was more severe or affected the bird more than those that flew off without elevation loss.

Future powerline collision levels, and their non-lethal effects, were derived from the powerline mortality rate calculations described below, under the assumption that mortalities were 28.8 percent of all collisions. The derived number of collisions was then multiplied by 24.5 percent to calculate the associated number of collisions resulting in non-lethal injuries. This number was multiplied by 21.4 percent to account for the proportion of collisions that are expected to be breeding adults (Cooper and Day 1998). And the resulting number of collisions resulting in non-lethal injuries of breeding age birds was divided by the number of breeding birds in an area each year, and used as a percentage reduction in reproductive success rate in that area that year.

Breeding Probability

Breeding probability is the percentage of adults (age 6 or older) that breed each year. This probability has been estimated through long-term studies of active breeders at the conservation sites and is 0.993 for Newell's shearwater (ʻaʻo) (Raine et al. 2022b). The breeding probability value is assumed to be constant across all geographic areas and through time in the model.

5E.1.1.3 Powerline Mortality

The powerline mortality rate for each area *i* with no minimization was calculated for subadults and adults by dividing the proportion of unminimized powerline mortalities for each age class by the corresponding estimates of abundance for that area.

$$\psi_{a,i}^{sa} = \frac{p_i \Omega \rho \nu \pi_{sa}}{\sum_{a=3}^{5} \widehat{N}_{a,i}^{sa}}$$

(Equation 1)

$$\psi_{6+,i} = \frac{p_i \Omega \rho \nu (1 - \pi_{sa})}{\widehat{N}_{6+,i}}$$

Where:

- $\psi_{a,i}^{sa}$ and $\psi_{6+,i}$ are the annual powerline mortality rates for subadults, ages 3–5 years, and adults (ages 6 years and older; Figure 5E-2) in area *i* prior to any minimization (i.e., unminimized). In the context of powerline strikes, subadults refer to ages 3–5 years because ages 1 and 2 are assumed to be at sea and are not vulnerable to powerline strikes in the model (Equation 3). The powerline mortality rates are assumed to be equal for subadults of each vulnerable age.
- p_i is the modelled fraction of total powerline strikes for each species that are associated with birds from area *i* in 2016 (see Table 5E-2 for list of areas).
- Ω is the estimated number of seabird powerline strikes in 2016 (Hawaiian petrels [ʻuaʻu] and Newell's shearwater [ʻaʻo] combined).
- ρ is the proportion of total strikes that are Newell's shearwater (ʻaʻo) (Travers et al. 2021).
- ν is the total grounding rate (i.e., the proportion of strikes that result in mortality; Travers et al. 2021).
- π_{sa} is the proportion of powerline strikes that are subadults (Cooper and Day 1998).
- $\widehat{N}_{a,i}^{sa}$ is the number of subadults at age (ages 3–5 years) and $\widehat{N}_{6+,i}$ is the number of adults in 2016, which when projected forward through time in the model, equal the island-based estimates from 2021 (see Table 5E-3). The initial age structure in the model, for those areas outside Hanalei to Kekaha and Waimea, assumes that 63.7 percent of the population is composed of breeding adults (the remaining 36.3 percent are assumed to be ages 1–5 subadults), following Ainley et al. (2001).

Table 5E-4 shows the assumed values for most of the variables above. The text below the table explains the rationale for these variables.

Table 5E-4. Powerline Strike Assumptions for the Population Dynamics Model

Powerline Strike Variable	Model Variable	Assumed Value
2016 annual powerline strikes of Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) combined, before minimization (i.e., average annual unminimized strike estimate during 2013–2019)	Ω	15,853[a]
Total grounding rate	ν	0.288[b]
Proportion of strikes that are Newell's shearwater (ʻaʻo)	ρ	0.70[c]
2016 annual estimated mortalities of Newell's shearwater (ʻaʻo)	calculation	3,196[d]
Proportion of powerline strikes that are subadults	π_{sa}	0.79[e]

[a] Total number of estimated seabird powerline strikes of Newell's shearwater (ʻaʻo) and Hawaiian petrels (ʻuaʻu) combined. Estimate excludes waterbird strikes and strikes minimized during the Short-Term HCP. Based on 2013–2019 acoustic data and the Bayesian estimate model described in Travers et al. (2020).

[b] The total grounding rate includes 13 percent "immediately grounded," 10.2 percent "unknown outcome", and 5.6 percent of birds that strike powerlines having been observed with the most severe of post-flight behaviors and that are hence assumed to have eventually died (Travers et al. 2021).

[c] Travers et al. (2021)

[d] Mortalities are calculated as the proportion of unminimized seabird strikes for each species, multiplied by the total grounding rate.

[e] See text for additional explanation (Cooper and Day 1998).

Powerline Strike Allocation by Subpopulation

The powerline strike allocation by subpopulation is based on the percentage of acoustically detected strikes that have been analyzed to estimate strike totals across the island (Travers et al. 2020). The assumed empirical strike allocations are: 89.1 percent of strikes in the Hanalei to Kekaha area, 10.8 percent of strikes in the Waimea Canyon area, and 0.1 percent of strikes from the Wainiha and Lumahaʻi Valleys area (Travers et al. 2020; Travers unpublished data). Some variance from the empirical acoustic detections was incorporated in the modeled allocation so that 3.1 percent of strikes from the Hanalei to Kekaha area were assumed to result from collisions by individuals from breeding colonies in the remote northwestern areas. This allowed the model to incorporate a low level of powerline collision vulnerability for individuals associated with the conservation sites and surrounding areas, which is consistent with observations from tagging studies (Raine et al. 2017a). In general, the spatial differences that have been observed through acoustic powerline collision monitoring data served as a key motivating factor for developing a spatially explicit population dynamics modeling framework.

Powerline Strike Allocation by Species

As described in Chapter 5, *Effects*, estimates of powerline strikes of the covered seabirds are derived from acoustic data on strikes for all seabirds combined. Acoustic data cannot be separated by species. Instead, we must make an assumption of the proportion of strikes allocated to either Newell's shearwater (ʻaʻo) or Hawaiian petrel (ʻuaʻu). Travers et al. (2021) has reported that powerline collisions directly observed in the field occur in a proportion of 70.5 percent Newell's shearwater (ʻaʻo) to 29.5 percent Hawaiian petrel (ʻuaʻu). The modeling assumption corresponds to these proportions, with 70 percent of all estimated strikes assumed to be Newell's shearwater (ʻaʻo) and 30 percent assumed to be Hawaiian petrel (ʻuaʻu) (Table 5E-4).

Powerline Strike Allocation by Age Class

Birds detected colliding with powerlines through acoustic monitoring, which is used to estimate strike numbers, cannot be identified to age class. However, the proportions of strikes that are subadults and adults are important for the population dynamics model. Limited evidence suggests that subadults are more susceptible to powerline strikes than adults. For the purposes of this model, powerline strikes of Newell's shearwater (ʻaʻo) are assumed to be composed of 79 percent subadults (ages 3–5 years) and 21 percent adults (ages 6 years and older) (Table 5E-4).

This assumption corresponds to the proportions estimated by Cooper and Day (1998), who analyzed brood patch vascularization and wear of rectrices for 14 downed Newell's shearwater (ʻaʻo) collected on powerline mortality searches during 1993–1994. Three of those downed Newell's shearwater (ʻaʻo) had highly vascularized brood patches and worn rectrices, which suggests those birds were incubating eggs in burrows, and hence they were classified as breeding adults (age 6+). The remaining 11 birds either had no brood patch (n=10) or a downy brood patch (n=1); all but the latter had unworn rectrices. Those 11 birds (78.6 percent) were classified as subadults, and the three others (21.4 percent) were classified as breeding adults.

Mortality from Future Powerlines

Mortality due to construction of future powerlines was assumed to apply only to the Hanalei to Kekaha area (Figure 5E-1). The vast majority (> 99 percent) of new powerlines are expected to be constructed in this area, which is where human population growth is forecast to occur on Kauaʻi (see Chapter 2, *Covered Activities*, for details). As described in Chapter 5, *Effects*, at the end of the 50-year permit term, powerline strikes would be increased by an estimated 6.8 percent. The species-specific increase in future strikes was calculated by applying the species split to this percentage, and then applying a linear increase in the strike mortality rate each year, such that by the end of the HCP term, the strike mortality rate was equal to the estimated percent increase in strikes.

Mortality from Fallout from Existing and Future Streetlights and Covered Facility Lights

Appendix 5C, *Light Attraction Modeling*, describes the process for quantifying take of the covered seabirds from attraction to lights owned and operated by KIUC. Mortality due to fallout from light attraction was assumed to affect fledglings (age 1 year) only in the Hanalei to Kekaha area. Fallout is assumed to result in 100% mortality in the model, so as a conservative approach the benefits of Save Our Shearwaters (SOS) rehabilitation efforts are not counted (given that there is little data on survival once the birds are released). Based on this assumption, and the light attraction modeling (Appendix 5C), the number of mortalities from fallout each year for Newell's shearwater (ʻaʻo) was set to 92.6 in the model. This estimate represents expected mortalities resulting from existing and future light sources anticipated by the end of the 50-year permit term. However, this value was applied at the start of the population trajectories as a conservative approach for modeling fallout mortality levels through time, so annual fallout mortalities from attraction to lights owned and operated by KIUC is likely overestimated at the start of the metapopulation projections.

5E.1.1.4 Predation Rates

Predation mortality rates have been estimated at the conservation sites, both with and without trapping and fencing (i.e., mitigation). Prior to dedicated predator control, predation mortality rates for all predators combined were estimated to be 0.18 for chicks in the nest, and 0.0272 for breeding adults[4] at the nest (Raine et al. 2022a; Raine unpublished data). For areas outside the conservation sites (with no active management), predation rates at the nest were assumed to be equal to the estimates for the conservation sites prior to dedicated predator control, with three exceptions. The exceptions were the Nā Pali Coast, Wainiha and Lumahaʻi Valleys, and Waimea Canyon areas, where predation mortality rates are assumed to be 25 percent of the unmitigated rates. These values were assumed for the Wainiha and Lumahaʻi Valleys in order to match the stable trend in abundance estimated from radar surveys in this area during 2006–2020 (Raine and Rossiter 2020). In the Nā

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[4] In other words, 18 percent of all chicks at all conservation sites are assumed to be lost to predators in the absence of dedicated predator control structures or actions. Similarly, 2.7 percent of all adults at the conservation sites are assumed to be lost to predators annually in the absence of any predator control structures or actions. Chicks are not tracked explicitly in the model, but chick survival (and mortality from predation) is measured in the estimated reproductive success rates of adults from burrow monitoring studies, and those reproductive success rate estimates (and hence chick mortality) from monitoring studies are explicitly included in the model.

Pali Coast and Waimea Canyon areas predation rates are expected to be substantially less than other areas due to the steep and inaccessible cliff locations to which breeding pairs are largely confined. As discussed in Chapter 4, *Conservation Strategy*, breeding colonies likely persist in these locations because of their inaccessibility to mammalian predators (as well as being far away from the majority of threats from powerline collision and light attraction).

With predator control measures at the conservation sites, predation mortality rates were estimated to decrease to 0.02 for chicks and 0.0023 for adults (Raine et al. 2022a; Raine unpublished data). The effect of these reductions in predation rates at the nests is also evident in the reproductive success rates estimated before (55.8 percent reproductive success rate) and after dedicated predator control measures (86.7 percent reproductive success rate) at the conservation sites (e.g., Raine et al. 2022a). Although predation mortality rates for chicks are not explicitly included as a variable in the model and are therefore not considered further, they are subsumed in the reproductive success rate estimates used in the model, as discussed above under *Reproductive Success Rate*.

Barn owl predation rates on the wing for adults were assumed to be equal to the adult predation rate at the nest (0.0023; Raine et al. 2022a; Raine unpublished data), and the same barn owl predation rate on the wing was assumed for ages 3–6+ in the absence of additional information. The assumed barn owl predation rate on the wing was added to the terrestrial predation rates at the nest for all areas. For example, in the Kalalau east to Upper Mānoa area, the adult predation rates at the nest were assumed to be equal to those estimated at the conservation sites prior to dedicated predator control measures (0.0272) plus the assumed barn owl predation rate on the wing (0.0023), or a total adult predation rate of 0.0295 (Table 5E-5). For areas with predator-proof fences, the terrestrial predation rate was assumed to be zero, and the assumed predation rate was limited to that assumed for barn owls on the wing. In other words, the adult predation rate was modeled as the sum of the applied nest predation rate (which differed between areas in the model) and the assumed barn owl predation rate on the wing (which was constant between areas in the model). Predation rates at the nests were assumed to vary between different areas according to different management measures (Table 5E-5).

The predation rate for ages 3–5 was set to 0.0023, under the assumption that those ages are not vulnerable to terrestrial predators because they are not nesting, but they are vulnerable as prospectors to being killed by barn owls on the wing (Table 5E-5).

Table 5E-5. Assumptions for Annual Predation Rates, with and without Predator Control

	Without Predator Control[a]		With Predator Control[b]	
Site	**Adults**	**Subadults (3–5 yrs)**	**Adults**	**Subadults (3–5 yrs)**
Conservation Sites	--	--	0.0046	0.0023
Conservation Sites with Predator-Proof Fences	--	--	0.0023	0.0023
Kalalau east to Upper Mānoa	0.0295	0.0023	--	--
Hanalei to Kekaha	0.0295	0.0023	--	--
Wainiha and Lumahaʻi Valleys[c]	0.0074	0.0006	--	--
Nā Pali Coast[c]	0.0074	0.0006	--	--
Waimea Canyon[c]	0.0074	0.0006	--	--

[a] Without predator control is defined as no fencing, no predator trapping, and no predator removal efforts. With predator control includes trapping and ungulate fences for the conservation sites, or sites with predator-proof fences (second row).

[b] See Table 5E-6 for differences in predation mortality rates assumed for different age classes.

[c] Due to the inaccessibility of these sites (Nā Pali Coast and Waimea Canyon), predation rates for adults and subadults are set at 25 percent of the rates of other sites without predator control. The same assumption is made in terms of reduced predation rates for Wainiha and Lumahaʻi Valleys in order for the initial modeled trend to match the stable trend in radar survey data at the two monitoring sites for these valleys during 2006–2020 (Raine and Rossiter 2020).

5E.1.2 Population Dynamics Model and Projections of Abundance

This section describes the model structure, each of the model parameters, and the rationale for each model input.

The population dynamics model is described below in terms of the numbers of females-at-age for each species, under the assumption of a 50:50 sex-ratio:

$$N_{1,t,i} = 0.5\gamma_{t-1,i}\beta N_{6+,t-1,i}S^{*}_{6+,t-1,i} - F_{t,i} \qquad \text{(Equation 2)}$$

$$\begin{aligned} N_{2,t,i} &= N_{1,t-1,i}S^{*}_{1,t-1,i} \\ N_{3,t,i} &= N_{2,t-1,i}S^{*}_{2,t-1,i} \\ N_{4,t,i} &= N_{3,t-1,i}S^{*}_{3,t-1,i} \\ N_{5,t,i} &= N_{4,t-1,i}S^{*}_{4,t-1,i} \\ N_{6+,t,i} &= N_{5,t-1,i}S^{*}_{5,t-1,i} + N_{6+,t-1,i}S^{*}_{6+,t-1,i} \end{aligned}$$

Where:

- $N_{a,t,i}$ is the number of female birds at age a during year t in area i. Birds aged 6 years and older (denoted as age 6+) are modeled as a plus-group, *aka* a self-loop group (Figure 5E-2). Fledglings are denoted as age 1 in the model.
- $\gamma_{t,i}$ is the reproductive success rate during year t in area i. Reproductive success rates in the model vary between conservation sites and unmanaged areas, and can change with time for areas with future predator control measures (e.g., predator-proof fences).
- β is the breeding probability for sexually mature birds (assumed constant across areas).

- "Fertility" is defined here as the product: $0.5\gamma_{t-1,i}\beta S^{*}_{6+,t-1,i}$
- Hence, fertility, or the number of female fledglings produced per breeding female per year, is a function of the adult survival rate. Chick mortality rates, which are subsumed in the reproductive success rate variable, are therefore directly related to parental mortality rates in the model vis-à-vis reductions in the numbers of fledglings produced.
- $F_{t,i}$ is the number of age 1 birds that die from fallout due to KIUC lights during year *t* in area *i*. This term is included with a time and area component for generality, but in practice, fallout is assumed to be limited to the Hanalei to Kekaha subpopulation with 46.3 age 1 female mortalities per year (i.e., 92.6 fallout mortalities per year for age 1 males and females combined).
- $S^{*}_{a,t,i}$ is the survival rate of birds at age *a* during year *t* in area *i*, which for ages 3 years and older is a function of the estimated predation and powerline mortality rates-at-age, as well as the powerline minimization level in year *t*:

$$\begin{aligned}
S^{*}_{1,t,i} &= S_1 \\
S^{*}_{2,t,i} &= S_2 \\
S^{*}_{3,t,i} &= S_3(1-\phi_{3,t,i})\left[1-\psi_{3,i}(1-\delta_t)\right] \\
S^{*}_{4,t,i} &= S_4(1-\phi_{4,t,i})\left[1-\psi_{4,i}(1-\delta_t)\right] \\
S^{*}_{5,t,i} &= S_5(1-\phi_{5,t,i})\left[1-\psi_{5,i}(1-\delta_t)\right] \\
S^{*}_{6+,t,i} &= S_{6+}(1-\phi_{6+,t,i})\left[1-\psi_{6+,i}(1-\delta_t)\right]
\end{aligned} \qquad \text{(Equation 3)}$$

Where:

- S_a is the natural survival rate at age *a* prior to any mortalities from predators or powerlines (Table 5E-5).
- $\phi_{a,t,i}$ is the predation mortality rate at age *a* during year *t* in area *i* (Tables 5E-5 and 5E-6). Predation rates vary through time in the model in the areas where future predator control measures will occur or where predator-proof fences are installed.
- $\psi_{a,i}$ is the unminimized powerline mortality rate at age *a* in area *i.* The unminimized powerline mortality rates vary by area due to unequal per-capita vulnerability to powerline strikes (Equation 1; Table 5E-3).
- δ_t is the minimization efficacy in terms of reducing powerline strikes during year *t*. The minimization rate varies between years according to the strike minimization schedule under the HCP (Table 5E-8).

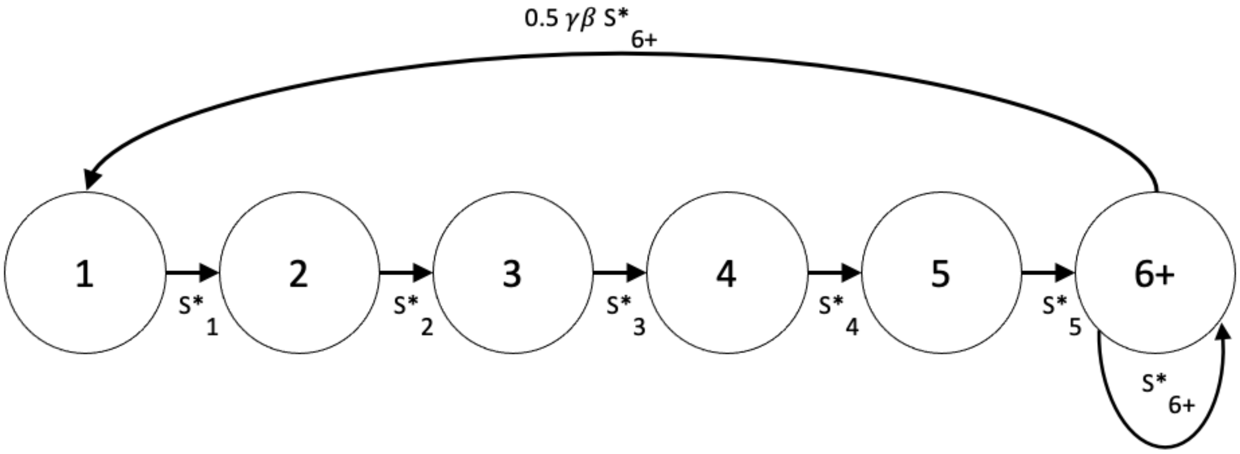

Figure 5E-2. Life Cycle Graph with Age-Structured Transition Parameters for the Population Dynamics Model

The life-cycle model shown in Figure 5E-2 is similar to the model developed by Griesemer and Holmes (2011). The circles, and numbers therein, correspond with a single age-class in the model. Birds aged 6 years and older were modeled as a self-loop group (i.e., senescence was not assumed to be a knife-edge where all birds die at a given age). The survival rates at age a, S_a^* are a function of predation and powerline mortality rates at age as well as the powerline strike minimization rates (Equation 3). For conciseness, the subscripts for year and area are dropped in the transition parameters shown in the figure.

Table 5E-6. Survival, Predation Mortality, and Fertility Rates by Age for Newell's Shearwater (ʻaʻo)

Age	Natural Survival Rate[a]	Predation Mortality Rate without Predator Control or Fencing[b]	Predation Mortality Rate with Predator Control and Ungulate Fencing[b]	Predation Mortality Rate with Predator-Proof Fencing[d]	Natural Fertility[a]	Fertility without Predator Control or Fencing[e]
1	0.371	0	0	0	0	0
2	0.924	0	0	0	0	0
3	0.924	0.0023[c]	0.0023[c]	0.0023[c]	0	0
4	0.924	0.0023[c]	0.0023[c]	0.0023[c]	0	0
5	0.924	0.0023[c]	0.0023[c]	0.0023[c]	0	0
6+	0.924	0.0295	0.0046	0.0023[c]	0.416	0.243

[a] Natural survival and natural fertility represent the modeled rates in the absence of predation and powerline mortalities. The value of 0.924 for natural survival is based on survival rates estimated from studies of Manx shearwater and Hawaiian petrel (ʻuaʻu) (Simmons 1984, 1985), with age 1 survival adjusted to result in ~25 percent of birds reaching breeding age, based on satellite tagging results for Newell's shearwater (ʻaʻo) on Kauaʻi (Raine et al. 2020).

[b] Estimated from burrow monitoring studies at conservation sites (e.g., Raine et al. 2022a), and assuming that ages 1 and 2 are not vulnerable to introduced predators on the island, because they are largely expected to be at sea.

[c] Taken from estimated barn owl predation rates for nesting birds and assumed in the model to be equal for age 3–5 birds (i.e., the barn owl predation rate is applied to this age under the assumption that ages 3–5 would be "prospectors" and predated by barn owls on the wing).

[d] All predation mortality rates are assumed to be reduced to zero by predator-proof fences, except for ages 3–6+ which are assigned the estimated barn owl predation rate on the wing.

[e] This fertility value corresponds to the Hanalei to Kekaha subpopulation with unminimized powerline strike mortality rates. The fertility values are a function of the adult powerline mortality rates and non-lethal injury calculations, and therefore change through time in the model as a function of the minimization schedule. Likewise, the fertility rates differ between areas in the model due to spatial differences in the adult powerline mortality rates between areas in the model. Because the Hanalei to Kekaha area has the highest powerline strike mortality rate, it also has the lowest modeled fertility rate, which reflects the expectation that if a nesting parent is killed, its egg/chick will not survive to fledge.

Table 5E-7. Reproductive Rates Assumed in the Population Dynamics Model

Vital Rate	Value
Sex ratio	0.5
Reproductive success rate without predator control and without fencing	0.558[a]
Reproductive success rate with predator control	0.867[a]
Reproductive success rate with predator-proof fencing	0.891[a]
Breeding probability	0.993[b]
Age at sexual maturity	6 yr

[a] Estimated from burrow monitoring studies at management sites prior to dedicated predator control ("Year 0") and after predator control measures (e.g., Raine et al. 2022a). The reproductive success rate with predator control measures is estimated from the 3-year, 2019–2021 average reproductive success rate and includes bycatch of seabirds in predator traps at conservation sites. The reproductive success rate at conservation sites with predator-proof fencing is assumed to be 2.23 percent greater than at conservation sites with trapping and ungulate fencing. This is comparable to reducing the estimated adult and chick predation rates (combined) from terrestrial predators at nests in those conservation sites to zero.

[b] Estimated from long-term studies of active breeders at the conservation sites (Raine et al. 2022b).

Table 5E-8. The Annual Powerline Minimization Schedule[a]

Year	Annual Island-Wide Powerline Mortality Minimization Rate[b]
2019	0
2020	0.127
2021	0.303
2022	0.550
2023–2053	0.653

[a] See Conservation Measure 1, *Implement Powerline Collision Minimization Projects*, in Chapter 4, *Conservation Strategy*, for details on the specific powerline minimization projects and the locations.

[b] Minimization represents the efficacy to reduce the mortality rate due to powerline strikes. In other words, minimization = 0.0 corresponds to no change in powerline mortality rate (without any minimization measures implemented). A minimization = 1.0 represents a scenario where a powerline was removed or modified so that bird collisions no longer occurred, and powerline mortality rates are zero. A minimization efficacy of 0.5 represents a 50 percent reduction in strike mortalities.

5E.1.3 Social Attraction Site Dynamics and Dispersal

The population dynamics model assumes natal fidelity and internal recruitment for each subpopulation, such that birds that fledge in area *i* return to the same area to breed for the remainder of their lives. The exception to this is immigration into social attraction sites. The numbers of new breeding birds that immigrate into each social attraction site each year following the installation of the site are shown in Table 5E-9. The model assumes that the number of breeding birds that immigrate into a social attraction site each year from area *i* is proportional to the abundance of the subpopulation in area *i* relative to total abundance that year. For example, if a subpopulation in area *i* in year *t* represents 50 percent of total abundance, then 50 percent of the immigrants into social attraction sites that year will be from that subpopulation. Age 3 subadults are the only age class assumed to immigrate into social attraction sites. This age class represents subadult "prospectors" that are searching for suitable habitat to establish a nest. The number of subadult prospectors immigrating into social attraction sites was determined such that the expected number of established breeding pairs 3 years later was matched (Table 5E-9). Immigration into social attraction sites is assumed to be permanent and once breeding pairs are established their offspring are assumed to have natal fidelity (Procellariids exhibit strong natal philopatry) and return to breed at the same social attraction site in subsequent years.

5E.1.3.1 Carrying Capacity

Because the proposed social attraction sites are relatively small compared to their surrounding management areas at the conservation sites, and because they are enclosed by a predator exclusion fence, we assume that each social attraction site has a finite carrying capacity. Suitable habitat within the proposed predator exclusion areas was used by ARC to estimate the carrying capacity of nesting Newellʻs shearwater (ʻaʻo) breeding pairs for each site: 136 Pōhākea PF; 468 at Honopū PF; 396 at Conservation Site 10 (inside PF), and 453 at Upper Limahuli (inside PF). Once the carrying capacity of breeding pairs is reached within each predator exclusion fence, the subpopulation is held constant. Any reproduction that occurs within the predator exclusion fence in excess of this carrying capacity, and any immigration due to continued social attraction is assumed to result in new breeding age birds nesting in the adjacent management area of the same site, as seen in Figure 5E-3 for the four sites with predator exclusion fences. These are estimates only based on theoretical limits of carrying capacity. Current social attraction sites are nowhere near these limits and show no signs yet of slowing population growth.

5E.1.3.2 Kauaʻi Seabird HCP Social Attraction Site

To accurately reflect the island-wide population of Newell's shearwater (ʻaʻo), a additional social attraction site was added to this population dynamics model to account for the Kauaʻi Seabird HCP[5] (KSHCP). The KSHCP, approved in 2020, began implementation in 2021. A primary conservation measure of the KSHCP is the establishment of a new social attraction at the Kahuamaʻa Seabird Preserve (abbreviated here to Kahuamaʻa). This site is approximately 5 acres (2 hectares) in size and is located on the Kalalau Rim in northwestern Kauaʻi at approximately 3,500 feet in elevation (see Figure 5-1 in the KSHCP for specific location). The site is surrounded by a predator-proof fence (completed in 2021) and site management will be very similar to that proposed for this HCP (i.e., cat and rodent control, barn owl control, and invasive plant management). Because it is similar in size to Pōhākea PF, the same carrying capacity for breeding pairs was assumed.

The one exception in the KIUC HCP population dynamics model to the assumption for the number of new breeding pairs immigrating into social attraction sites is at the Kahuamaʻa site. The dynamics for this site assume that the number of new breeding pairs that become established each year is one

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[5] See https://fws.gov/pacificislands/documents/KSHCP/Kauai-Seabird-HCP.pdf

half the number shown in Table 5E-9. This results in 511 new fledglings produced over the first 30 years of the modeled projection, given the assumed predation rates for sites with predator proof fences (Table 5E-5) and powerline mortality rates set equal to the Kalalau to Upper Mānoa area. The assumption of a lower immigration rate to this social attraction site is meant to mimic the assumed benefit in the KSHCP for the number of fledglings that would be produced at the Kahuamaʻa site over 30 years (Table 7 of KSHCP Appendix C under predation scenario 2, and 90–95 percent site fidelity, provides a comparable prediction of 462–932 new fledglings produced over 30 years at this site).

Table 5E-9. Number of Breeding Pairs Expected to Immigrate into Each Social Attraction Site from Other Areas Each Year Following the Introduction of Social Attraction Efforts

Immigration into social attraction sites is assumed in the model to be permanent. After 30 years, the rate of immigration due to social attraction is assumed to remain constant at the average immigration rate during years 20 to 30 modeled for each site. Once a social attraction site has reached the estimated carrying capacity of the predator fenced area, additional immigration and recruitment into the breeding colony is assumed to occur in the surrounding open management area.

Social Attraction Site Year	New Breeding Pairs[a]	Total Breeding Pairs
1	0	0
2	0	0
3	0	0
4	0	0
5	3	3
6	2	5
7	2	7
8	5	12
9	1	13
10	1	14
11	16.77	30.77
12	14.60	45.37
13	14.68	60.05
14	14.34	74.39
15	14.21	88.60
16	13.94	102.54
17	14.14	116.68
18	12.73	129.41
19	13.33	142.74
20	13.03	155.77
21	13.43	169.20
22	12.96	182.16
23	13.09	195.25
24	13.58	208.83
25	13.54	222.37
26	11.85	234.22
27	13.10	247.32
28	13.30	260.62
29	13.23	273.85
30	13.13	286.98

Source: Raine 2020

[a] The expected number of breeding pairs immigrating into social attraction sites is based on data collected at multiple existing social attraction sites, including those for Huttons shearwater (New Zealand), Bermuda petrel (Bermuda) and Newell's shearwater (ʻaʻo) (Makamakaʻole). All show the same pattern of slow establishment (low immigrantion in the first few years), and then immigration increases more quickly after year 10.

5E.2 Model Results

All model results for Newell's shearwater (ʻaʻo) are presented in Figures 5E-3 through 5E-7 at the end of this section. The population dynamics results in Figures 5E-3 and 5E-4 demonstrate that the conservation measures implemented will substantially benefit Newell's shearwater (ʻaʻo) relatively quickly at four of the conservation sites. Benefits to Newell's shearwater (ʻaʻo) are modest at three other conservation sites. The only conservation site with no benefit to Newell's shearwater (ʻaʻo) is Pihea, which is designed primarily to benefit Hawaiian petrel (ʻuaʻu). HCP benefits are greatest at the four conservation sites with predator exclusion fencing and social attraction, as expected (Figure 5E-3).

The population trajectory for Newell's shearwater (ʻaʻo) at all conservation sites combined is shown in Figure 5E-5 and shows a similar pattern. According to the model, the total population size of Newell's shearwater (ʻaʻo) at all of the conservation sites is expected to increase immediately with the rate gradually increasing through approximately 2035. After that, the population increases steadily and more substantially due to the contributions of the newest social attraction sites (Upper Limahuli PF, Conservation Site 10 PF, Pōhākea PF[6], and Honopū PF[7]). By the end of the permit term the combined number of breeding pairs in all conservation sites is projected to be over 4,300.

Continued predator control by the HCP at the six conservation sites with ungulate fencing, combined with powerline collision minimization, will prevent substantial declines of existing subpopulations of Newell's shearwater (ʻaʻo) and likely prevent local extirpation (red lines in Figure 5E-4). Four of these conservation sites with predator control (Upper Limahuli, Pōhākea, Conservation Site 10, and Honopū) collectively contribute substantial numbers of new breeding pairs to the Kauaʻi metapopulation of Newell's shearwater (ʻaʻo) with the HCP (blue lines in Figure 5E-4). Combined, these four conservation sites are projected to have a breeding pair abundance of over 2,500 by the end of the permit term.

Figure 5E-6 shows the subpopulation trajectories at each of the five areas outside the conservation sites (see Figure 5E-1 for area locations), with and without the KIUC HCP. Hanalei to Kekaha is the largest subpopulation area, by far. This area is projected to be locally extirpated without the HCP, and severely depleted with a continued downward trend with the HCP, under the initial modeled rate of decline based on the Hanalei radar site. Without the HCP, local extirpation is projected to occur by approximately 2050. With the HCP, extirpation would be delayed beyond 30 years in the model, but not avoided in the more distant future. The difference in subpopulation declines is due largely to powerline minimization. Because 86 percent of powerline collisions for Newell's shearwater (ʻaʻo) are assumed to be from individuals associated with breeding colonies within this area (see Figure 5E-1), powerline minimization provides a greater benefit in this area than in other areas. This result is not surprising, because for all areas other than Hanalei to Kekaha and Waimea Canyon there is an assumed much lower risk of powerline collisions in the first place (Table 5E-3). By 2023 the rate of modeled decline has slowed from the initial 2016 applied radar trend in the Hanalei to Kekaha and Waimea Canyon areas due to powerline strike minimization (Table 5E-10). For Hanalei to Kekaha the rate of decline in abundance then increases again through time, due to the modeled effect of future powerline construction and fledgling fallout mortality.

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[6] PF stands for predator exclusion fence

[7] Honopū PF awaits final approval from the landowner (State of Hawaiʻi Division of Forestry and Wildlife).

The subpopulation trajectory in the Wainiha and Lumahaʻi Valleys area is similar with and without the HCP (Figure 5E-6). This is due to the assumptions that (1) powerline strikes are minimal in this area, so powerline minimization with the HCP has a small benefit, and (2) there is no predator control in this area. The trajectory of abundance starts off stable, which is consistent with the lack of trend in either direction estimated at the Wainiha and Lumahaʻi Valleys radar sites (Raine and Rossiter 2020). Because of the model assumptions for social attraction sites (Figure 5E-3), the stable trend becomes slightly negative due to emigration from this area to social attraction sites (Figure 5E-6). This "pull" of social attraction sites becomes more pronounced later in the permit term as all of the planned social attraction sites become operational, they have all reached a critical mass of breeding pairs increasing their attraction, and more breeding adults are assumed to be permanently dispersing into the social attraction sites (Table 5E-9). This modeled dynamic is not unique to Newell's shearwater (ʻaʻo) from the Wainiha and Lumahaʻi Valleys, but because this area has a relatively high abundance with a stable trend it is predicted to act as a substantial source of new breeding pairs into the social attraction sites. It is also the area where it is easiest to visualize the effect of the modeled emigration graphically (Figure 5E-6), and likewise the effect of emigration is also evident in the tabled values for the rates of change in abundance through time for this area (Table 5E-11). This emigration would be beneficial to the metapopulation of the species because it would mean that birds were being drawn from unprotected areas in these two valleys into management areas with predator exclusion fences and predator control measures.

Two of the remaining three areas in Figure 5E-6, Kalalau east to Upper Mānoa and the Nā Pali Coast area, are assumed to have relatively low vulnerabilities to powerline strikes, given their geographic remoteness (especially the Nā Pali Coast area) and orientation away from any existing powerlines and light sources. The initial stable trend modeled for the Nā Pali Coast area (Table 5E-10) matches observed patterns in Newell's shearwater (ʻaʻo) acoustic call detection data from that area. The overall trend in call rates in the Nā Pali Coast area has been stable in recent years, with no pattern of increase or decrease in call rates (Raine, unpublished data). Like discussed above for the Wainiha and Lumahaʻi Valleys, the modeled trend in the Nā Pali Coast area eventually turns to a small rate of decline, which is largely independent of powerline mortality, but results instead because a proportion of subadult birds are modeled to emigrate into social attraction sites. Again, while this dynamic reduces the number of modeled breeding pairs in certain areas like the Nā Pali Coast (Table 5E-11), there is a benefit to the metapopulation as a whole from individuals relocating to areas with predator exclusion fences and predator control measures.

The Waimea Canyon area has the second highest modeled vulnerability to powerline collisions and mortalities (Table 5E-2; based on 10.8 percent of all detected powerline strikes during 2013–2019 having occurred in this area (Travers et al. 2020; Travers, unpublished data). Unlike areas with lower powerline strike rates, the modeled trend in this area benefits from minimization efforts (Figure 5E-6). In other words, the trend becomes less negative due to the modeled reduction in powerline mortality rates in this area, moving from -6.9 percent without minimization to -3.3 percent per year under the HCP (Table 5E-10). Similar to the Hanalei to Kekaha area, the modeled slowdown in the rate of decline is not sufficient to prevent continued reductions in modeled abundance in these areas (Tables 5E-11 and 5E-12).

When all subpopulations are combined (Figure 5E-7), the Newell's shearwater (ʻaʻo) metapopulation on Kauaʻi is projected to continue to decline without the HCP (red line; unminimized take scenario). Without the HCP, the total population size is projected to continue to decline from approximately 12,600 breeding pairs at the start of the permit term to less than 3,000 by the end of 2073, a decline of over 70 percent (Figure 5E-7; red line). With the HCP conservation measures the Newell's shearwater (ʻaʻo) metapopulation on Kauaʻi is projected by the end of the permit term to reverse this decline and result in an increasing Kauaʻi metapopulation (Figure 5E-7, blue line). HCP conservation measures are projected to slow the metapopulation decline considerably between 2050 and 2060, stabilizing at approximately 6,400 breeding pairs during that time, before increasing (Table 5E-12).

The metapopulation is projected to increase gradually, as the continued increases in abundance of Newell's shearwater (ʻaʻo) colonies at the conservation sites overcomes the declines in abundance in the Kalalau east to Upper Mānoa, Hanalei to Kekaha, and Waimea Canyon areas (Figure 5E-7). The latter two areas have the highest initial modeled abundance, and in addition to the Kalalau to Upper Mānoa area, they also have a relatively high degree of uncertainty in terms of initial and therefore projected abundance (Table 5E-2). Therefore, the metapopulation projection, especially as it relates to the relative contribution of the abundance in the E-31forementioned areas to the overall island-wide trend, is also uncertain. However, the abundance and life history parameters of Newell's shearwater (ʻaʻo) within the conservation sites are relatively well understood given dedicated monitoring efforts at those sites, leading to higher confidence in the population projections in these areas. This means we have a relatively high confidence that the increase in subpopulations of the 10 conservation sites combined will provide a substantial net benefit to Newell's shearwater (ʻaʻo) on Kauaʻi.

Without the HCP, the Kauaʻi metapopulation of Newell's shearwater (ʻaʻo) would be approaching extirpation throughout much of its breeding range by 2073. Depending on the age structure and spatial distribution of the species at that time, it may become functionally extinct without conservation efforts under the HCP, due to the species' slow reproductive rate and other factors. However, with the continuation of conservation efforts associated with the HCP, by 2073 the metapopulation increase is forecast to continue. The 10 conservation sites are large enough in size and have such extensive suitable habitat for Newell's shearwater (ʻaʻo) that subpopulations (and densities) are expected to increase during the permit term without experiencing any density-dependent constraints outside of the smaller social attraction sites with predator exclusion fencing, assuming management actions continue at the same level as outlined in this HCP.

The cumulative number of strikes for each area from these modeled projections are provided in Table 5E-13. The predictions of strikes should be considered conservative (i.e., strike predictions may be too low) because these results are based on modeling a rate of decline for Hanalei to Kekaha that represents a worst-case scenario based on the most drastic rate of decline estimated from the 1993–2020 radar survey data. This rate of decline, while based on data, is more negative than the average rate of decline estimated across all radar sites in the Hanalei to Kekaha area during the same period; further, it does not reflect the more recent stabilization of trend across radar sites in this area during 2010–2020 (Raine and Rossiter 2020). Additionally, the 2010–2020 decade of radar data exhibiting a stable trend in relative abundance for the Hanalei to Kekaha area also overlaps in time with the estimate of unminimized seabird strikes from acoustic powerline monitoring data during 2013–2019 (Travers et al. 2020). Together, these two sources of monitoring data suggest that, at least during the last decade, the Hanalei to Kekaha subpopulation experienced a relatively high level of powerline mortality while also maintaining a stable abundance level. If this situation were to continue in the future (i.e., trends in both powerline strikes and abundance are stable), the modeled decline in abundance for Hanalei to Kekaha, and hence the modeled reduction in strikes associated with declining future abundance in this area, would underestimate future strikes.

Table 5E-10. Modeled Newell's Shearwater (ʻaʻo) Subpopulation Lambda Values, Starting with the First Year of the HCP (2023), and then Shown at Five-Year Snap-Shot Intervals over the 50-year Permit Term (to 2073)

Lambda is the population multiplier, i.e., the rate of change in abundance from the prior year is equal to one minus Lambda. Values of Lambda less than 1.0 represent a decline in abundance; values greater than 1.0 represent an increase. For example, a Lambda value of 1.01 represents a positive rate of change of 1 percent per year. The maximum possible intrinsic value for Lambda in the model is 1.024 (2.4 percent growth), which is never achieved in practice because each subpopulation (even those behind predator-proof fences) is assumed to have some level of vulnerability to introduced predators (e.g., barn owl predation) and some level of vulnerability to powerline collisions. Values in the table greater than 1.024 include a combination of births and deaths plus the assumed level of future immigration associated with social attraction sites. "NA" represents pre-operational social attraction sites.

Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
HCP Conservation Sites											
Upper Limahuli	1.013	1.014	1.010	1.008	1.008	1.008	1.009	1.017	1.017	1.017	1.032
Upper Limahuli PF	NA	NA	1.195	1.266	1.112	1.079	1.061	1.051	1.044	1.037	1.002
Conservation Site 10	1.014	1.014	1.011	1.009	1.009	1.008	1.008	1.008	1.008	1.050	1.047
Conservation Site 10 PF	NA	NA	1.195	1.266	1.113	1.08	1.061	1.052	1.045	1.005	1.000
Pōhākea	1.016	1.016	1.012	1.010	1.026	1.035	1.032	1.029	1.027	1.025	1.023
Pōhākea PF	NA	1.468	1.559	1.148	1.041	1.000	1.000	1.000	1.000	1.000	1.000
Pihea	1.012	1.013	1.009	1.006	1.007	1.008	1.008	1.007	1.010	1.008	1.008
North Bog	1.011	1.013	1.009	1.007	1.007	1.007	1.007	1.007	1.007	1.007	1.007
Hanakāpiʻai	1.014	1.015	1.011	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009
Hanakoa	1.016	1.016	1.013	1.011	1.011	1.010	1.010	1.010	1.010	1.011	1.011
Honopū	1.016	1.016	1.013	1.010	1.010	1.010	1.010	1.010	1.010	1.098	1.078
Honopū PF	NA	1.468	1.559	1.148	1.090	1.067	1.057	1.048	1.043	1.006	1.000
Other Areas (outside conservation sites)											
Wainiha and Lumahaʻi Valleys	1.000	1.000	0.997	0.994	0.994	0.994	0.994	0.994	0.994	0.994	0.994
Hanalei to Kekaha	0.929	0.939	0.935	0.930	0.928	0.924	0.919	0.91	0.894	0.864	0.882
Kalalau east to Upper Mānoa	0.971	0.971	0.968	0.965	0.965	0.965	0.965	0.965	0.965	0.965	0.966
Nā Pali Coast	1.001	1.001	0.998	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.995
Waimea Canyon	0.964	0.974	0.970	0.967	0.967	0.967	0.967	0.967	0.967	0.967	0.967
Kahuamaʻa (KSHCP)	NA	1.468	1.559	1.147	1.089	1.066	1.048	1.002	1.000	1.000	1.000

Table 5E-11. Modeled Newell's Shearwater (ʻaʻo) Breeding Pair Abundance (ages 6 years and older) at Five-Year Intervals for each Subpopulation over the 50-Year Permit Term (2023–2073)

Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
HCP Conservation Sites											
Upper Limahuli	509	541	567	585	604	623	642	696	753	811	957
Upper Limahuli PF	0	0	11	64	114	170	230	299	373	453	454
Conservation Site 10	203	217	228	236	245	253	261	270	279	350	444
Conservation Site 10 PF	0	0	11	64	114	171	232	301	376	396	396
Pōhākea	298	319	338	353	380	453	532	611	695	782	874
Pōhākea PF	0	6	40	94	136	136	136	136	136	136	136
Pihea	0	0	0	0	0	0	0	0	0	0	0
North Bog	68	72	75	77	79	81	83	85	88	90	92
Hanakāpiʻai	78	83	88	91	95	98	102	105	109	113	117
Hanakoa	46	49	53	55	58	60	63	65	68	71	74
Honopū	90	97	103	107	112	117	122	127	133	199	301
Honopū PF	0	6	40	94	149	209	279	354	437	468	468
Other Areas (outside conservation sites)											
Wainiha and Lumahaʻi Valleys	2,338	2,339	2,311	2,242	2,178	2,113	2,046	1,980	1,918	1,859	1,805
Hanalei to Kekaha	4,625	3,433	2,477	1,745	1220	844	574	381	245	149	82
Kalalau east to Upper Mānoa	749	647	553	463	389	325	272	227	190	159	133
Nā Pali Coast	410	412	410	400	391	382	372	362	353	344	336
Waimea Canyon	773	682	588	497	421	356	300	253	214	181	153
Kahuamaʻa (KSHCP)	0	3	20	47	74	103	136	136	136	136	136
Total	**10,186**	**8,907**	**7,913**	**7,215**	**6,759**	**6,494**	**6,381**	**6,391**	**6,501**	**6,696**	**6,958**

Table 5E-12. Modeled Newell's Shearwater (ʻaʻo) Total (non-chick) Abundance at Five-Year Intervals for each Subpopulation over the 50-Year Permit Term (2023–2073)

Initial abundance is based on the estimates of breeding pairs from ARC, with two exceptions: (1) Hanalei to Kekaha and (2) Waimea Canyon. In both cases, the pre-HCP abundance is estimated as a function of the allocated strikes for that area (86 percent and 10 percent of all strikes in each area) and trends in abundance from radar, which are assumed to be -10.7 percent and -6.9 percent per year in 2016, respectively, given the trend at the Hanalei radar site and the averaged trend across all radar sites on Kauaʻi during 1993–2020 (Raine and Rossiter 2020).

Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
HCP Conservation Sites											
Upper Limahuli	1,921	2,039	2,147	2,221	2,292	2,364	2,437	2,614	2,828	3,050	3,531
Upper Limahuli PF	0	0	35	195	397	609	838	1,099	1,379	1,684	1,761
Conservation Site 10	767	817	863	896	928	960	992	1,025	1,059	1,265	1,618
Conservation Site 10 PF	0	0	35	195	398	612	844	1,108	1,393	1,530	1,536
Pōhākea	1,123	1,204	1,280	1,338	1,421	1,672	1,967	2,271	2,588	2,920	3,268
Pōhākea PF	0	18	114	320	501	529	529	529	529	529	529
Pihea	1	1	1	1	1	1	1	1	1	1	1
North Bog	256	271	284	292	301	309	316	324	333	341	350
Hanakāpiʻai	294	314	332	346	359	373	386	399	414	429	445
Hanakoa	173	187	199	209	218	228	238	248	259	270	282
Honopū	341	365	389	408	426	445	463	483	503	687	1,063
Honopū PF	0	18	114	320	528	758	1,020	1,306	1,623	1,807	1,818
Other Areas (outside conservation sites)											
Wainiha and Lumahaʻi Valleys	8,118	8,117	8,046	7,831	7,605	7,378	7,146	6,916	6,698	6,493	6,300
Hanalei to Kekaha	14,985	10,896	7,849	5,491	3,783	2,559	1,681	1,056	612	310	163
Kalalau east to Upper Mānoa	2,422	2,093	1,792	1,506	1,263	1,058	885	740	619	518	434
Nā Pali Coast	1,422	1,431	1,427	1,397	1,365	1,332	1,298	1,264	1,232	1,201	1,172
Waimea Canyon	2,724	2,362	2,047	1,738	1,471	1,244	1,050	885	747	631	534
Kahuamaʻa (KSHCP)	0	9	57	159	262	375	500	528	528	528	528
Total	**34,546**	**30,140**	**27,010**	**24,864**	**23,520**	**22,804**	**22,592**	**22,796**	**23,343**	**24,194**	**25,334**

Table 5E-13. Modeled Newell's Shearwater (ʻaʻo) Strikes, Starting with the First Year of the HCP (2023), and then Shown as a Cumulative Total at Five-Year Intervals for each Subpopulation until the End of the Permit Term (2073)

Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
HCP Conservation Sites											
Upper Limahuli	19	115	217	324	434	548	665	788	919	1,061	1,218
Upper Limahuli PF	0	0	0	4	16	38	72	117	175	247	331
Conservation Site 10	6	36	67	100	135	171	208	246	285	327	379
Conservation Site 10 PF	0	0	0	3	12	30	56	91	136	191	250
Pōhākea	4	23	44	67	90	115	145	180	220	266	318
Pōhākea PF	0	0	1	3	10	19	28	37	46	55	64
Pihea	0	0	0	0	0	0	0	0	0	0	0
North Bog	3	19	36	54	72	91	110	130	150	171	192
Hanakāpiʻai	2	11	21	31	41	52	64	76	88	101	114
Hanakoa	0	2	3	4	6	8	9	11	13	15	17
Honopū	1	4	8	12	16	21	25	30	35	40	48
Honopū PF	0	0	0	2	6	12	20	32	46	63	82
Other Areas (outside conservation sites)											
Wainiha and Lumahaʻi Valleys	47	279	511	741	963	1,179	1,389	1,592	1,789	1,979	2,164
Hanalei to Kekaha	1,616	8,203	12,924	16,307	18,649	20,231	21,264	21,901	22,253	22,401	22,437
Kalalau east to Upper Mānoa	14	76	130	176	215	247	274	297	316	332	345
Nā Pali Coast	3	17	30	44	58	71	83	96	108	120	131
Waimea Canyon	266	1,483	2,520	3,420	4,184	4,831	5,377	5,839	6,228	6,556	6,834
Kahuamaʻa (KSHCP)	0	0	1	3	9	18	30	45	61	78	94
Total	**1,979**	**10,268**	**16,515**	**21,296**	**24,917**	**27,681**	**29,821**	**31,507**	**32,869**	**34,005**	**35,019**

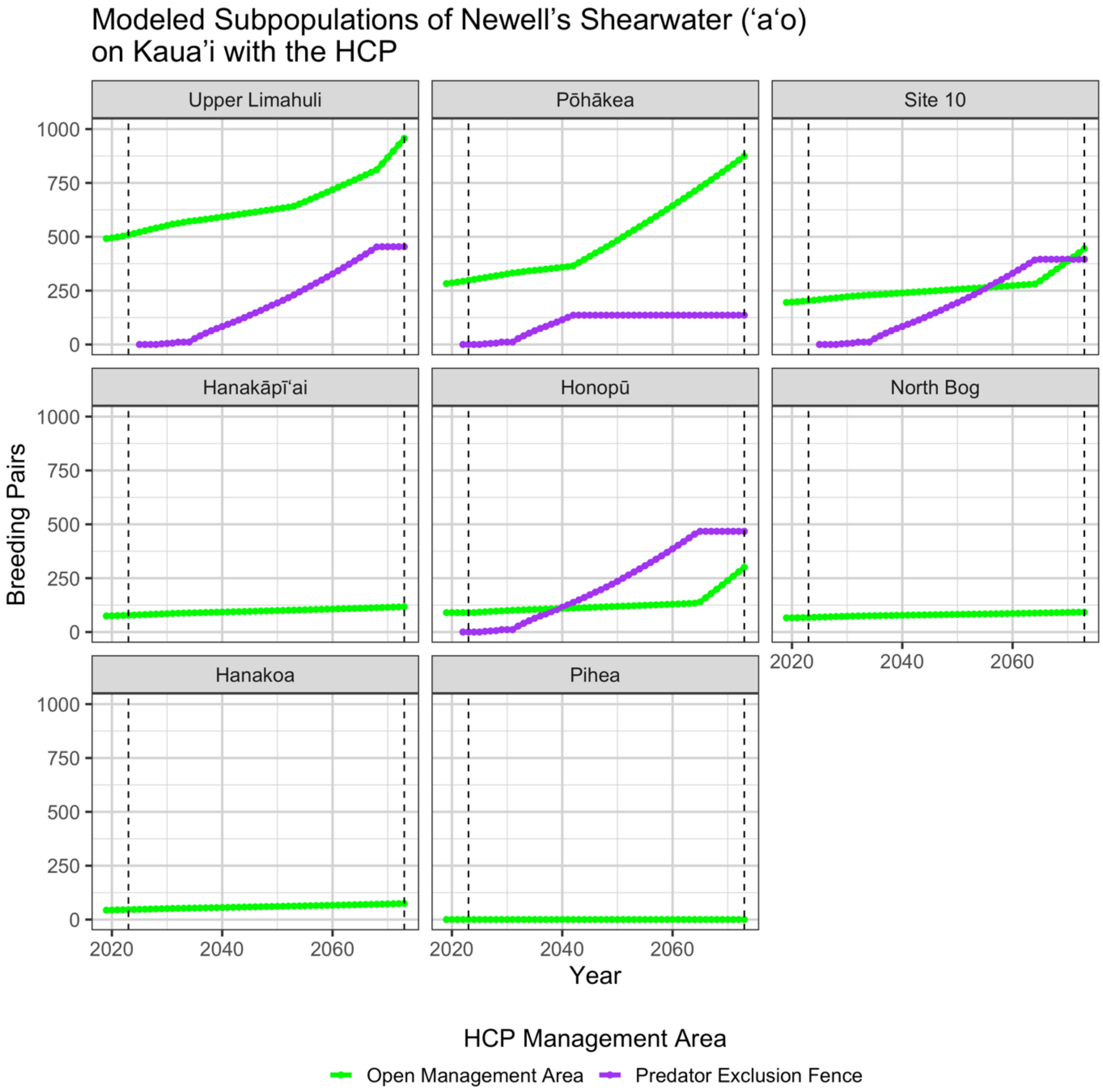

Figure 5E-3. Population Dynamics Model Results for Newell's Shearwater (ʻaʻo) for each Subpopulation at the Conservation Sites showing the Relative Contribution of Different Management Areas to Breeding Pair Abundance

Purple lines show breeding pair abundance in the social attraction sites enclosed with predator exclusion fences (PF). These trajectories plateau at the nesting burrow carrying capacities estimated for each site inside the proposed PF area. It is assumed that social attraction will continue in the future and that once the PF carrying capacities are reached, new breeding pairs (either those hatched in the PF, or prospecting subadults attracted from other areas) will spill over to nest in the surrounding open management area under predator control measures. Green lines show breeding pair abundance in the open management areas. The leftmost vertical dashed line denotes the first year of the proposed HCP (2023) and the rightmost vertical dashed line denotes the end of the 50-year permit term (2073). See Figure 5E-1 for site locations.

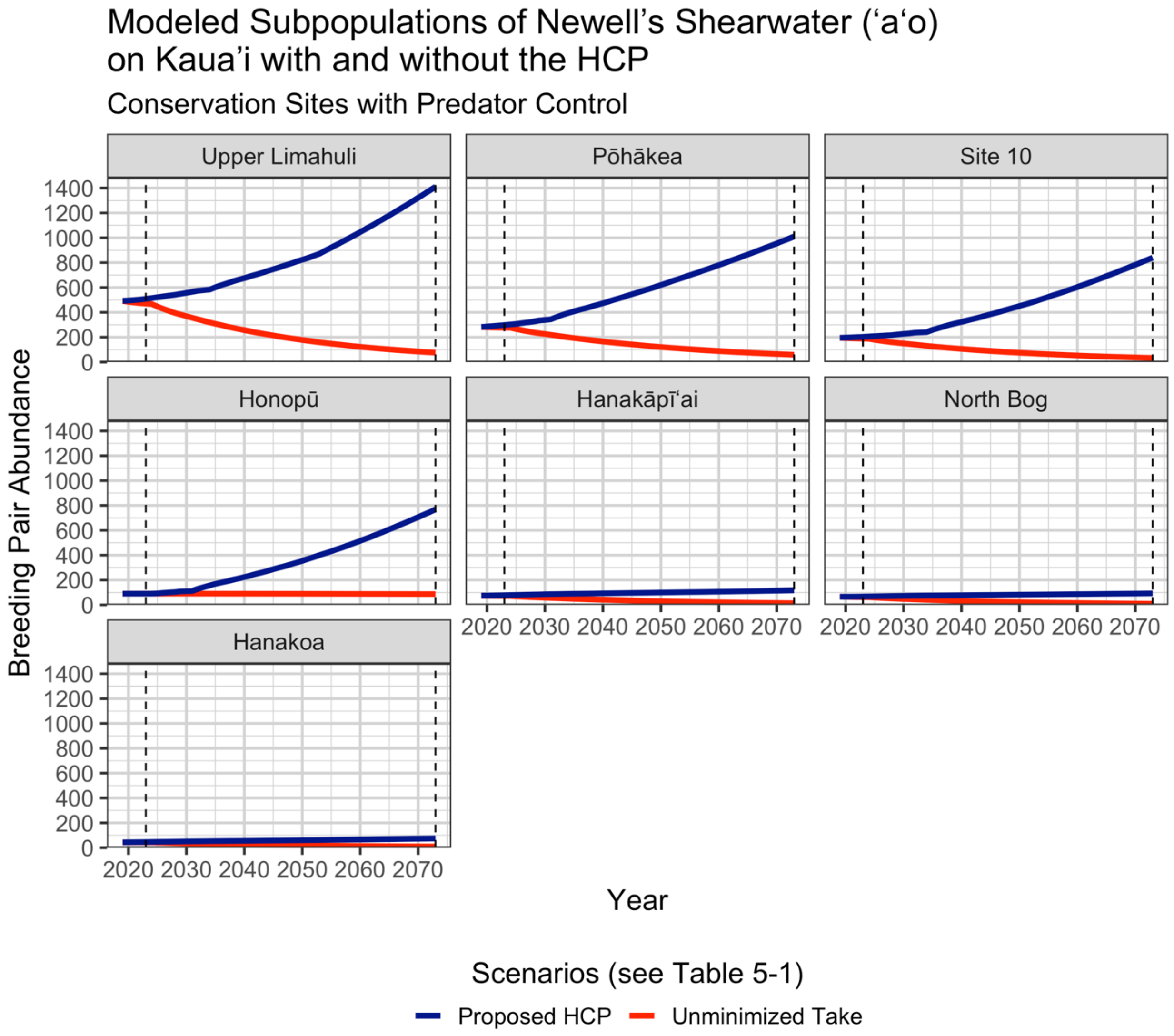

Figure 5E-4. Population Dynamics Model Results for Newell's Shearwater (ʻaʻo) for each Subpopulation with Predator Control Measures and Ungulate Fencing

Red lines show the unminimized take model scenario without the HCP (take continues without powerline minimization, and without conservation measures; see Table 5-1 in Chapter 5). Blue lines are with the proposed HCP according to the schedule of conservation measures described in Chapter 4. The vertical dashed lines denote the first and last year of the permit term. See Figure 5E-1 for site locations. Note: Pihea is not shown in this plot because no appreciable number of Newell's shearwater (ʻaʻo) are estimated to be associated with that area.

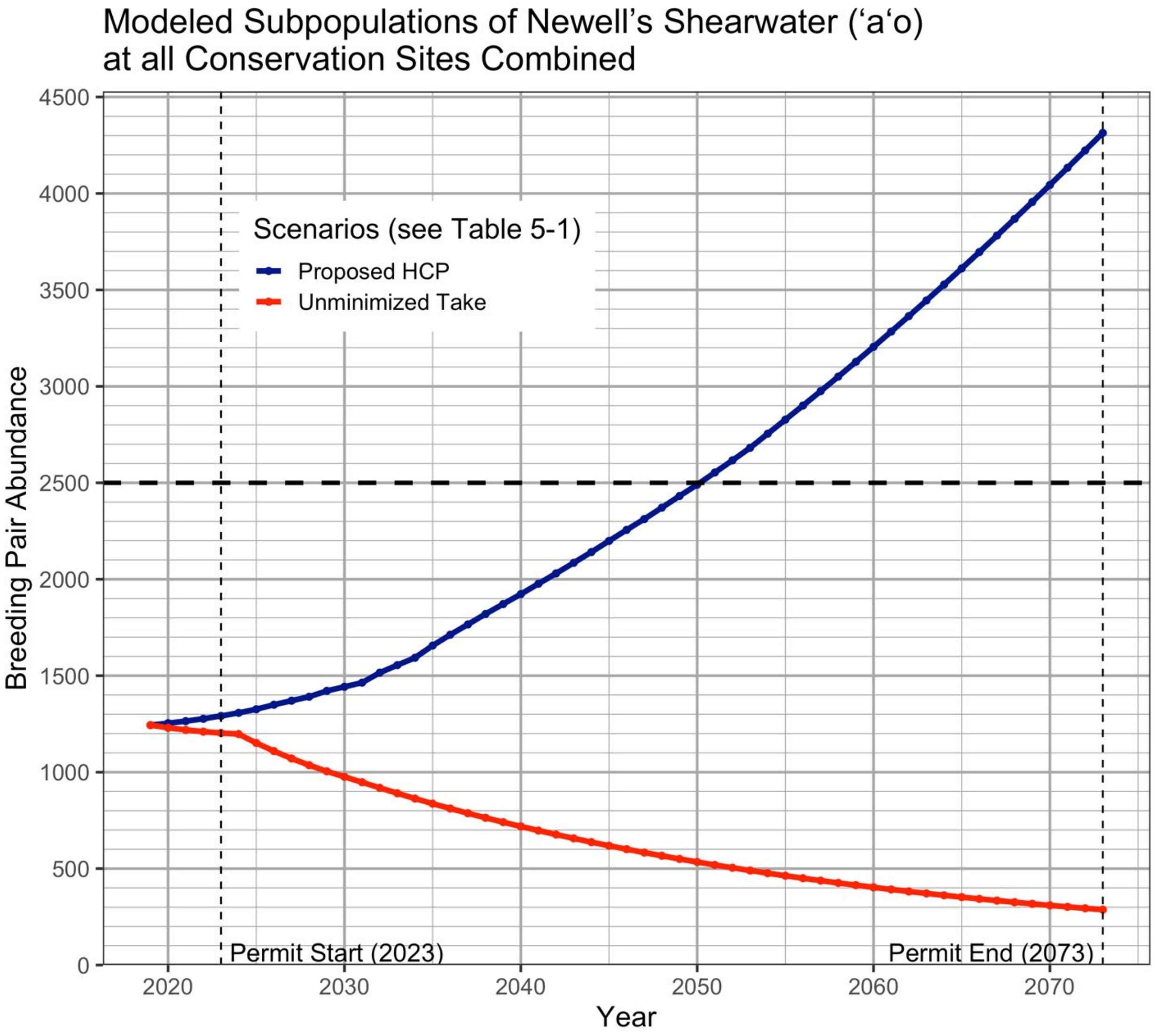

Figure 5E-5. Population Dynamics Model Results for Newell's Shearwater (ʻaʻo) for all 10 Conservation Sites Combined

Red line shows the unminimized take scenario without the HCP (take continues without powerline minimization, and without conservation measures; see Table 5-1 in Chapter 5). Blue line is with the HCP according to the schedule of conservation measures described in Chapter 4. The benefits of the KSHCP Kahuamaʻa social attraction site (with predator-proof fencing) are included in both lines. The horizontal dashed line highlights 2,500 breeding pairs, which the U.S. Fish and Wildlife Service considers to be a rough threshold for a viable metapopulation on the island (see Chapter 5 for details).

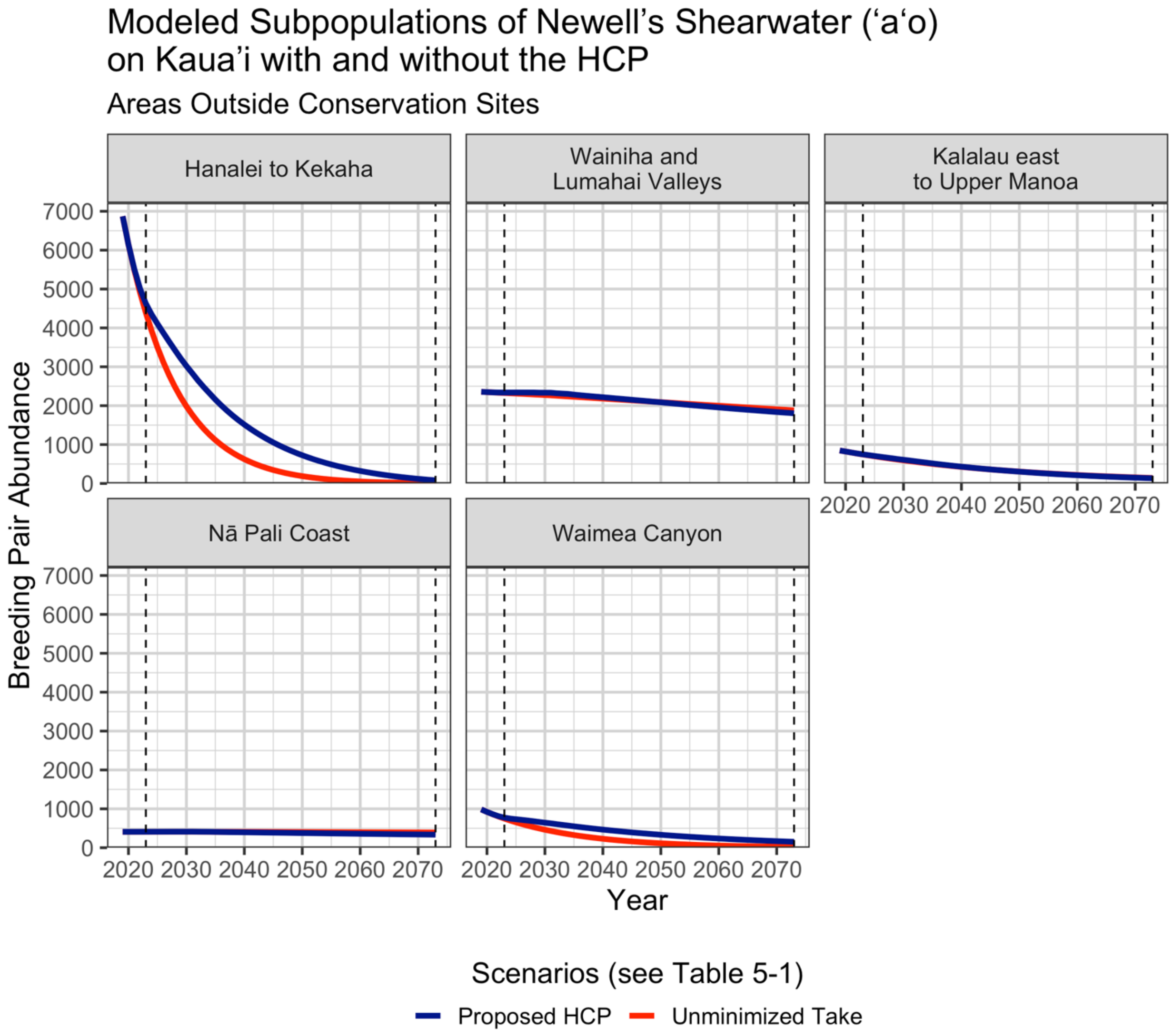

Figure 5E-6. Population Dynamics Model Results for Newell's Shearwater (ʻaʻo) for each Subpopulation outside the Conservation Sites

Red lines show the unminimized take model scenario without the HCP (take continues without powerline minimization, and without conservation measures; see Table 5-1 in Chapter 5). Blue lines are with the proposed HCP according to the schedule of conservation measures (i.e., powerline collision minimization) described in Chapter 4. The vertical dashed lines denote the first and last year of the permit term. See Figure 5E-1 for site locations.

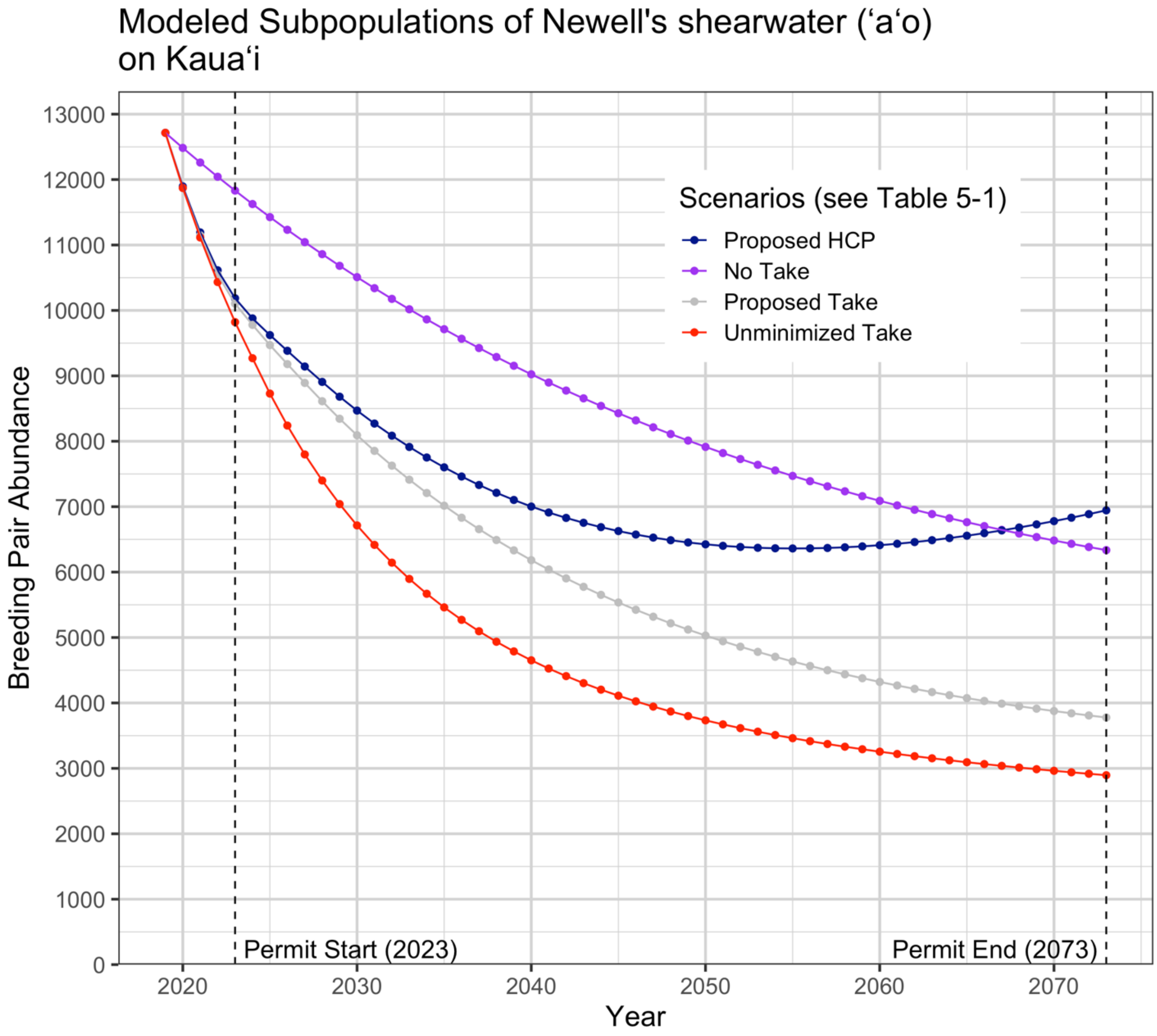

Figure 5E-7. Population Dynamics Model Results for Newell's Shearwater (ʻaʻo) for all Subpopulations Combined (all of Kauaʻi)

Red line is the unminimized take model scenario without the HCP (take continues without powerline minimization, and without conservation measures). Blue line is with the proposed HCP according to the schedule of conservation measures (i.e., powerline collision minimization) described in Chapter 4. The grey line is with the proposed minimized take; the purple line is with no take. See Table 5-1 in Chapter 5 for additional description of each model scenario. The vertical dashed lines denote the first and last year of the permit term.

5E.3 Model Limitations, Uncertainties, and Assumptions

The population dynamics model described in this appendix is a useful tool with which to compare outcomes to Newell's shearwater (ʻaʻo) on Kauaʻi both with and without the KIUC HCP. The model is also an important tool to confirm that the quantitative biological objectives for Newell's shearwater (ʻaʻo), particularly at the conservation sites, can be achieved by the end of the permit term. However, as with all models there are uncertainties in model inputs and outputs that should be considered. Model limitations include, but are not limited to, the following.

- Lack of statistical confidence limits around the island-based estimates of abundance.
- Uncertainty in certain vital rates (e.g., barn owl predation rates on the wing and predation rates in areas without predator control and burrow monitoring).
- Uncertainty in the efficacy of future powerline strike minimization efforts (although continued powerline monitoring will help narrow those uncertainties within a few years).
- Logistical difficulties in monitoring the population outside of established conservation sites.

Due to these limitations, the uncertainty in the model results has not been quantified. However, any population dynamics model of Newell's shearwater (ʻaʻo) relies on a suite of assumptions. The assumptions chosen for this model were selected to be as conservative as reasonably possible knowing that many model uncertainties have not been quantified. A list of the key assumptions is provided below for this model, with reasons these assumptions may be conservative or optimistic in terms of predicting effects of the HCP conservation measures on this species. These sections are intended to provide the reader with a qualitative understanding of the level and sources of uncertainty in model results.

5E.3.1 Conservative Assumptions

Reasons why the population dynamics model may be conservative (i.e., overestimates adverse effects or underestimates beneficial effects for Newell's shearwater [ʻaʻo]) include the following.

- **Total powerline strikes.** The reported point estimate that is used as a model input for the annual average of seabird strikes corresponds to the mean of the Bayesian posterior predictive probability distribution, corrected to account for strikes that were subsequently recategorized as waterbirds (Travers et al. 2020; Travers, unpublished data). For a right skewed (longer right tail) probability distribution, like the Bayes posterior predictive probability distribution for seabird strikes, the mean is greater than the expectation of the estimate. Statistically, this results in using a conservative (i.e., higher) level of powerline collisions in the model than would be expected from the data.
- **Strike allocation.** Allocation of powerline strikes may be even lower at some or all of the conservation sites than estimated, given flight paths, and observed altitudes from satellite tagging. For example, the estimated breeding probability from burrow monitoring data at seven conservation sites for Newellʻs shearwater (ʻaʻo) during 2012–2019 is 0.993 (Raine et al. 2022b), which indicates that non-predation sources of mortality for breeding adults were quite low in these areas.

- **Population trend and optimal growth rate.** The modeled population trend for the Hanalei to Kekaha area assumes a relatively steep rate of decline, based on the long-term trend from the Hanalei radar site. Given both recent and longer term radar trends from the other non-Hanalei radar sites, the population trend is unlikely to be that steep for all breeding colonies in this area.

  Raine and Rossiter (2020) have shown that the average trend in radar estimates across sites has leveled out since 2010, indicating that after a very large decline in abundance the population trend may now be relatively stable in the Hanalei to Kekaha area. For example, a regression of radar data including all 13 monitored sites was flat with no significant increase or decrease during the last decade (2010–2020). This seems to suggest that during the last decade mortality levels have decreased, perhaps due to mechanisms like remaining colonies being confined to habitat that is less accessible to introduced predators (Raine and Rossiter 2020).

  This pattern is also consistent with data on the amounts of rescues of Newell’s shearwater (‘a‘o) from the SOS Program, which are relatively stable over a similar period (Ainley et al. submitted).

  Therefore, based on these three data sources (radar signatures, SOS rescues, and acoustic call rates) the aggregate modeled population trend in the absence of minimization and mitigation is likely to be conservative, at least in terms of observed trends over the last decade. If the aggregate population trend is more positive (either a smaller negative number or a number close to zero for a stable population), then the effects of the HCP conservation strategy will result in a greater benefit to the island-wide metapopulation of Newell’s shearwater (‘a‘o) than what is estimated.

  It is also worth noting that the optimal rate of modeled population growth assumed in the model is much lower than has been estimated for the family Procellariidae (all petrels, prions and shearwaters) in many published allometric and demographic modeling studies. The results of those studies are consistent with species in this seabird family having expected maximum rates of population growth closer to 6.8 percent per year (Dillingham et al. 2016) or 7.1 percent per year (Dillingham and Fletcher 2011), depending on the methods used. This model assumed a maximum rate of modeled population growth (i.e., in the absence of introduced predators, powerline strikes or light fallout mortality) of 2.36 percent per year.

- **Social attraction.** Birds are assumed to be attracted to social attraction sites with an equal per capita probability from all other areas for which island-based abundance estimates are available.[8] This is a reasonable assumption without any data to suggest otherwise.[9] However, the assumption may be conservative. If birds attracted to social attraction sites come mostly from non-managed sites, then the benefits to the island-wide metapopulation of the social attraction sites would be even greater than what the model estimates.

  Additionally, the modeled dynamics of social attraction sites ignore any benefits that nearby nesting birds may have in terms of attracting prospecting birds. The modeled numbers at social attraction sites start at zero birds for the first 3 years, then slowly increase with an average of 1.6 new breeding pairs during the first 9 years, after which that number increases to an average of 13.7 new breeding pairs becoming established each year (Table 5E-9). In other words, there

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[8] The exception to this is when a bird is born into a social attraction site after social attraction begins, that bird is assumed to return to that site or spillover and nest in the surrounding open management area for the rest of its life and not emigrate to another social attraction site. In general, the model assumes natal fidelity and internal recruitment to each modeled area, with the exception being dispersal of breeding age birds into the social attraction sites from other areas.

[9] Social attraction assumptions were based, in part, on published literature for similar seabirds outside of the Hawaiian Islands.

is a lag before social attraction sites reach a critical mass and start attracting more than 10 breeding pairs per year. Given that the planned social attraction sites exist in areas with existing breeding pairs nearby (e.g., at Upper Limahuli), there may be less of a time lag for the initial rate of attraction to social attraction sites than assumed in the model. If this is the case, the growth at a conservation site would be faster than predicted by the model, resulting in a larger conservation site subpopulation at the end of the permit term than predicted.

- **Fallout from light attraction.** A constant number of 92.6 age-1 (fledglings) from the Hanalei to Kekaha subpopulation are assumed to die annually from fallout associated with KIUC facilities and streetlights. The estimated level of fallout includes correction factors for the proportion of grounded seabirds that go undetected, e.g., for KIUC streetlights, 89.6% of grounded Newell's shearwater (ʻaʻo) are assumed to go undetected (Appendix 5C: *Light Attraction Modeling*). Fallout, whether detected or not, is assumed to result in 100% mortality in the model. This assumption is conservative for three reasons: (1) The estimate for fallout is based on the number of expected streetlights and facility lights at the end of the permit term, not at the beginning. Fallout from light attraction is therefore likely overestimated at the start of the projections; (2) This assumes zero individuals rehabilitated by the SOS program survive; and, (3) Fallout mortality is modeled as a fixed number of fledglings lost, not a mortality rate. In other words, even when the Hanalei to Kekaha subpopulation is much smaller at the end of 50 years, 92.6 fledglings (or the number of modeled fledglings produced, whichever is smaller) are still removed in the model from this area each year. Furthermore, the level of mortality from fallout is estimated to be less than five percent of the level of mortality estimated from powerline collisions. So, while fallout mortality is a contributing factor to metapopulation dynamics, it does not have as large of an effect on metapopulation trends as powerline collisions.
- **Conservation actions performed by others.** The population dynamics of the Kauaʻi metapopulation of Newell's shearwater (ʻaʻo) are modeled only assuming the full implementation of this HCP's conservation strategy and that of the KSHCP (i.e., the Kahuamaʻa social attraction site). Numerous federal, state, and local agencies and conservation organizations are either implementing or planning to implement additional conservation actions separately from this HCP and the KSHCP, and which will benefit Newell's shearwater (ʻaʻo). Similarly, due to a lack of available estimates for reductions in predation rates resulting from barn owl control at the conservation sites, no attempt has been made to include the benefit of that form of predator control effort at the conservation sites. Because this model does not consider these other current or planned conservation actions, the impacts of the taking of this HCP are conservative (i.e., overestimates effects).

5E.3.2 Potentially Optimistic Assumptions

Reasons why the population dynamics model for Newell's shearwater (ʻaʻo) may be too optimistic (i.e., underestimates adverse effects or overstates benefits) include the following.

- **Total metapopulation size.** The estimate of the island-wide metapopulation may be too high, despite the integration of multiple independent data sources, and what are thought to be conservative assumptions by experts. If this is true, then impacts of the taking would be greater than predicted by the model. However, all else being equal, the *relative* effects of the HCP would be the same because the comparison is made with and without the HCP using the same initial abundance estimate and estimates of trends in relative abundance (i.e., positive trends in call rates from the conservation sites and negative trends in relative abundance from the radar survey). Also, if a smaller value for metapopulation abundance were used, the modeled trend would become inconsistent with long-term monitoring data (e.g., the modeled rate of decline in the Hanalei to Kekaha area would be even more negative compared to the lowest estimated rates of decline from the radar survey). Such a steep rate of decline, which would result from the estimated number of powerline collisions if abundance was indeed lower would not be supported by the best available science on long-term trends in abundance.

- **Social attraction.** As noted above, birds are assumed to be attracted to social attraction sites with an equal per capita probability from all other sites (e.g., if half the island-wide population is estimated to be from Hanalei to Kekaha area in a given year, then half the number of birds immigrating into social attraction sites would be from Hanalei to Kekaha that year). Shearwaters and petrels are known to have a high level of natal fidelity (e.g., Harris 1966; Perrins et al. 1973; Warham 1980), however, and therefore this assumption could be optimistic because it would result in more immigration from areas with high predation and powerline mortality rates into "safe havens" than under a stronger model of natal fidelity.
- **Cat predation events.** The model is deterministic, which means that mortality and reproductive rates are assumed to be constant between years (with the exceptions of powerline collision minimization and the effects of immigration into social attraction sites). As such, interannual variation (stochasticity) in predation rates is not modeled even though the number of predations by cats can be variable between years. In particular, there have been instances of individual cats predating multiple nests during certain years before they have been caught. As such, a conservation site may have low predation mortality rates for a period of years, with an incursion of a single problem cat one year leading to a spike in predation mortality rates that year. Breeding pairs and chicks inside predator exclusion fences may be subject to such events in rare instances (i.e., before the cat incursion is caught on camera and additional control efforts can be deployed). Such events may also occur outside of conservation sites despite aggressive predator control techniques.

  The predation mortality rates used in the model are based on burrow monitoring data from multiple conservation sites over multiple years. The resulting estimate represents an average annual predation mortality rate under predator control that includes punctuated predation mortality events due to single cats. If the estimated predation mortality rate from burrow monitoring surveys does not fully capture the extent or frequency of these predation events, the model results with respect to the benefits of predator control at the conservation sites would be optimistic. However, independent acoustic monitoring data indicate that at least since 2014/2015, the extent of punctuated cat predation events has not resulted in negative trends in recruitment into the breeding colonies at the conservation sites. Instead, call rates have continued to increase, and have doubled at most of the conservation sites under predator control efforts (Raine et al. 2022a). Call rates have continued to increase, despite predation events having occured during the same time.
- **Carrying capacity.** Social attraction sites inside predator exclusion fenced sites are modeled using estimates of carrying capacity for the number of breeding pairs that could nest in these areas. These sites are relatively small and available nesting habitat is well defined by the fenced permiter. Additionally, the rate of increase in breeding pairs in these areas is assumed to be relatively high after 10 years, given the expected number of new immigrants attracted to these areas once they reach a critical mass (Table 5E-9). Therefore, reaching carrying capacity of breeding pairs during the permit term seems likely.

Conversely, there is no assumption in the model that population growth in the adjacent management areas will be limited by carrying capacity during the 50-year permit term. If, in the future, population growth in the adjacent mangement areas is limited by the carrying capacity of suitable nesting habitat, and there is emigration out of those conservation sites to areas without the benefit of predator control and where powerline collision vulnerability may be higher, the model results would overestimate the long-term benefit of the conservation sites to the metapopulation. However, not only are carrying capacities difficult to estimate reliably for the large, adjacent management areas, but estimates of predation rates prior to dedicated predator control in the conservation sites in combination with the assumed low rates of population recovery suggest that reaching carrying capacity in the adjacent management areas is not likely during the permit term.

- **Allee effects.** The model does not account for compensatory or depensatory density dependence on the population growth rate. The former would account for higher expected population growth rates at lower population sizes, for example due to decreasing competition for resources. The latter, also known as "Allee" effects, arises in situations where population growth rates might be expected to decrease at lower abundance levels, for example due to difficulties finding a mate at low densities. Given that Newell's shearwater (ʻaʻo) is a threatened species with a low intrinsic rate of increase, there does not seem to be support for considering compensatory density dependence during the permit term. However, if modeled subpopulations that are predicted to be vulnerable to large declines (e.g., Waimea Canyon and Hanalei to Kekaha areas) experience Allee effects at lower densities in the future, the degree of the modeled declines there could be optimistic. There is no indication that Allee effects are occurring at recent abundance levels, at least at the broader scales monitored by the radar survey. Recent population trends from the radar data seem to be generally flattening out instead of showing accelerating rates of decline (Raine and Rossiter 2020), but Allee effects are a possibility at smaller spatial scales with remnant breeding colonies in areas of the island without predator control.

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Appendix 5F

Population Dynamics Model for Hawaiian Petrel (‘ua‘u) on Kaua‘i

The purpose of this appendix is to describe the population dynamics models developed by KIUC for Hawaiian petrel (ʻuaʻu). The population dynamics model for Newell's shearwater (ʻaʻo) is presented in Appendix 5E, *Population Dynamics Model for Newell's Shearwater (ʻaʻo) on Kauaʻi*.

A population dynamics model was not developed for band-rumped storm-petrel (ʻakēʻakē) because of the lack of data on this species.

The population dynamics model for Hawaiian petrel (ʻuaʻu) was developed for the following specific uses in the HCP.

1. To evaluate the effects of the requested take authorization of the species from KIUC's covered activities (described in Chapter 5, *Effects*) in the absence of any mitigation.
2. To quantify the benefits of the conservation measures proposed in Chapter 4, *Conservation Strategy*, to the Kauaʻi metapopulations of these species.
3. To determine the net effects of the HCP covered activities and conservation measures on the Kauaʻi metapopulation of this species and to quantify the net benefit provided by the HCP.
4. To track population trends during HCP implementation over the 50-year permit term.

This appendix is divided into four sections: (1) Overview of the model, including methods, initial conditions, technical specifications, and tables with model input values, (2) Model results, (3) A discussion of model limitations, uncertainties, and assumptions, and (4) References cited.

The appendix and population dynamics models were developed by John R. Brandon, PhD, Senior Biometrician at ICF with extensive review by David Zippin, PhD, Senior Conservation Biologist. Dr. Brandon designed the mathematics and code for the modeling framework. Model inputs were developed in close collaboration with André F. Raine, PhD, Science Director for Archipelago Research and Conservation (ARC) and Marc Travers, MS, Senior Scientist at ARC, both of whom are experts on seabird biology and lead scientists on multiple studies of endangered seabirds on Kauaʻi. Dr. Raine and Mr. Travers provided input and data for many of the model parameters as cited throughout the appendix.

5F.1 Overview of the Population Dynamics Models

The model for Hawaiian petrel (ʻuaʻu) is composed of nine distinct subpopulations. Six of the subpopulations correspond to conservation sites proposed in the HCP where Hawaiian petrel (ʻuaʻu) breeding pairs are estimated to occur. Breeding pairs of Hawaiian petrel (ʻuaʻu) have not been observed and are not predicted based on habitat suitability models (Troy et al. 2017) to nest at Conservation Site 10.[1] Hence, unlike Newell's shearwater (ʻaʻo) a subpopulation of Hawaiian petrel (ʻuaʻu) was not modeled for this conservation site. Likewise, it was assumed that the planned social attraction site at Conservation Site 10 would not benefit this species. In general, the social attraction site efforts are not aimed at attracting Hawaiian petrel (ʻuaʻu). For example, species-specific playback calls are only planned for Newell's shearwater (ʻaʻo). Therefore, it is assumed that no Hawaiian petrel (ʻuaʻu) will immigrate into the social attraction sites. The modeled subpopulations

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[1] KIUC will select a tenth conservation site (Conservation Site 10) but the final location of this site is still under evaluation. See Figure 4-6 for the general location of the site. The conservation benefits of Site 10 are based on the previously selected site that proved infeasible (Upper Mānoa Valley). KIUC will ensure that Site 10 will provide equal or greater benefit than the Upper Mānoa Valley site it is replacing.

are listed in Table 5F-1 with their locations illustrated in Figure 5F-1 (see Chapter 4, *Conservation Strategy*, and Appendix 4A, *Conservation Site Selection*, for a map and details of the corresponding conservation sites).

Outside of the six conservation sites with Hawaiian petrels (ʻuaʻu), the rest of Kauaʻi was subdivided into three subregions[2] that correspond to the known metapopulation distribution of this species on Kauaʻi (see Figure 2 in Appendix 3A, *Species Accounts*). Unlike Newell's shearwater (ʻaʻo), no Hawaiian petrel (ʻuaʻu) are estimated to occur in the Waimea Canyon area, but they are known to occur in the Hanalei to Kekaha area, the Wainiha and Lumahaʻi Valleys area, and the Kalalau east to Upper Mānoa area, so these areas were included in the model for this species. Each area in the model encompasses a geographic portion of the island that has similar conservation threats and management efforts for the species, as well as similar available data sources for estimating the abundance and trends of breeding pairs that nest there (Table 5F-2).

The modeling framework allows each subpopulation to have its own set of vital rate values and therefore different trends in abundance through time. This reflects the fact that pressures such as powerline collisions and predation vary depending on region and topography. For example, the remote areas in the northwestern region of the island do not have powerlines (see Figure 5F-1). Available tagging data is consistent with the flyways of breeding colonies in those areas, resulting in little to no vulnerability to powerline collisions (e.g., Raine et al. 2017a). For breeding colonies in northwestern Kauaʻi (including the conservation sites), where powerline collision vulnerability is low and predator control efforts have been effective, acoustic monitoring data has demonstrated increases in abundance since 2014–2015 (Raine et al. 2022). The opposite is true in other areas of the island where breeding colonies are particularly vulnerable to powerline collisions and light attraction. Examples include those sites that have flyways crossing the Powerline Trail in the middle of the island, where collisions are known to be highest (Travers et al. 2020; also see Figure 5-1 for estimated relative rates of bird strikes per wire span).

Furthermore, available monitoring data also differs by each area. For example, radar survey data, which is the longest running systematic monitoring study to estimate trends in relative abundance for this species on Kauaʻi, are only available from areas with road access (the radar system is mounted on a vehicle).

The spatially explicit model developed here accounts for these differences and complexities in the overall metapopulation dynamics and allows monitoring data (e.g., trends) from different areas to be incorporated in the model. The vital rates for each subpopulation are also modeled to change through time as future management efforts are implemented, corresponding to the timeline of these measures described in Chapter 4, *Conservation Strategy*. For example, increases in estimated powerline strike minimization efficacy are modeled through time to reduce powerline strike mortality rates. Similarly, the timing of installation of predator exclusion fencing around particular management sites are modeled to reduce predation mortality rates for the corresponding subpopulations at those sites in future years.

Island-based estimates of abundance for each subpopulation are used to initialize population trajectories, which are then projected forward in time through the 50-year permit term. For

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[2] Unlike Newell's shearwater (ʻaʻo; Appendix 5E), there were zero Hawaiian petrel (ʻuaʻu) breeding pairs estimated in one of the four subregions of Kauaʻi outside the conservation sites. The breeding pair estimates for Hawaiian petrel (ʻuaʻu) are described in Section 1.1, *Initial Conditions*. Subpopulation dynamics of Hawaiian petrel (ʻuaʻu) were not modeled for those subregions with zero estimated breeding pairs.

simplicity, the model does not assume any dispersal among the Kauaʻi subpopulations, which is reasonable because shearwaters and petrels exhibit strong natal philopatry[3] (e.g., Harris 1966; Perrins et al. 1973; Warham 1980) and established breeding pairs typically return to the same nesting burrow year after year. The model also does not assume any dispersal between Kauaʻi and other islands in Hawaiʻi.

Table 5F-1. Modeled Subpopulations, HCP Status, and Associated HCP Management Actions

Modeled Subpopulation	HCP Status	HCP Management Actions (see Chapter 4 for details)
Pihea[a]	Conservation site	Predator control[b] and partial pig fence
North Bog[a]	Conservation site	Predator control[b] and partial pig fence
Pōhākea[a]	Conservation site	Predator control[b] and partial pig fence
Hanakāpiʻai[a]	Conservation site	Predator control[b]
Hanakoa[a]	Conservation site	Predator control[b]
Upper Limahuli Preserve[a]	Conservation site	Predator control[b] and ungulate exclusion fencing
Hanalei to Kekaha	N/A	None
Wainiha and Lumahaʻi Valleys	N/A	None
Kalalau east to Upper Mānoa (excluding conservation sites)	N/A	None

[a] Ungulate (deer, pig, and goat) exclusion or partial pig exclusion fence is already in place. Partial pig exclusion fences block pigs from accessible portions of a site's perimeter.
[b] Predator control involves species specific efforts for ungulates, cats, rodents, and barn owls.

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[3] *Natal philopatry* is the tendency of an animal to return to breed in the place of its birth.

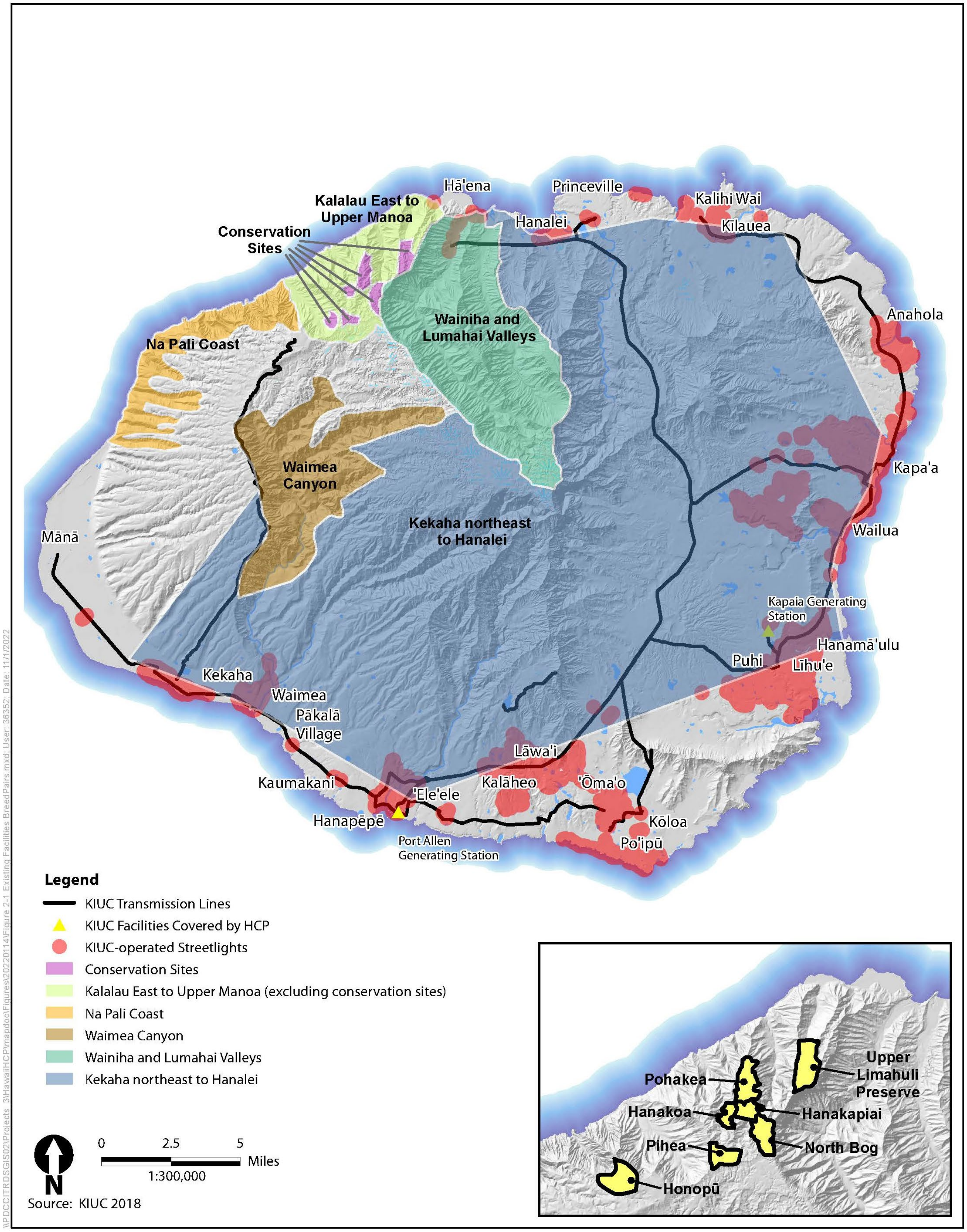

Figure 5F-1. Locations of Regional Subpopulations in Population Dynamics Models for Hawaiian Petrel (ʻuaʻu) and Location of KIUC's Covered Facilities

5F.1.1 Initial Conditions

The initial conditions for the model were set in 2019, before projections forward in time from that year were carried out. Modeled reductions in powerline line mortality rates due to minimization efforts that are accounted for in the model start in 2020. Population trajectories for Hawaiian petrel (ʻuaʻu) were based on the following parameter categories, each of which is described below:

1. Estimates of **abundance** on Kauaʻi.
2. **Vital rates** by age class under optimal conditions (i.e., natural mortality rates in the absence of introduced predators and powerlines).
3. Estimates of **powerline injury and mortality**, prior to 2020 minimization efforts.
4. Estimates of **predation rates** with and without predator control measures.
5. For the Hanalei to Kekaha area and the Waimea Canyon area, the modeled abundance was initialized based on **trends from the long-term radar survey**, in combination with estimates of powerline injury and mortality, prior to 2020 minimization efforts.

5F.1.1.1 Estimates of Abundance on Kauaʻi

All population dynamics models must begin with an estimate of initial population size to forecast future abundance levels. Published estimates of abundance for Hawaiian petrel (ʻuaʻu) are available from transect surveys conducted on ships at sea (Spear et al. 1995; Joyce 2016). Because of the use of these estimates in previous studies for listed seabirds on Kauaʻi, the at-sea population estimates and their limitations are summarized below. This summary is followed by an explanation of the methods used for this HCP to develop a spatially explicit metapopulation abundance estimate of Hawaiian petrel (ʻuaʻu) on Kauaʻi.

At-Sea Abundance Estimates

Seabird populations are often estimated using counts of birds observed at sea and calculations of what proportion of the total population may have been sampled. This technique is used because (1) a substantial fraction of seabirds remain at sea prior to reaching breeding age, and (2) at-sea surveys can enumerate populations which may have breeding colonies spread over different islands or geographic locations, and which can otherwise be difficult to locate and count on land during the breeding season. This is the case for Hawaiian petrel (ʻuaʻu)—nesting adults are nocturnal, and nests are located underground in densely vegetated and rugged, remote montane environments.

At-sea estimates were not adopted for the HCP seabird population dynamics models because they include serious spatial deficiencies in geographical survey coverage. For example, during the breeding season adult Hawaiian petrel (ʻuaʻu) are known to forage in the North Pacific (e.g., Adams and Flora 2010), outside the survey areas included in the at-sea abundance estimates, leading to uncorrected sources of statistical bias. Further, at-sea estimates alone, even if they could be corrected for these biases, provide only a single population estimate. That single estimate would need to be split into the proportion of the at-sea population of Hawaiian petrel (ʻuaʻu) that are associated with breeding colonies on Kauaʻi, and then further subdivided for different areas (e.g., the conservation sites) on Kauaʻi, given the spatial complexities that are relevant to conservation and management. In other words, what proportion of the at-sea estimates of abundance represents those birds associated with the conservation sites? Such assumptions would have a high degree of uncertainty, so it is preferable to use available survey data from the conservation sites themselves. Survey data at the conservation sites provide a more current and defensible estimate of covered seabird abundance than older at-sea estimates.

For all of these reasons we chose not to utilize at-sea population estimates. Instead, the population estimates used to initialize the model are based on different Kauaʻi-specific data sets, as described below.

Breeding Pair Population Estimates on Kauaʻi

Given the serious limitations of the at-sea abundance estimates, which miss a significant (but as of yet unquantified) proportion of the island's breeding population—as well as the fact that breeding colonies in different areas of Kauaʻi are not uniformly vulnerable to threats such as introduced predators, light fallout, or powerline strike mortalities —staff at ARC developed spatially explicit estimates of Hawaiian petrel (ʻuaʻu) breeding pair abundance on Kauaʻi for this HCP.

These estimates were adopted as the basis for calculating the initial model population size in the HCP population dynamics model. They also allow for a modeling approach that can help to address the fundamental question of whether localized conservation efforts (e.g., predator control, predator-proof fencing, or social attraction sites) in targeted breeding areas on Kauaʻi can result in a sufficient net benefit to offset future minimized powerline strike mortalities for the island-wide population (i.e., metapopulation) on Kauaʻi. An important innovation of the HCP population dynamics model is that it considers important spatial differences in mortality risk in different areas of Kauaʻi, as discussed below.

Breeding pair abundance in 2021 was estimated for each of the modeled subpopulations (Table 5F-2, Figure 5F-1). The approach used to estimate the number of breeding pairs differed between areas, dictated in part by the extent to which various data sources are available (or lacking) for each area. In general, however, the breeding pair estimates developed by ARC are informed by acoustic call rate and nesting burrow monitoring studies, which have demonstrated a significant relationship between call rates and estimated densities of active nesting burrows (e.g., Raine et al. 2019). These acoustic call rates are used in combination with published habitat suitability models (Troy et al. 2014, 2017). To the extent possible, the most recently analyzed study data from 2021 have been used to inform the resulting breeding pair estimates.

For the single modeled area of Kauaʻi that has the highest level of powerline collisions (Hanalei to Kekaha; Travers et al. 2020), preliminary model results indicated that ARC's estimates of breeding pairs for this area was, in combination with the biological assumptions in the model, incompatible with the observed trends from the radar survey and the level of mortality from the average annual unminimized strike estimate during 2013–2019. In other words, preliminary model results for the Hanalei to Kekaha area, when based on ARC's breeding pair estimates and the low modeled maximum population growth rate (i.e., resiliency), produced modeled subpopulation trends from unminimized powerline strike mortality rates that were much more negative (i.e., much greater projected declines) than any trends estimated from the radar survey since that systematic survey began collecting data in 1993.

Therefore, an alternative approach was used to calculate the breeding pair abundance necessary to sustain the rate of decline observed in the radar data (Raine et al. 2017b; Raine and Rossiter 2020), given the estimated average annual number of unminimized powerline collisions during 2013–2019 for these two areas (Travers et al. 2020). This approach to initialize the breeding pair abundance in the model for the Hanalei to Kekaha area is described in more detail under the area-specific descriptions of breeding pair abundance estimation process and background considerations for each modeled subpopulation below. Using estimated trends from radar data to initialize the model also integrates the effects of powerline collisions and light fallout prior to the HCP, to the extent available data allow, because the trend estimate is based on radar survey data starting in 1993.

Table 5F-2 provides a summary of the approach used for each modeled subpopulation as well as a relative comparison of mortality sources (the differences in mortality help explain why individual subpopulations were modeled) and uncertainty in the estimate of abundance. Where certainty in abundance was "moderate" and habitat suitability modeled was used (i.e., Kalalau east to Upper Mānoa), nesting densities were extrapolated from other areas with available data and expert opinion was used to derive density correction factors to account for lower expected nest densities in areas with higher levels of mortality (i.e., due to unmanaged predation outside the conservation sites).

Table 5F-2. Summary of Approach to Initial Population Estimate, Relative Mortality Levels by Source, and Data Availability by Modeled Subpopulation for Hawaiian Petrel (ʻuaʻu)

Modeled Subpopulation	Data Sources Used for Initial Population Estimate	Relative Population-Level Mortality by Source			Certainty in Abundance Estimate
		Powerlines	Light Attraction	Predation	
Existing Conservation Sites (6)[a]	Habitat suitability model and auditory survey polygons (based on annual surveys)	Low	Low	Low	High
Wainiha and Lumahaʻi Valleys	Habitat suitability model and auditory survey polygons	Low	Low	Moderate	Moderate
Kalalau east to Upper Mānoa	Habitat suitability model and cover ratios[b] calculated from auditory survey polygons in Wainiha & Lumahaʻi	Low	Low	Moderate	Moderate
Hanalei to Kekaha	Radar trend and powerline strike estimate	**High**	Moderate	**High**	Low

[a] There are six existing conservation sites where Hawaiian petrel (ʻuaʻu) are known to occur: (1) Upper Limahuli Preserve; (2) Pihea; (3) North Bog; (4) Pōhākea; (5) Hanakāpiʻai; and, (6) Hanakoa.

[b] Cover ratios were used to extrapolate the fraction of suitable habitat used by nesting seabirds detected through acoustic surveys to areas without available acoustic survey data, before applying density correction factors to account for lower nesting densities in areas that have been more greatly impacted by powerline strike, light attraction, and predation mortalities (Raine et al. 2019).

Hanalei to Kekaha

This area is the most affected by powerline collisions, light attraction, and predation (e.g., Troy et al. 2017; Figure 5F-1). It is also the area of the island for which trends in relative abundance have been estimated through the long-term systematic radar survey since 1993 (e.g.,Day and Cooper 1995; Raine et al. 2017b). Thirteen radar sites have been surveyed since 1993 in the Hanalei to Kekaha area. Two additional radar sites have also been surveyed in Wainiha and Lumahaʻi Valleys starting in 2006, where trends have been stable (Raine and Rossiter 2020; see below for details).

The radar survey on Kauaʻi represents the longest systematic monitoring study of trends in abundance for this species. Raine et al. (2017a) estimated the average rate of decline in Newell's shearwater (ʻaʻo) abundance, between 1993 and 2013, across all radar sites in the Hanalei to Kekaha area at approximately -6 percent per year. Since that study, Raine and Rossiter (2020) present the most recent estimates for the long-term subpopulation trend for this area. When averaged across all radar sites in this area, the more recent estimate of the average annual rate of decline is -4.7 percent per year during 1993–2020. During those three decades, the most extreme rate of decline for any of the 13 individual radar sites in this area has been estimated at the Waiakalua Stream site. The trend in relative abundance from that radar site is -8.1 percent per year during 1993–2020.

As noted above, the total breeding pair estimates developed by ARC for Hanalei to Kekaha were found through preliminary modeling results to be incompatible with the estimated number of powerline collisions, associated mortalities, and the most negative trend estimated from radar survey data. Given the biological assumptions in the model, this combination of factors, as initially explored (i.e., relatively small abundance relative to the magnitude of powerline collision mortalities for a species with low maximum rates of modeled population growth) led to modeled rates of decline that were much greater than any trends that have been observed through the radar surveys in this area, or elsewhere.

To correct this inconsistency, an alternative approach to initializing abundance for the Hanalei to Kekaha area was developed so the model would match both the magnitude of powerline collisions estimated from acoustic monitoring and trends in abundance estimated from the long-term systematic radar surveys.

The initialization approach for Hanalei to Kekaha involved solving for the combination of (1) abundance at age, and (2) the subadult and adult powerline mortality rates that result in the estimated number of collision mortalities, while matching the -8.1 percent rate of decline estimated from the radar survey at the Waiakalua Stream radar site (a worst-case recent trend) and the assumed proportions of powerline collisions that are subadults and adults. The solutions for abundance and powerline mortality rates at age were found using non-linear numerical optimization (a penalized maximum likelihood approach) as implemented in the Stan programming language using the *cmdstanr* package (Stan Development Team 2022; Gabry and Češnovar 2022). The specific penalties used to fit the model were as follows.

1. The Bayes acoustic estimate of powerline strikes was assumed to follow a log-normal distribution with a mean in log-space corresponding to the strike allocation for this area (described below), and a coefficient of variation assumed to be 0.01, which ensures the resulting modeled number of strikes matches the mean of the reported estimate.
2. The trend from the radar data was modeled as a normally distributed random variable with a standard error of 0.01, which again ensured the resulting modeled trend matched the point estimate for the rate of decline.

3. The proportion of powerline collisions that were subadult was assumed to follow a Beta (11, 3) probability distribution, which corresponds to the sample of 14 downed Newell's shearwaters (ʻaʻo) examined by Cooper and Day (1998), with 11 of those birds categorized as subadults and 3 as adults, i.e., the expected proportional age-class split for Hawaiian petrel (ʻuaʻu) was assumed to be the same as estimated for Newell's shearwater (ʻaʻo) and was 79 percent subadult and 21 percent adult.

The estimate of powerline collisions is an annual average during 1993–2019. It was assumed that this estimate pertained to 2016, the midpoint year of the acoustic monitoring data analyzed by Travers et al. (2020). In an analogous example, this approach is to the same as solving a problem where one wants to calculate the amount of money in a stock market account one year earlier. If one knows the rate of decline in the market from one year to the next was -10 percent, and the account lost $10 last year, there must have been $100 in the account before the loss.

The resulting abundance at age from this approach was then projected forward from 2016, under the assumption of a stable age distribution at the -8.1 percent rate of decline, through 2019, after which time the initial unminimized powerline mortality rates at age were reduced each year according to the modeled minimization schedule under the HCP.

Estimates for the number of annual powerline collisions are not available prior to 2013. However, incorporating estimated trends from radar data to initialize the model integrates the effects of powerline collisions and other sources of mortality prior to 2013, to the extent available data allow, because the radar trend is based on observations starting in 1993.

Upper Limahuli Preserve, Pihea, North Bog, Pōhākea, Hanakāpiʻai, and Hanakoa)

These conservation sites have the highest level of management (mainly predator control) and are in northwest Kauaʻi away from most powerlines and light sources (Figure 5F-1). The Upper Limahuli Preserve and North Bog conservation sites are close to the towns of Hāʻena and Wainiha and thus closer to powerlines and light sources. There is one streetlight at Hāʻena Beach Park that is approximately 0.4 mile (0.64 kilometer [km]) north of the Upper Limahuli Preserve; however, all lights and powerlines are over 1 mile (1.6 km) to the east. The remaining four conservation sites, which are in the Hono O Nā Pali Natural Area Reserve, are west of the Upper Limahuli Preserve and North Bog conservation sites, and thus are over 3 miles (4.8 km) from the nearest powerlines or light sources to the east.

The covered seabirds in this area are expected to be affected the least of any area by all stressors (Table 5F-2). This area also has the best available data (e.g., annual auditory surveys, extensive burrow searches) for abundance estimates based on annual monitoring surveys (e.g., Raine et al. 2022). Breeding pair estimates have been conducted on an individual basis for the conservation sites and have been presented previously in annual ARC monitoring reports (e.g., Archipelago Research and Conservation 2021; Raine et al. 2022).

In 2017, the first population estimates were produced for all monitored management areas using two independent methods: a habitat suitability model, which utilized the peer-reviewed models presented in Troy et al. (2014, 2017) where suitable habitat ranked 7+ and an average nearest-neighbor distance was used from known burrows at monitored colonies to model density, and a regression analysis of acoustic monitoring data, which provides an estimate of active burrows (i.e., breeding pairs) as a function of call detections, given previous studies comparing paired visual and acoustic data in the same nesting areas. Based on the outputs of the two models, it was decided that the habitat suitability model was the most appropriate way of providing population estimates and that the acoustic method would need to be further refined before it could be used for this metric (see Raine et al. 2019). For these sites, habitat suitability modeling (Troy et al. 2014, 2017) is also employed for portions of the conservation sites outside the acoustic arrays, using the estimated nearest neighbor distances between active burrows (i.e., burrow densities) to predict breeding pair numbers outside the acoustic array footprint.

The habitat suitability model was updated in 2021 by including (i) new polygons from auditory surveys undertaken in 2021 and (ii) total surface area to take into account vertical space such as drainages and cliff walls. Two population estimates were then created for each site: (i) a low population estimate using only polygons related to “hot spot heavy” or “ground calling activity” and (ii) a high population estimate using *all polygons* collected during auditory surveys. In areas where suitable nesting habitat overlapped between Newell’s shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu), i.e., where the habitat is suitable for nesting for either species, the habitat was partitioned between species to prevent double counting of available nesting habitat.

The breeding pair abundance in 2021 in the population dynamics model is equal to the lower of the two estimated values for all areas except for Hanalei to Kekaha, where the approach to estimating initial modeled abundance is described in the respective area description.

Kalalau East to Upper Mānoa

This area is in the northwest of Kauaʻi away from most powerlines and light attraction issues. However, this area is unmanaged and thus more heavily affected by predators than adjacent conservation sites. Like Hanalei to Kekaha, the Troy et al. (2014, 2017) habitat suitability model was used to estimate breeding pairs in this area, but only included suitable habitat with the highest probability of nesting occurrence (i.e., suitable habitat with less than the highest ranking was assumed to contain zero breeding pairs). The modeled suitable habitat was also further reduced by an elevation cutoff, such that suitable habitat below 1,922 feet (585.9 meters) above sea level for Hawaiian petrel (ʻuaʻu) was assumed to contain zero breeding pairs. This altitude represents the lowest height above sea level that an active nest has been detected during burrow monitoring studies in the conservation sites. The Kalalau east to Upper Mānoa area is largely unsurveyed, and therefore the estimated densities of active nests from Lumahaʻi Valley were used with the nearest neighbor distance from the conservation sites multiplied by 1.5, to account for active nests being more dispersed in this unmanaged area due to a lack of predator control measures.

Wainiha and Lumahaʻi Valleys

This area encompasses two of the largest valleys on Kauaʻi with Hawaiian petrel (ʻuaʻu). While affected to some degree by powerlines and light attraction, radar data has shown no trend since monitoring began in 2006 (e.g., Raine and Rossiter 2020) and tracking data shows that birds transiting over this area are predominantly higher than powerlines (Raine et al. 2017a). There is no predator management in this area, but in order to match the stable radar trend since 2006, it was assumed that predation rates were 25 percent of those in other unmanaged areas (i.e., that birds in these valleys have been confined to very steep and less accessible habitat and have reduced predation rates).

Auditory surveys were conducted in portions of Lumahaʻi Valley in 2020, and the corresponding call rate data was combined with survey data in both valleys in 2012–2014 and used after filtering out any call rates that did not meet the “heavy” and “ground calling” criteria (e.g., Raine et al. 2020), which excluded any breeding pairs associated with low-density nesting areas. Like other areas, habitat suitability modeling was also incorporated, and the breeding pair estimate for Wainiha and Lumahaʻi Valleys only included suitable habitat ranked at 8+ (i.e., suitable habitat ranked lower than 8 was assumed to contain zero breeding pairs). For areas within each valley that were not surveyed a cover ratio was applied. This was created by considering all areas within each site where auditory surveys were undertaken, drawing a. 0.6-mile (1-km) radius around each survey point, and creating a cover ratio within that survey radius of seabird activity polygons (heavy and ground calling) to suitable habitat. The cover ratio was then extrapolated to unsurveyed areas. The modeled suitable habitat was also further reduced by an elevation cutoff, such that suitable habitat below 1,922 feet (585.9 meters) above sea level for Hawaiian petrel (ʻuaʻu) was assumed to contain zero breeding pairs. This altitude represents the lowest height above sea level that an active nest has been detected during burrow monitoring studies in the conservation sites. The estimated densities of active nests were multiplied by 1.5, which reduced the breeding pair estimate, to account for active nests being more dispersed in unmanaged areas.

Table 5F-3. Abundance Estimates of Hawaiian Petrel (ʻuaʻu) on Kauaʻi in 2020 by Subpopulation and Age Class (males and females combined)

Subpopulation (see Figure 5F-1 for locations)	2021 Breeding Adults (ages 6+)[a]	2021 Subadults (ages 1–5)[b]	2021 Total Abundance (ages 1+)	Fraction of Total Powerline Strikes[c]	2016 Powerline Mortalities (all ages) per 100 breeding adults
Pihea	1,291	736	2,027	0.005	0.5
North Bog	1,759	1,002	2,761	0.020	1.5
Pōhākea	321	183	504	0.002	1.0
Hanakāpīʻai	578	330	908	0.004	1.0
Hanakoa	342	195	536	0.001	0.5
Upper Limahuli Preserve	224	127	351	0.003	2.5
Wainiha and Lumahaʻi Valleys	2,383	1,358	3,741	0.027	1.5
Hanalei to Kekaha	9,215	5,635	14,850	0.925	13.7
Kalalau east to Upper Mānoa (excluding conservation sites)	1,361	775	2,136	0.015	1.5
Total Kauaʻi abundance	**17,473**	**10,341**	**27,814**		

[a] Values for breeding adults correspond with the minimum theoretical estimate of abundance based on several alternative data sources, methods for estimation, and expert opinion (e.g., Raine et al. 2019; Raine et al. 2022). Estimates for all conservation sites with established subpopulations (first 3 rows) were derived from 2021 burrow monitoring data. Estimates of unmanaged subpopulations (last 3 rows) are derived from the habitat suitability analysis of Troy et al. (2017) restricted to 1,922 feet (585.6 meters) above sea level and above (the lowest elevation in managed colonies with a known burrow) correcting for the more dispersed nature of unmanaged colonies as compared to managed colonies.

[b] Except for the Hanalei to Kekaha area, the initial number of subadults was derived under the assumption that subadults comprise 36.3 percent of the age 1+ (non-chick) component of the population (Ainley et al. 2001).

[c] The powerline strike allocation is based on the percentage of acoustically detected strikes that have been analyzed to estimate strike numbers (Travers et al. 2020). The empirical strike percentages are: 89.1 percent of strikes in the

Hanalei to Kekaha area, 10.8 percent of strikes in the Waimea area, and 0.1 percent of strikes from the Wainiha and Lumahaʻi Valleys area (Travers et al. 2020; Travers, unpublished data). The modeled allocation differs slightly from these values to account for a percentage of strikes that are seabirds associated with different breeding colonies transiting across powerlines in other areas (e.g., to account for breeding adults at the conservation sites having some vulnerability to colliding with powerlines).

5F.1.1.2 Vital Rates under Optimal Conditions

A critical set of assumptions used in the KIUC HCP population dynamics model relate to the vital rates of the target species. *Vital rates* for any population dynamics model dictate population trajectories in the absence of any external factors, also referred to here as *optimal conditions*. Estimated reductions in vital rates relative to optimal conditions allow for the modeling of expected impacts on population dynamics from combined threats (e.g., mortalities due to introduced predators and powerline collisions). Likewise, the estimated effects of conservation measures on vital rates allow for the modeling of expected benefits of mitigation and minimization measures. Vital rates for this model include the following.

- Survival from one age class to the next age class
- Age at first reproduction (also termed the “adult” age)
- Annual breeding probability for adults (expressed as a fraction of adult birds that breed each year)
- Reproductive success rate (i.e., the fraction of eggs laid by adults that survive to emerge from the nest as fledglings)

During the last decade, burrow monitoring and other studies have led to a substantial increase in available species-specific estimates of endangered seabird vital rates on Kauaʻi (e.g., Archipelago Research and Conservation 2021; Raine et al. 2022). Likewise, advances in powerline monitoring methods have resulted in estimates of powerline strike numbers, resulting mortalities, and locations (e.g., Travers et al. 2020, 2021). In addition to recent estimates of vital rates related to reproduction and recruitment from burrow monitoring studies, acoustic monitoring of call rates and satellite tagging studies also provide information on trends in abundance and relative vulnerability to powerline collisions for breeding colonies in conservation sites in northwestern Kauaʻi. These newly available estimates serve to inform the biological assumptions of the KIUC HCP population dynamics model.

However, even with the improved estimates of vital rates and additional information on trends in abundance that recent monitoring efforts provide, there remains a high level of uncertainty for many of the biological assumptions that are input parameters for the population dynamics model. For example, the most recently reported estimate of the number of seabird powerline strikes from the Bayesian analysis of acoustic strike monitoring data collected between 2013 and 2019 has a 95 percent posterior predictive probability interval of 4,417–56,903 strikes per year (Travers et al. 2020). Moreover, in some instances, the parameter values adopted for this set of biological assumptions may be based wholly, or in part, upon expert opinion, and therefore confidence intervals cannot be calculated. Despite these limitations, the biological assumptions described here represent the best available scientific data, which is the regulatory standard for HCPs under the federal Endangered Species Act and Hawaiʻi Endangered Species Act.

The optimal rate of population growth is related to (but might be less than) the intrinsic rate of growth of the population, which is the maximum expected exponential growth rate that populations can achieve in the absence of density dependent competition for resources and decreases in vital rates through anthropogenic effects and nonnative predators (e.g., Caughley 1977). The optimal rate of population growth is a key parameter in conservation risk assessments and management strategy evaluations (e.g., Niel and Leberton 2005). However, the optimal population growth rate is also a difficult parameter to estimate, especially for species without long-term surveys of abundance to monitor the rate of recovery from low population levels. At present, no empirical estimate exists for the optimal rate of population growth for Hawaiian petrel (ʻuaʻu).

Given the biological assumptions for the vital rates of this model, the resulting optimal rate of modeled population growth (i.e., in the absence of introduced predators, powerline strike or light fallout mortality) is 2.0 percent per year. This is similar to the optimal rate of population growth modeled by Griesemer and Holmes (2011:30) for Newell's shearwater (ʻaʻo), which was 2.3 percent per year.

In practice, however, the optimal rate of population growth is never achieved in the KIUC model, because even for those sites with predator-proof fences, birds are still assumed to be vulnerable to powerline strike mortalities (albeit at relatively low levels) and aerial predation by introduced barn owls. The highest rate of population growth achieved in the model is at the Pihea and Hanakoa conservation sites. These sites have a relatively low powerline strike mortality rate in the model (0.5 unminimized powerline mortalities per 100 breeding adults), due to their remote geographic location. The underlying modeled population growth rate reaches 1.1 percent per year at Pihea and Hanakoa.

The optimal rate of population growth in a population dynamics model is a function of the optimal input values for the vital rates. All else being equal, higher optimal input values for survival or reproductive rates (or lower age at reproduction) result in higher values of optimal population growth rates and vice versa (e.g., Caswell 2001). The biological assumptions for the individual component life history values in the model are as follows.

Fledgling Survival Rates

Fledgling (age 1) survival rates and subsequent survival rates to breeding age are not available from empirical data. Instead, the modeled Hawaiian petrel (ʻuaʻu) survival rates were assumed to be equal to those employed for Newell's shearwater (ʻaʻo; Appendix 5E, *Population Dynamics Model for Newell's Shearwater (ʻaʻo) on Kauaʻi*). These rates were derived from the satellite tagging study reported by Raine et al. (2020). In that study, 12 Newell's shearwater (ʻaʻo) fledglings were tracked at sea. From the tag signals it was possible to estimate if a fledgling had died at sea (i.e., the tag stopped reporting movements in a manner that indicated it had not simply fallen off). Based on the observations of tagged fledglings, only 25 percent of tagged fledglings survived their first month at sea, suggesting that this percentage (or lower) would reach breeding age (Raine et al. 2020). This low level of fledgling survival was also assumed for Hawaiian petrel (ʻuaʻu); the fledgling survival rate assumed in the model was set such that, in combination with the assumed subadult survival rate, 25 percent of fledglings in the model (under near-optimal conditions) would reach breeding age. Combined with the subadult survival rates at age described below, this assumption yields a fledgling survival rate of 0.371 (i.e., survival from age 1 to age 2). Accounting for fallout from light attraction further reduces the fledgling survival rate in the Hanalei to Kekaha area of the model (see Section 3.1, *Conservative Assumptions*). The estimated level of fallout includes correction factors for the proportion of grounded seabirds that go undetected, e.g., for KIUC streetlights, 89.6% of grounded Hawaiian petrel (ʻuaʻu) are assumed to go undetected (Appendix 5C: *Light Attraction Modeling*). Fallout, whether detected or not, is assumed to result in 100% mortality in the model.

Subadult and Adult Survival Rates

There are no available empirical estimates of adult survival rates for Hawaiian petrel (ʻuaʻu). Instead, adult survival rates were based on multiple studies undertaken on the similar Manx shearwater (Harris 1966; Perrins et al. 1973; Brooke 1977) and were set to 0.924. Subadult survival rates (ages 2–5 years) were set equal to the adult survival rate, which is consistent with a life history punctuated by very high first year at-sea mortality rates for fledglings, followed by relatively low natural mortality rates for subadults and adults. The exact values for subadult survival rates at age are uncertain, in part because subadults may spend several years at sea, making conventional approaches for estimating survival rates, like mark-recapture, impracticable. The values for subadult survival rates at age assumed in the model are consistent with the Raine et al. (2020) satellite tagging study on Kauaʻi for Newell's shearwater (ʻaʻo), described above in *Fledgling Survival Rates* and result in 25 percent of modeled fledglings reaching breeding age (age 6) under near-optimal conditions.

Age at First Breeding

The age at first breeding was assumed to occur at six years, following the common assumption for Newell's shearwater (ʻaʻo) and the similarity between demographic traits for these two seabird species.

Reproductive Success Rate

The reproductive success rate (RS) in the model measures the fraction of eggs that develop into a chick that survives to fledge. This is consistent with how RS rates have been defined in the burrow monitoring study data. RS rates have been estimated from burrow monitoring studies at the conservation sites, both before (RS = 0.413) and after (RS = 0.787) dedicated predator mitigation measures. The RS rate at the conservation sites is taken from a 3-year average value estimated across sites during 2019–2021 (e.g., Archipelago Research and Conservation 2021; Raine et al. 2022). For areas in the model without predator mitigation, the RS rate is assumed to be equal to that estimated at the conservation sites prior to dedicated mitigation measures. An adjustment was made for the Wainiha and Lumahaʻi Valleys area, given that the radar trend for this area has been stable (neither increasing or decreasing) since monitoring began in 2006, which in combination with the assumed low population growth rate and relatively low vulnerability to powerline strikes, suggests that predation mortality rates in this area are 25 percent of those in estimated at the conservation sites prior to dedicated predator control measures (see also *Predation Rates*). It was also assumed that the RS rate in the Wainiha and Lumahaʻi Valleys area is 25 percent greater than in other unmanaged areas (RS = 0.516).

The RS rates in areas with predator-proof fences were based on the estimated RS rates at the conservation sites following dedicated predator mitigation, with an upward percentage adjustment corresponding to observed predation rates on nests without predator proof fences, which were 0.0023 for adults and 0.02 for chicks (Raine et al. 2022; Raine, unpublished data). This resulted in a modeled RS rate inside predator-proof fences of 0.872 * (1 + 0.0023 + 0.02) = 0.805, or a 2.23 percent increase compared to the estimated RS rate from burrow monitoring studies at the conservation sites.

An additional area-specific adjustment was made to the RS values to account for powerline collisions that result in injury but not mortality and might cause breeding individuals to be unable to fledge a chick successfully (e.g., due to an inability to forage effectively that season). Following the observations of Travers et al. (2021), 24.5 percent of powerline collisions were assumed to result in nonlethal injury. These were individuals with post-collision elevation loss that were not assigned to immediate grounding mortality or short-term grounding mortality (within 3,609 feet [1,100 meters] of wires). The observed elevation loss of these birds not assigned as grounded/mortality, was used as a proxy for injury. That is, the elevation loss indicates the collision was more severe or affected the bird more than those that flew off without elevation loss.

Future powerline collision levels, and their non-lethal effects, were derived from the powerline mortality rate calculations described below, under the assumption that mortalities were 28.8 percent of all collisions. The derived number of collisions was then multiplied by 24.5 percent to calculate the associated number of collisions resulting in non-lethal injuries. This number was multiplied by 21.4 percent to account for the proportion of collisions that are expected to be breeding adults (Cooper and Day 1998). And the resulting number of collisions resulting in non-lethal injuries of breeding age birds was divided by the number of breeding birds in an area each year, and used as a percentage reduction in reproductive success rate in that area that year.

Breeding Probability

Breeding probability is the percentage of adults (age 6 or older) that breed each year. This probability has been estimated through long-term studies of active breeders at the conservation sites and is 0.982 for Hawaiian petrel (‘ua‘u) (Raine et al. 2022). The breeding probability value is assumed to be constant across all geographic areas and through time in the model.

5F.1.1.3 Powerline Mortality

The powerline mortality rate for each area *I* with no minimization was calculated for subadults and adults by dividing the proportion of unminimized powerline mortalities for each age class by the corresponding estimate of abundance for that area:

$$\psi_{a,i}^{sa} = \frac{p_i \Omega \rho \nu \pi_{sa}}{\sum_{a=3}^{5} \hat{N}_{a,i}^{sa}}$$

(Equation 1)

$$\psi_{6+,i} = \frac{p_i \Omega \rho \nu (1 - \pi_{sa})}{\hat{N}_{6+,i}}$$

Where:

- $\psi_{a,i}^{sa}$ and $\psi_{6+,i}$ are the annual powerline mortality rates for subadults, ages 3–5 years, and adults (ages 6 years and older, denoted as age "6+"; Figure 5F-2) in area *i* prior to any minimization (i.e., unminimized). In the context of powerline strikes, subadults refer to ages 3–5 years because ages 1 and 2 are assumed to be at sea and are not vulnerable to powerline strikes in the model (Equation 3). The powerline mortality rates are assumed to be equal for subadults of each vulnerable age.

- p_i is the modeled fraction of total powerline strikes for each species that are associated with birds from area i in 2016 (see Table 5F-2 for list of areas).
- Ω is the estimated number of seabird powerline strikes in 2016 (Hawaiian petrels [ʻuaʻu] and Newell's shearwater [ʻaʻo] combined).
- ρ is the proportion of total strikes that are Hawaiian petrel (ʻuaʻu; Travers et al. 2021).
- ν is the total grounding rate (i.e., the proportion of strikes that result in mortality; Travers et al. 2021).
- π_{sa} is the proportion of powerline strikes that are subadults.
- $\widehat{N}_{a,i}^{sa}$ is the number of subadults at age (ages 3–5 years) and $\widehat{N}_{6+,i}$ is the number of adults in 2019, which when projected forward in the model 1 year, equal the island-based estimates from 2021 (see Table 5F-3). The initial age structure in the model, for those areas outside Hanalei to Kekaha, assumes that 63.7 percent of the population is composed of breeding adults (the remaining 36.3 percent are assumed to be ages 1–5), following Ainley et al. (2001).

Table 5F-4 shows the assumed values for most of the variables above. The text below the table explains the rationale for these variables.

Table 5F-4. Powerline Strike Assumptions for the Population Dynamics Model

Powerline Strike Variable	Model Variable	Assumed Value
2016 Annual powerline strikes of Newell's shearwater (ʻaʻo) and Hawaiian petrel (ʻuaʻu) combined, before minimization (i.e., average annual unminimized strike estimate during 2013–2019)	Ω	15,853[a]
Total grounding rate	ν	0.288[b]
Proportion of strikes that are Hawaiian petrel (ʻuaʻu)	ρ	0.30[c]
2016 annual estimated mortalities of Hawaiian petrel (ʻuaʻu)	calculation	1,370[d]
Proportion of powerline strikes that are subadults	π_{sa}	0.79[e]

[a] Total number of estimated seabird powerline strikes of Newell's shearwater (ʻaʻo) and Hawaiian petrels (ʻuaʻu) combined. Estimate excludes waterbird strikes and strikes minimized during the Short-Term HCP. Based on 2013–2019 acoustic data and the Bayesian estimate model described in Travers et al. (2020).

[b] The total grounding rate includes 13 percent immediately grounded, 10.2 percent unknown outcome, and 5.6 percent of birds that strike powerlines having been observed with the most severe of post-flight behaviors and that are hence assumed to have eventually died (Travers et al. 2021).

[c] Travers et al. 2021

[d] Mortalities are calculated as the proportion of unminimized seabird strikes for each species, multiplied by the total grounding rate.

[e] See text for additional explanation. Assumes Hawaiian petrel (ʻuaʻu) vulnerability at age to powerline strikes is the same as that of Newellʻs shearwater (ʻaʻo), i.e., follows the sampling distribution of 11 out of 14 downed birds categorized as subadults by Cooper and Day (1998).

Powerline Strike Allocation by Subpopulation

The powerline strike allocation by subpopulation is based on the percentage of acoustically detected strikes that have been analyzed to estimate strike totals across the island (Travers et al. 2020). The empirical distribution of seabird strikes during 2013–2019 was: 89.1 percent of strikes in the Hanalei to Kekaha area, 10.8 percent of strikes in the Waimea Canyon area, and 0.1 percent of strikes from the Wainiha and Lumahaʻi Valleys area (Travers et al. 2020; Travers, unpublished data).

Some variance from the empirical acoustic detections was incorporated in the modeled allocation because, for example, Hawaiian petrel (ʻuaʻu) are not assumed to occur in the modeled Waimea area, and likewise approximately 5 percent of strikes were assumed to result from collisions by individuals from breeding colonies in the remote northwestern areas. This allowed the model to incorporate a low level of powerline collision vulnerability for individuals associated with the conservation sites and surrounding areas, which is consistent with observations from tagging studies (Raine et al. 2017a). In general, the spatial differences that have been observed through acoustic powerline collision monitoring data served as a key motivating factor for developing a spatially explicit population dynamics modeling framework.

Powerline Strike Allocation by Species

As described in Chapter 5, *Effects*, estimates of powerline strikes of the covered seabirds are derived from acoustic data on strikes for all seabirds combined. Acoustic data cannot be separated by species. Instead, we must assume of the proportion of strikes allocated to either Newell's shearwater (ʻaʻo) or Hawaiian petrel (ʻuaʻu). Travers et al. (2021) has reported that powerline collisions directly observed in the field occur in a proportion of 70.5 percent Newell's shearwater (ʻaʻo) to 29.5 percent Hawaiian petrel (ʻuaʻu). The modeling assumption corresponds to these proportions, with 70 percent of all estimated strikes assumed to be Newell's shearwater (ʻaʻo) and 30 percent assumed to be Hawaiian petrel (ʻuaʻu) (Table 5F-3).

Powerline Strike Allocation by Age Class

Birds detected colliding with powerlines through acoustic monitoring, which is used to estimate strike numbers, cannot be identified to age class. However, the proportions of strikes that are subadults and adults are important for the population dynamics model. Although there are no available estimates for Hawaiian petrel (ʻuaʻu), limited evidence suggests that Newell's shearwater (ʻaʻo) subadults are more susceptible to powerline strikes than adults. For the purposes of this model, powerline strikes of Hawaiian petrel (ʻuaʻu) are assumed to be composed of 79 percent subadults (ages 3–5 years) and 21 percent adults (ages 6 years and older) (Table 5F-3).

This assumption corresponds to the proportions estimated by Cooper and Day (1998), who analyzed brood patch vascularization and wear of rectrices[4] for 14 downed Newell's shearwater (ʻaʻo) collected on powerline mortality searches during 1993–1994. Three of those downed Newell's shearwaters (ʻaʻo) had highly vascularized brood patches and worn rectrices, which suggests those birds were incubating eggs in burrows, and hence they were classified as breeding adults (age 6+). The remaining 11 birds either had no brood patch (n=10) or a downy brood patch (n=1); all but the latter had unworn rectrices. Those 11 birds (78.6 percent) were classified as subadults, and the three others (21.4 percent) were classified as breeding adults.

Mortality from Future Powerlines

Mortality due to construction of future powerlines was assumed to apply only to the Hanalei to Kekaha area (Figure 5F-1). The vast majority (more than 99 percent) of new powerlines are expected to be constructed in this area, which is where human population growth is forecast to occur on Kauaʻi (see Chapter 2, *Covered Activities*, for details). As described in Chapter 5, *Effects*, at

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[4] A brood patch is a featherless patch of skin near the belly, which allows heat transfer from nesting parents to their eggs during incubation. Rectrices are the larger tail feathers, which may show signs of wear associated with nesting.

the end of the 50-year permit term, powerline strikes would be increased by an estimated 6.8 percent. The species-specific increase in future strikes was calculated by applying the species split to this percentage, and then applying a linear increase in the strike mortality rate each year, such that by the end of the permit term, the strike mortality rate was equal to the estimated percent increase in strikes.

Mortality from Fallout from Existing and Future Streetlights and Covered Facility Lights

Appendix 5C, *Light Attraction Modeling*, describes the process for quantifying take of the covered seabirds from attraction to lights owned and operated by KIUC. Mortality due to fallout from light attraction was assumed to affect fledglings (age 1 year) only in the Hanalei to Kekaha area. Fallout is assumed to result in 100% mortality in the model, so as a conservative approach the benefits of Save Our Shearwaters (SOS) rehabilitation efforts are not counted (given that there is little data on survival once the birds are released). Based on this assumption, and the light attraction modeling (Appendix 5C), the number of mortalities from fallout each year for Hawaiian petrel (ʻuaʻu) was set to 5.3 in the model. This estimate represents expected mortalities resulting from existing and future light sources anticipated by the end of the 50-year permit term. However, this value was applied at the start of the population trajectories as a conservative approach for modeling fallout mortality levels through time, i.e., annual fallout mortalities from attraction to lights owned and operated by KIUC is likely overestimated at the start of the metapopulation projections.

5F.1.1.4 Predation Rates

Predation mortality rates have been estimated at the conservation sites, both with and without trapping and fencing (i.e., mitigation). Prior to dedicated predator control, predation mortality rates for all predators combined were estimated to be 0.18 for chicks in the nest, and 0.0272 for breeding adults[5] at the nest (Raine et al. 2022; Raine, unpublished data). For areas outside the conservation sites (with no active management), predation rates at the nest were assumed to be equal to the estimates for the conservation sites prior to dedicated predator control, with one exception. The exception was the Wainiha and Lumahaʻi Valleys area, where predation mortality rates are assumed to be 25 percent of the unmitigated rates. This reduction in assumed predation rates allowed the model to match the stable trend in abundance that has been observed through the radar survey data (Raine and Rossiter 2020). This observed stable trend in the Wainiha and Lumahaʻi Valleys area, where powerline strikes are relatively uncommon, would be consistent with lower predation rates, perhaps due to the remaining breeding colonies being confined to areas that are less accessible to mammalian predators.

With predator control measures at the conservation sites, predation mortality rates were estimated to decrease to 0.02 for chicks and 0.0023 for adults (Raine et al. 2022; Raine, unpublished data). The effect of these reductions in predation rates at the nests is also evident in the RS rates estimated before (41.3 percent RS rate) and after dedicated predator control measures (78.7 percent RS rate)

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[5] In other words, 18 percent of all chicks at all conservation sites are assumed to be lost to predators in the absence of any dedicated predator control structures or actions. Similarly, 2.7 percent of all adults at the conservation sites are assumed to be lost to predators annually in the absence of any predator control structures or actions. Chicks are not tracked explicitly in the model, but chick survival (and mortality from predation) is measured in the estimated RS rates of adults from burrow monitoring studies, and those RS rate estimates (and hence chick mortality) from monitoring studies are explicitly included in the model.

at the conservation sites. Although predation mortality rates for chicks are not explicitly included as a variable in the model and are therefore not considered further, they are subsumed in the RS rate estimates used in the model, as discussed above under RS rates.

Barn owl predation rates on the wing for adults were assumed to be equal to the adult predation rate at the nest (0.0023; Raine et al. 2022; Raine, unpublished data), and the same barn owl predation rate on the wing was assumed for ages 3–6+ in the absence of additional information. The assumed barn owl predation rate on the wing was added to the terrestrial predation rates at the nest for all areas. For example, in the Kalalau east to Upper Mānoa area, the adult predation rates at the nest were assumed to be equal to those estimated at the conservation sites prior to dedicated predator control measures (0.0272) plus the assumed barn owl predation rate on the wing (0.0023), or a total adult predation rate of 0.0295 (Table 5F-5). Predation rates at the nests were assumed to vary between different areas according to different management measures (Table 5F-5).

The predation rate for ages 3–5 was set to 0.0023, under the assumption that those ages are not vulnerable to terrestrial predators because they are not nesting, but they are vulnerable as prospectors to being killed by barn owls on the wing (Table 5F-5).

Table 5F-5. Assumptions for Annual Predation Rates, with and without Predator Control

	Without Predator Control[a]		With Predator Control[b]	
Site	**Adults**	**Subadults (3–5 yrs)**	**Adults**	**Subadults (3–5 yrs)**
Conservation Sites	--	--	0.0046	0.0023
Kalalau east to Upper Mānoa[c]	0.0295	0.0023	--	--
Hanalei to Kekaha	0.0295	0.0023	--	--
Wainiha and Lumahaʻi Valleys[c]	0.0074	0.0006	--	--

[a] Without predator control is defined as no fencing, no predator trapping, and no predator removal efforts. With predator control includes trapping and ungulate fences for the conservation sites, or sites with predator-proof fences (second row).
[b] See Table 5F-6 for differences in predation mortality rates assumed for different age classes.
[c] Reduced predation rates were assumed for the Wainiha and Lumahaʻi Valleys area in order for the initial modeled trend to match the stable trend in radar survey data at the two monitoring sites for these valleys during 2006–2020 (Raine and Rossiter 2020).

5F.1.2 Population Dynamics Model and Projections of Abundance

This section describes the model structure, each of the model parameters, and the rationale for each model input.

The population dynamics model is described below in terms of the numbers of females-at-age for each species, under the assumption of a 50:50 sex-ratio:

$$N_{1,t,i} = 0.5\gamma_{t-1,i}\beta N_{6+,t-1,i}S^{*}_{6+,t-1,i} - F_{t,i} \qquad \text{(Equation 2)}$$

$$N_{2,t,i} = N_{1,t-1,i}S^{*}_{1,t-1,i}$$
$$N_{3,t,i} = N_{2,t-1,i}S^{*}_{2,t-1,i}$$
$$N_{4,t,i} = N_{3,t-1,i}S^{*}_{3,t-1,i}$$
$$N_{5,t,i} = N_{4,t-1,i}S^{*}_{4,t-1,i}$$

$$N_{6+,t,i} = N_{5,t-1,i}S^{*}_{5,t-1,i} + N_{6+,t-1,i}S^{*}_{6+,t-1,i}$$

Where:

- $N_{a,t,i}$ is the number of female birds at age a during year t in area i. Birds aged 6 years and older (age 6+) are modeled as a plus-group, *aka* a self-loop group (Figure 5F-2). Fledglings are denoted as age 1 in the model.
- $\gamma_{t,i}$ is the RS rate during year t in area i. RS rates in the model vary between conservation sites and unmanaged areas, and can change with time for areas with future predator control measures (e.g., predator-proof fences).
- β is the breeding probability for sexually mature birds (assumed constant across areas).
- "Fertility" is defined here as the product: $0.5\gamma_{t-1,i}\beta S^{*}_{6+,t-1,i}$

  Hence, fertility, or the number of female fledglings produced per breeding female per year, is a function of the adult survival rate. Chick mortality rates, which are subsumed in the reproductive success rate variable, are therefore directly related to parental mortality rates in the model vis-à-vis reductions in the numbers of fledglings produced.
- $F_{t,i}$ is the number of age 1 birds that die from fallout due to KIUC lights during year t in area i. This term is included with a time and area component for generality, but in practice, fallout is assumed to be limited to the Hanalei to Kekaha subpopulation with 2.65 age 1 female mortalities per year (i.e., 5.3 fallout mortalities per year for age 1 males and females combined).
- $S^{*}_{a,t,i}$ is the survival rate of birds at age a during year t in area i, which for ages 3 years and older is a function of the estimated predation and powerline mortality rates-at-age, as well as the powerline minimization level in year t:

$$\begin{aligned} S^{*}_{1,t,i} &= S_1 \\ S^{*}_{2,t,i} &= S_2 \\ S^{*}_{3,t,i} &= S_3(1-\phi_{3,t,i})[1-\psi_{3,i}(1-\delta_t)] \\ S^{*}_{4,t,i} &= S_4(1-\phi_{4,t,i})[1-\psi_{4,i}(1-\delta_t)] \\ S^{*}_{5,t,i} &= S_5(1-\phi_{5,t,i})[1-\psi_{5,i}(1-\delta_t)] \\ S^{*}_{6+,t,i} &= S_{6+}(1-\phi_{6+,t,i})[1-\psi_{6+,i}(1-\delta_t)] \end{aligned} \qquad \text{(Equation 3)}$$

Where:

- S_a is the natural survival rate at age a prior to any mortalities from predators or powerlines (Table 5F-5).
- $\phi_{a,t,i}$ is the predation mortality rate at age a during year t in area i (Tables 5F-5 and 5F-6). Predation rates vary through time in the model in the areas where future predator control measures will occur or where predator-proof fences are installed.
- $\psi_{a,i}$ is the unminimized powerline mortality rate at age a in area i. The unminimized powerline mortality rates vary by area due to unequal per-capita vulnerability to powerline strikes (Equation 1; Table 5F-3).

- δ_t is the minimization efficacy in terms of reducing powerline strikes during year t. The minimization rate varies between years according to the strike minimization schedule under the HCP (Table 5F-8).

Table 5F-6. Survival, Predation Mortality, and Fertility Rates by Age for Hawaiian Petrel ('ua'u)

Age	Natural Survival Rate[a]	Predation Mortality Rate without Predator Control or Fencing[b]	Predation Mortality Rate with Predator Control and Ungulate Fencing[c]	Predation Mortality Rate with Predator-Proof Fencing[d]	Natural Fertility[a]	Fertility without Predator Control or Fencing[e]
1	0.371	0	0	0	0	0
2	0.924	0	0	0	0	0
3	0.924	0.0023[c]	0.0023[c]	0.0023[c]	0	0
4	0.924	0.0023[c]	0.0023[c]	0.0023[c]	0	0
5	0.924	0.0023[c]	0.0023[c]	0.0023[c]	0	0
6+	0.924	0.0295	0.0046	0.0023[c]	0.416	0.182

[a] Natural survival and natural fertility represent the modeled rates in the absence of predation and powerline mortalities. The value of 0.924 for natural survival is based on survival rates estimated from studies of Manx shearwater and Hawaiian petrel ('ua'u) (Simmons 1984, 1985), with age 1 survival adjusted to result in ~25 percent of birds reaching breeding age, based on satellite tagging results for Newell's shearwater ('a'o) on Kaua'i (Raine et al. 2020).

[b] Estimated from burrow monitoring studies at conservation sites (Raine et al. 2022; Raine, unpublished data), and assuming that ages 1 and 2 are not vulnerable to introduced predators on the island because they are largely expected to be at sea. Predation mortality rates for the Wainiha and Lumaha'i Valleys area are reduced to 25 percent of the values at other unmanaged sites to match the stable trend in abundance from the radar survey data in that area during 2006–2020 (Raine and Rossiter 2020).

[c] Taken from estimated barn owl predation rates for nesting birds and assumed in the model to be equal for age 3–5 birds (i.e., the barn owl predation rate is applied to this age under the assumption that ages 3–5 would be "prospectors" and predated by barn owls on the wing).

[d] All predation mortality rates are assumed to be reduced to zero by predator proof fences, except for ages 3–6+ which are assigned the estimated barn owl predation rate on the wing.

[e] This fertility value corresponds to the Hanalei to Kekaha subpopulation with unminimized powerline strike mortality rates. The fertility values are a function of the adult powerline mortality rates, and therefore change through time in the model as a function of the minimization schedule. Likewise, the fertility rates differ between areas in the model due to spatial differences in the adult powerline mortality rates between areas in the model. Because the Hanalei to Kekaha area has the highest powerline strike mortality rate, it also has the lowest modeled fertility rate, which reflects the expectation that if a nesting parent is killed, it's egg/chick will not survive to fledge.

Table 5F-7. Reproductive Rates Assumed in the Population Dynamics Model

Vital Rate	Value
Sex ratio	0.5
Reproductive success rate without predator control and without fencing	0.413[a]
Reproductive success rate with predator control	0.787[a]
Breeding probability	0.982[b]
Age at sexual maturity	6 yr

[a] Estimated from burrow monitoring studies at management sites before (in parentheses) and after predator control measures (e.g., Raine et al. 2022; Raine unpublished data).

[b] Estimated from long-term studies of active breeders at the conservation sites (Raine et al. 2022).

Table 5F-8. Annual Powerline Minimization Schedule[a]

Year	Annual Island-Wide Powerline Mortality Minimization Rate[b]
2019	0
2020	0.127
2021	0.303
2022	0.550
2023–2053	0.653

[a] See Conservation Measure 1, *Implement Powerline Collision Minimization Projects*, in Chapter 4, *Conservation Strategy*, for details on the specific powerline minimization projects and the locations.

[b] Minimization represents the efficacy to reduce the mortality rate due to powerline strikes. In other words, minimization = 0.0 corresponds to no change in powerline mortality rate (without any minimization measures implemented). A minimization = 1.0 represents a scenario where a powerline was removed or modified so that bird collisions no longer occurred, and powerline mortality rates are zero. A minimization efficacy of 0.5 represents a 50 percent reduction in strike mortalities.

The life-cycle model shown in Figure 5F-2 is similar to the model developed by Griesemer and Holmes (2011). The circles, and numbers therein, correspond with a single age class in the model. Birds aged 6 years and older were modeled as a self-loop group (i.e., senescence was not assumed to be a knife-edge where all birds die at a given age). The survival rates at age a, S_a^* are a function of predation and powerline mortality rates at age as well as the powerline strike minimization rates (Equation 3). For conciseness, the subscripts for year and area are dropped in the transition parameters shown in the figure.

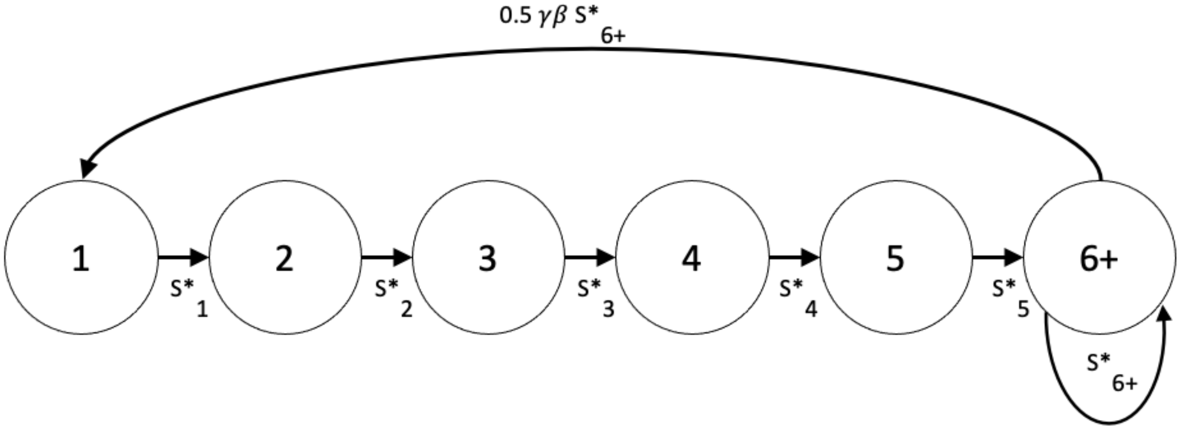

Figure 5F-2. Life Cycle Graph with Age-Structured Transition Parameters for the Population Dynamics Model

5F.2 Model Results

All model results for Hawaiian petrel (ʻuaʻu) are presented in Figures 5F-3 through 5F-6. The population dynamics results in Figures 5F-3 and 5F-4 demonstrate that the conservation measures implemented will substantially benefit Hawaiian petrel (ʻuaʻu) relatively quickly at all conservation sites where Hawaiian petrel (ʻuaʻu) are modeled and expected to occur.

The population trajectory for Hawaiian petrel (ʻuaʻu) at all conservation sites combined is shown in Figure 5F-4 and shows a similar pattern. According to the model, the total population size of Hawaiian petrel (ʻuaʻu) at all of the conservation sites is expected to increase immediately, consistent with observed increases in call rates at the conservation sites that have been ongoing with predator control since 2014–2015 (Raine et al. 2022). Of the conservation sites, North Bog and Pihea contribute the greatest number of new birds because of their much larger starting populations (Figure 5F-3).

Continued predator control by the HCP at the conservation sites, combined with powerline collision minimization, will prevent substantial declines of existing subpopulations of Hawaiian petrel (ʻuaʻu) and likely prevent local extirpation (red lines in Figure 5F-3). Three of these conservation sites with predator control (North Bog, Pihea, and Hanakāpiʻai) collectively contribute substantial numbers of new breeding pairs to the Kauaʻi metapopulation of Hawaiian petrel (ʻuaʻu) with the HCP (blue lines in Figure 5F-3). Combined, the six conservation sites are projected to have more than 3,100 Hawaiian petrel (ʻuaʻu) breeding pairs by the end of the permit term.

Figure 5F-5 shows the subpopulation trajectories at each of the three areas outside the conservation sites (see Figure 5F-1 for area locations), with and without the KIUC HCP. Hanalei to Kekaha is the largest subpopulation in the area, by far. This area is projected to be approaching extirpation without the HCP by approximately 2060. With the HCP, the negative rate of modeled decline is slowed, but not reversed by the end of the permit term (2073). The difference in declines between these scenarios is due largely to powerline minimization. Because 92 percent of all powerline collisions are assumed to involve Hawaiian petrel (ʻuaʻu) associated with breeding colonies within the Hanalei to Kekaha area (see Figure 5F-1), powerline minimization provides a greater benefit in this area compared to other areas. This result is not surprising, because for all areas other than Hanalei to Kekaha the risk of powerline collisions is assumed to be much lower in the first place (Table 5F-3). By 2023 the rate of modeled decline has slowed from the initial 2016 radar trend in the Hanalei to Kekaha area due to powerline strike minimization (Table 5F-9). For Hanalei to Kekaha the rate of decline in abundance then increases again through time, due to the modeled effect of future powerline construction and fledgling fallout mortality.

The subpopulation trajectory in the Wainiha and Lumahaʻi Valleys area benefits with the HCP (Figure 5F-5). This is due to the area having vital rates modeled to match a stable trend (based on radar data) prior to minimization, and as minimization decreases mortality rates in the future, abundance is projected to have a positive trend. The remaining area in Figure 5F-5, Kalalau east to Upper Mānoa, is assumed to have relatively low vulnerabilities to powerline strikes, given its geographic remoteness. Therefore, powerline strike minimization is not predicted to have much of an effect on the modeled trend in abundance for this area, i.e., the blue (with HCP) and the red (without HCP) trajectories of abundance overlap. Nevertheless, Hawaiian petrel (ʻuaʻu) are modeled to decline in this area throughout the permit term. This decline is therefore almost completely due to the assumed effect of unmitigated mortality from introduced predators in this area. In other words, given the assumption of a low rate of maximum population growth, when the predation mortality rates are applied from the conservation sites prior to dedicated control measures, the trend in modeled abundance for the Kalaua to Upper Mānoa area is approximately -3 percent per year.

When all subpopulations are combined (Figure 5F-6), the Hawaiian petrel (ʻuaʻu) metapopulation on Kauaʻi is projected to continue to decline without the HCP (red line). Without the HCP, the total population size is projected to continue to decline from approximately 9,200 breeding pairs at the start of the permit term to just under 1,500 by the end of the permit term (2073), a decline of over 80 percent. With the HCP conservation measures the Hawaiian petrel (ʻuaʻu) metapopulation on Kauaʻi is projected by the end of the permit term to stabilize and begin to experience a small net increase in the Kauaʻi metapopulation (Figure 5F-6, blue line). HCP conservation measures are projected to slow the metapopulation decline considerably between 2050 and 2060, stabilizing at approximately 5,200 breeding pairs, before increasing (Table 5F-11).

If conservation efforts are maintained for 50 years, the metapopulation is projected to increase gradually, governed in part by the assumed low maximum rate of population growth, as the continued increases in abundance of Hawaiian petrel (ʻuaʻu) colonies at the conservation sites overcomes the declines in abundance in the Hanalei to Kekaha area (Figure 5F-7; Tables 5F-10 and 5F-11). The Hanalei to Kekaha area has the highest initial modeled abundance, and in addition to the Kalalau to Upper Mānoa area, it also has a relatively high degree of uncertainty in terms of initial and therefore projected abundance (Table 5F-2). Therefore, the metapopulation projection, especially as it relates to the relative contribution of the abundance in the aforementioned areas to the overall island-wide trend, is also uncertain. However, the abundance and life history parameters of Hawaiian petrel (ʻuaʻu) within the conservation sites are relatively well understood, leading to higher confidence in the population projections in these areas. This means that we have a relatively high confidence that the increase in subpopulations of the conservation sites combined will provide a substantial net benefit to Hawaiian petrel (ʻuaʻu) on Kauaʻi.

Without the HCP, the Kauaʻi metapopulation of Hawaiian petrel (ʻuaʻu) would be greatly reduced by 2073. Depending on the age structure and spatial distribution of the species at that time, the viability of the metapopulation may be compromised without conservation efforts under the HCP, due to the species' slow reproductive rate and other factors. However, with the continuation of conservation efforts associated with the HCP, by 2073 the stabilization and eventual increase of the metapopulation is forecast. The conservation sites are large enough in size and have such extensive suitable habitat for Hawaiian petrel (ʻuaʻu) that subpopulations (and densities) are expected to continue to increase without experiencing any density-dependent constraints, assuming management actions continue at the same level as outlined in this HCP.

The cumulative number of strikes for each area from these modeled projections are provided in Table 5F-12. The predictions of strikes should be considered conservative (i.e., strike predictions may be too low) because these results are based on modeling a rate of decline for Hanalei to Kekaha that represents a worst-case scenario based on the most drastic rate of decline estimated from the 1993–2020 radar survey data. This rate of decline, while based on data, does not represent the less drastic average rate of decline estimated across all radar sites in the Hanalei to Kekaha area during the same period; further, it does not reflect the more recent stabilization of trend across radar sites in this area during 2010–2020 (Raine and Rossiter 2020). Additionally, the 2010–2020 decade of radar data exhibiting a stable trend in relative abundance for the Hanalei to Kekaha area also overlaps in time with the estimate of unminimized seabird strikes from acoustic powerline monitoring data during 2013–2019 (Travers et al. 2020). Together, these two sources of monitoring data suggest that, at least during the last decade, the Hanalei to Kekaha subpopulation experienced a relatively high level of powerline mortality while also maintaining a stable abundance level. If this situation were to continue in the future, i.e., trends in both powerline strikes and abundance area remain stable, the modeled decline in abundance for Hanalei to Kekaha (and hence the modeled reduction in strikes associated with declining future abundance in this area) would underestimate future strikes.

Table 5F-9. Modeled Hawaiian Petrel (ʻuaʻu) Subpopulation Lambda values, Starting with the First Year of the HCP (2023), and then Shown at Five-Year Snap-Shot Intervals Over the 50-year Permit Term (to 2073).

Lambda is the population multiplier, i.e., the rate of change in abundance from the prior year is equal to one minus Lambda. Values of Lambda less than 1.0 represent a decline in abundance, and values greater than 1.0 represent an increase. The maximum possible value for Lambda in the model is 1.02 (2.0 percent population growth), which is never achieved in practice because each subpopulation is assumed to have some level of vulnerability to introduced predators (e.g., barn owl predation on the wing) and some level of vulnerability to powerline collisions.

Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
HCP Conservation Sites											
Upper Limahuli	1.008	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009
Pōhākea	1.009	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.01
Pihea	1.010	1.011	1.011	1.011	1.011	1.011	1.011	1.011	1.011	1.011	1.011
North Bog	1.008	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009
Hanakāpiʻai	1.009	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.01
Hanakoa	1.010	1.011	1.011	1.011	1.011	1.011	1.011	1.011	1.011	1.011	1.011
Other Areas											
Wainiha and Lumahaʻi Valleys	1.000	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001
Hanalei to Kekaha	0.937	0.943	0.942	0.942	0.942	0.942	0.941	0.941	0.941	0.940	0.939
Kalalau east to Upper Mānoa	0.955	0.955	0.955	0.955	0.955	0.955	0.955	0.955	0.955	0.955	0.955

Table 5F-10. Modeled Hawaiian Petrel (ʻuaʻu) Breeding Pair Abundance (ages 6 years and older) at Five-Year Intervals for each Subpopulation over the 50-year Permit Term (2023–2073)

Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
HCP Conservation Sites											
Upper Limahuli	114	119	124	130	135	141	148	154	161	168	176
Pōhākea	164	172	181	190	199	209	219	230	241	253	265
Pihea	664	700	737	777	819	863	909	958	1,010	1,064	1,121
North Bog	894	933	974	1,018	1,063	1,110	1,159	1,211	1,265	1,321	1,380
Hanakāpiʻai	296	310	325	341	358	376	394	413	434	455	477
Hanakoa	176	185	195	206	217	228	241	254	267	282	297
Other Areas											
Wainiha and Lumahaʻi Valleys	1,183	1,188	1,193	1,199	1,204	1,210	1,216	1,221	1,227	1,233	1,238
Hanalei to Kekaha	5,503	4,118	3,061	2,275	1,690	1,253	929	687	508	375	276
Kalalau east to Upper Mānoa	588	468	372	296	236	187	149	119	95	75	60
Total	**9,580**	**8,191**	**7,162**	**6,429**	**5,918**	**5,576**	**5,362**	**5,245**	**5,205**	**5,223**	**5,288**

Table 5F-11. Modeled Hawaiian Petrel (ʻuaʻu) Total (non-chick) Abundance at Five-Year Intervals for each Subpopulation over the 50-year Permit Term (2023–2073)

Initial abundance is based on the estimates of breeding pairs from ARC, with the exception of the Hanalei to Kekaha area, where the pre-HCP abundance is estimated as a function of the allocated strikes (92 percent) for that subpopulation and trends in abundance from radar, which is assumed to be -8.1 percent per year in 2016 and corresponds to the trend for Hawaiian petrel (ʻuaʻu) at the Waiakalua Stream radar site, the most negative rate of decline observed at any single radar site for this species during 1993–2020 (Raine and Rossiter 2020).

Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
HCP Conservation Sites											
Upper Limahuli	417	435	455	475	496	518	541	565	591	617	644
Pōhākea	603	633	664	696	731	766	804	844	885	928	974
Pihea	2,441	2,572	2,710	2,856	3,010	3,171	3,342	3,522	3,711	3,911	4,121
North Bog	3,281	3,426	3,578	3,737	3,904	4,077	4,259	4,448	4,646	4,852	5,068
Hanakāpiʻai	1,086	1,139	1,195	1,254	1,315	1,380	1,447	1,519	1,593	1,671	1,753
Hanakoa	646	680	717	756	796	839	884	932	982	1,035	1,091
Other Areas											
Wainiha and Lumahaʻi Valleys	4,131	4,149	4,168	4,188	4,207	4,227	4,247	4,267	4,286	4,306	4,326
Hanalei to Kekaha	16,228	12,060	8,968	6,662	4,944	3,664	2,712	2,004	1,478	1,087	797
Kalalau east to Upper Mānoa	1,723	1,371	1,090	868	690	549	437	348	276	220	175
Total	**30,557**	**26,464**	**23,546**	**21,491**	**20,093**	**19,193**	**18,674**	**18,447**	**18,448**	**18,628**	**18,950**

Table 5F-12. Modeled Hawaiian Petrel (ʻuaʻu) Powerline Strikes, Starting with the First Year of the HCP (2023), and then Shown as a Cumulative Total at Five-Year Intervals for each Subpopulation until the End of the Permit Term (2073)

Area	2023	2028	2033	2038	2043	2048	2053	2058	2063	2068	2073
HCP Conservation Sites											
Upper Limahuli	5	31	57	85	115	145	177	210	245	281	319
Pōhākea	5	30	56	83	112	142	174	207	242	279	317
Pihea	10	61	114	171	230	293	359	429	502	579	661
North Bog	39	241	452	672	901	1,141	1,392	1,654	1,927	2,213	2,511
Hanakāpiʻai	9	54	101	150	202	256	313	373	436	502	571
Hanakoa	3	16	30	45	61	77	95	113	133	153	175
Other Areas											
Wainiha and Lumahaʻi Valleys	47	284	522	761	1,002	1,243	1,485	1,729	1,974	2,219	2,467
Hanalei to Kekaha	840	4,337	6,935	8,880	10,335	11,420	12,229	12,831	13,278	13,608	13,851
Kalalau east to Upper Mānoa	16	86	142	187	222	250	272	290	304	316	325
Total	**974**	**5,139**	**8,409**	**11,034**	**13,179**	**14,969**	**16,497**	**17,837**	**19,041**	**20,150**	**21,196**

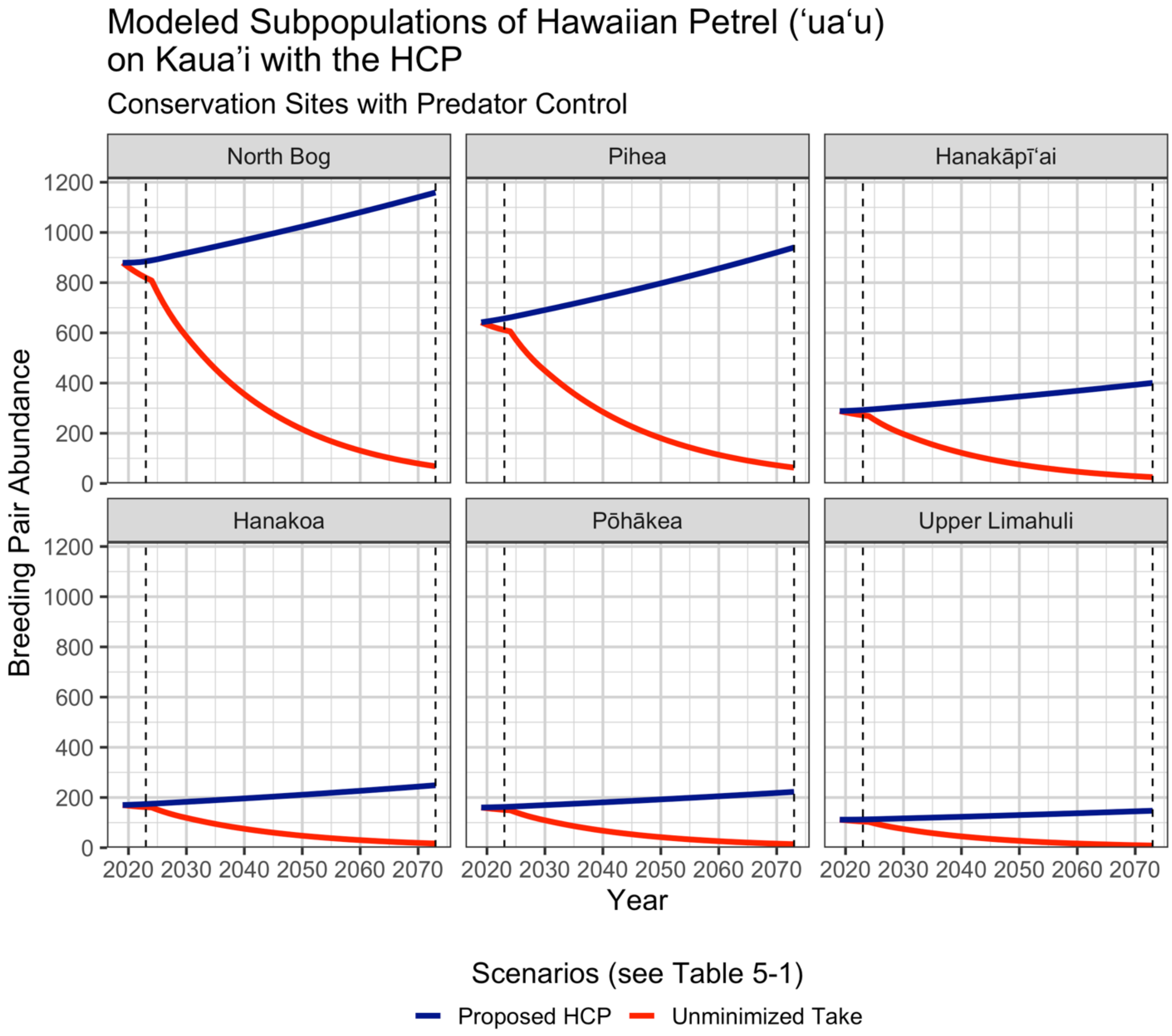

Figure 5F-3. Population Dynamics Model Results for Hawaiian Petrel (‘ua‘u) for each Subpopulation with Predator Control Measures and Ungulate Fencing

Red lines show the unminimized take model scenario without the HCP (take continues without powerline minimization, and without conservation measures; see Table 5-1 in Chapter 5). Blue lines are with the proposed HCP according to the schedule of conservation measures described in Chapter 4. The vertical dashed lines denote the first and last year of the permit term. See Figure 5F-1 for site locations.

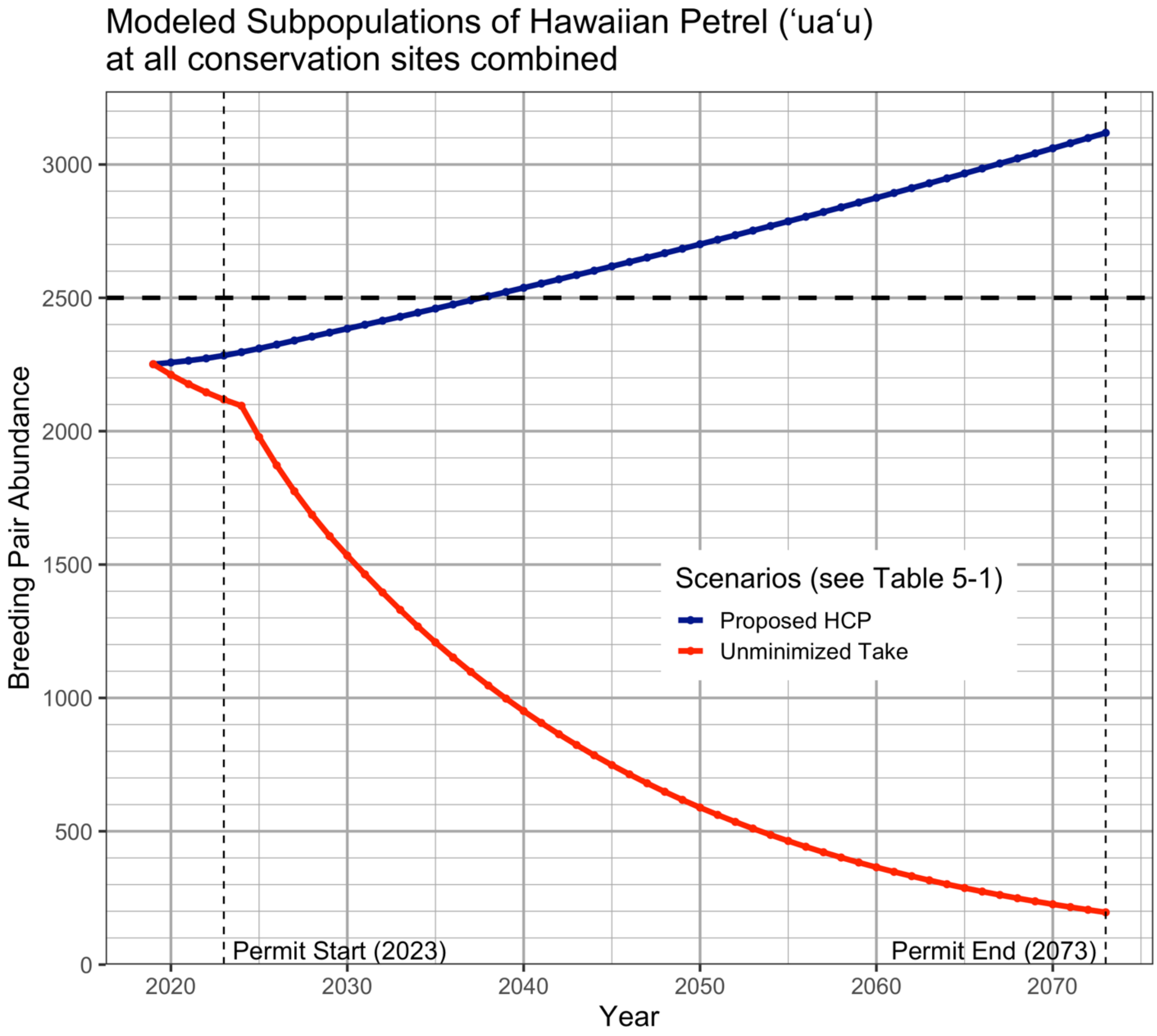

Figure 5F-4. Population Dynamics Model Results for Hawaiian Petrel (ʻuaʻu) for all Conservation Sites Combined

Red line shows the unminimized take scenario without the HCP (take continues without powerline minimization, and without conservation measures; see Table 5-1 in Chapter 5). Blue line is with the HCP according to the schedule of conservation measures described in Chapter 4. The horizontal dashed line highlights 2,500 breeding pairs, which USFWS considers to be a rough threshold for a viable metapopulation on the island (see Chapter 5 for details).

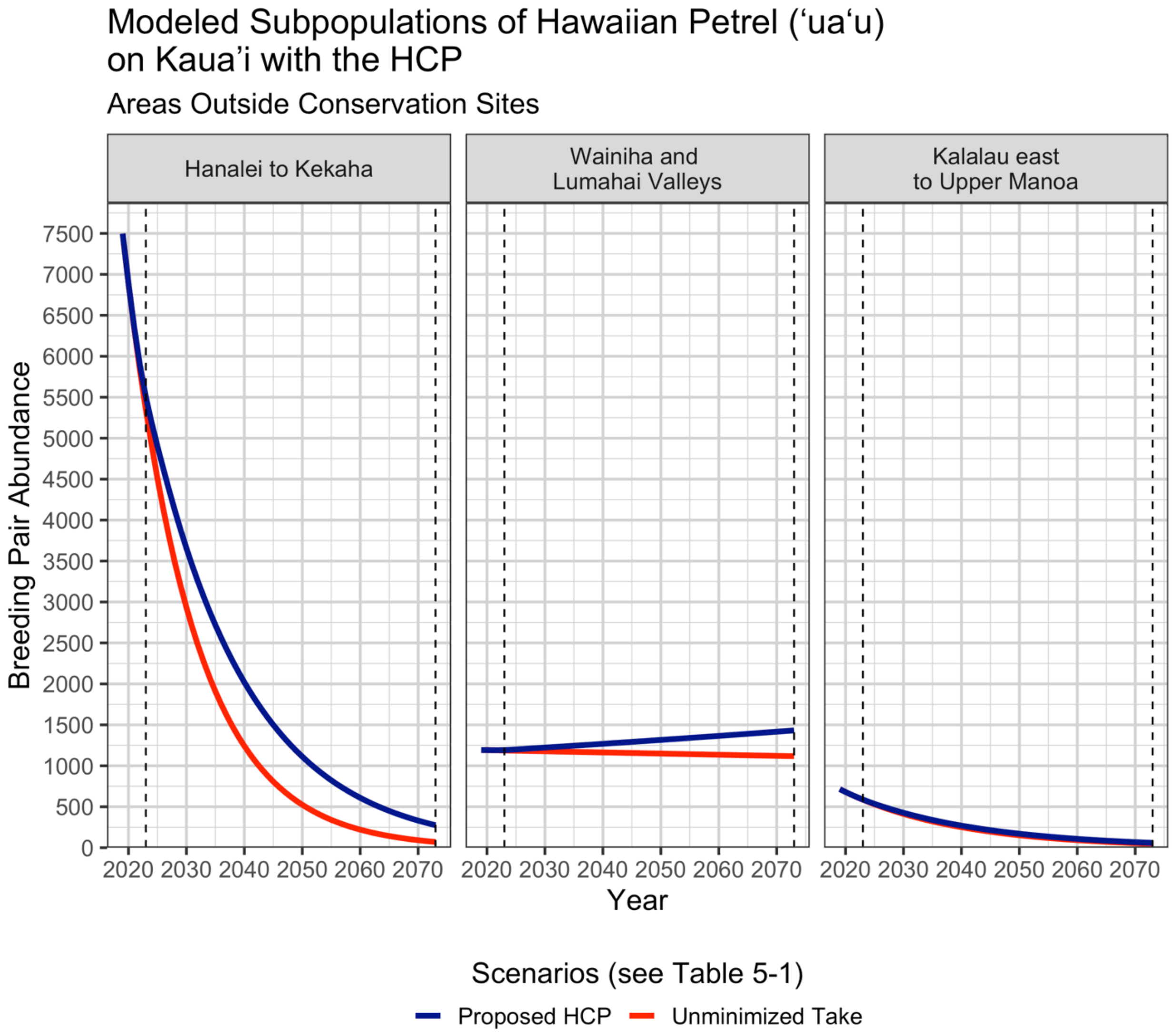

Figure 5F-5. Population Dynamics Model Results for Hawaiian Petrel (ʻuaʻu) for each Subpopulation outside the Conservation Sites

Red lines show the unminimized take model scenario (take continues without powerline minimization, and without conservation measures; see Table 5-1 in Chapter 5). Blue lines are with the proposed HCP according to the schedule of conservation measures (i.e., powerline collision minimization) described in Chapter 4. The vertical dashed lines denote the first and last year of the permit term. See Figure 5F-1 for site locations.

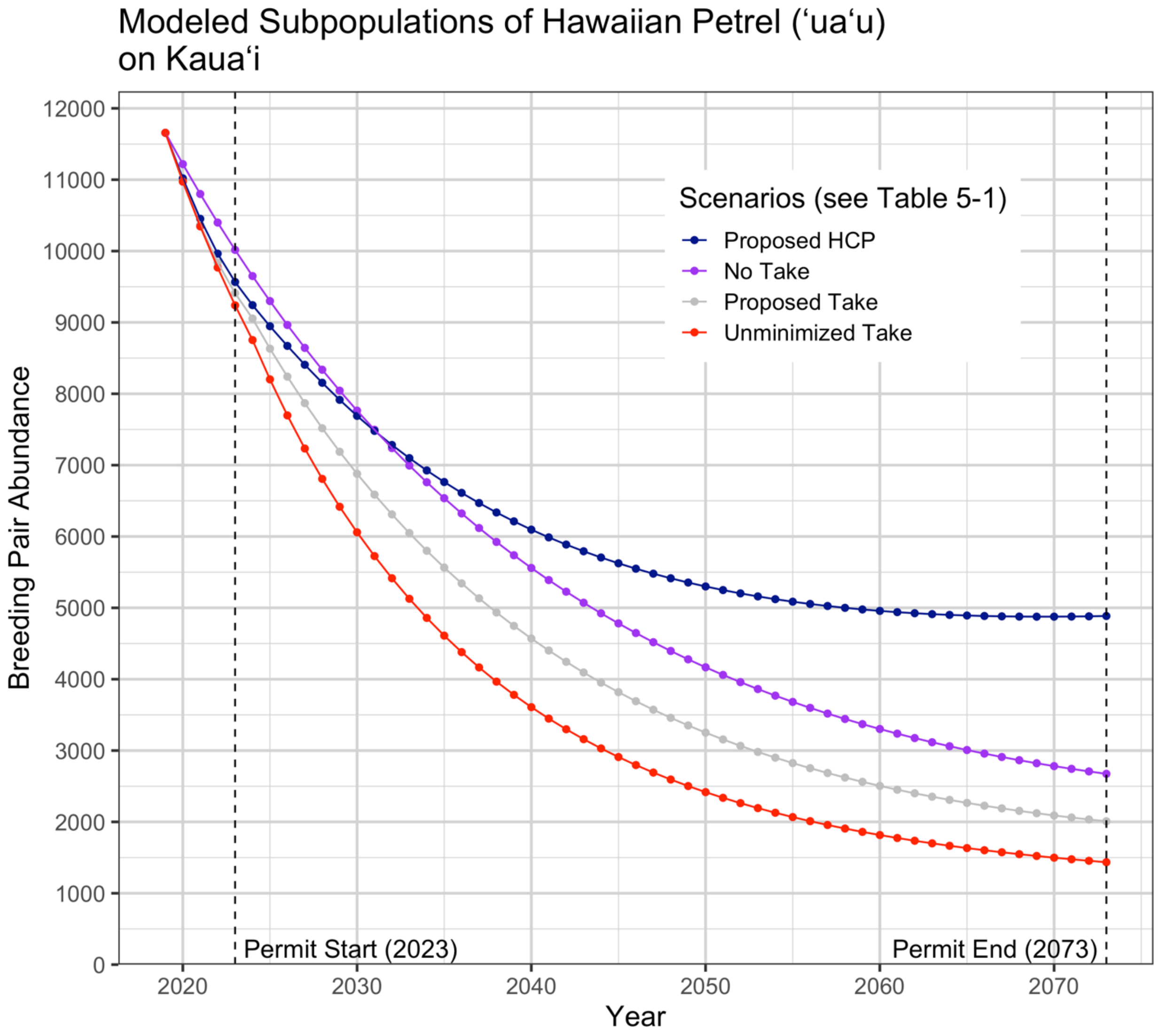

Figure 5F-6. Population Dynamics Model Results for Hawaiian Petrel (ʻuaʻu) for all Subpopulations Combined (all of Kauaʻi)

Red line is the unminimized take model scenario without the HCP (take continues without powerline minimization, and without conservation measures). Blue line is with the proposed HCP according to the schedule of conservation measures (i.e., powerline collision minimization) described in Chapter 4. The grey line is with the proposed minimized take; the purple line is with no take. See Table 5-1 in Chapter 5 for additional description of each model scenario. The vertical dashed lines denote the first and last year of the permit term.

5F.3 Model Limitations, Uncertainties, and Assumptions

The population dynamics model described in this appendix is a useful tool with which to compare outcomes to Hawaiian petrel (ʻuaʻu) on Kauaʻi both with and without the KIUC HCP. The model is also an important tool to confirm that the quantitative biological objectives for Hawaiian petrel (ʻuaʻu), particularly at the conservation sites, can be achieved by the end of the permit term. However, as with all models there are uncertainties in model inputs and outputs that should be considered. Model limitations include, but are not limited to, the following.

- Lack of statistical confidence limits around the island-based estimates of abundance.
- Uncertainty in certain vital rates (e.g., barn owl predation rates on the wing and predation rates in areas without predator control).
- Uncertainty in the efficacy of future powerline strike minimization efforts (although continued powerline monitoring will help narrow those uncertainties within a few years).
- Logistical difficulties in monitoring the population outside of established conservation sites.

Due to these limitations, the uncertainty in the model results has not been quantified. However, any population dynamics model of Hawaiian petrel (ʻuaʻu) relies on a suite of assumptions. The assumptions chosen for this model were selected to be as conservative as reasonably possible knowing that many model uncertainties have not been quantified. A list of the key assumptions is provided below for this model, with reasons these assumptions may be conservative or optimistic in terms of predicting effects of the HCP conservation measures on this species. These sections are intended to provide the reader with a qualitative understanding of the level and sources of uncertainty in model results.

5F.3.1 Conservative Assumptions

Reasons the population dynamics model may be conservative (i.e., overestimates adverse effects or underestimates beneficial effects for Hawaiian petrel [ʻuaʻu]) include the following.

- **Total powerline strikes.** The reported point estimate that is used as a model input for the annual average of seabird strikes corresponds to the mean of the Bayesian posterior predictive probability distribution, corrected to account for strikes that were subsequently recategorized as waterbirds (Travers et al. 2020; Travers unpublished data). For a right skewed (longer right tail) probability distribution, like the Bayes posterior predictive probability distribution for seabird strikes, the mean is greater than the expectation of the estimate. Statistically, this results in using a conservative (i.e., higher) level of powerline collisions in the model.
- **Strike allocation.** Allocation of powerline strikes may be even lower at some or all of the conservation sites than estimated, given flight paths, and observed altitudes from satellite tagging. For example, the estimated breeding probability from burrow monitoring data at seven conservation sites for Hawaiian petrel (ʻuaʻu) is 0.982 (Raine et al. 2022), which indicates that non-predation sources of mortality for breeding adults were quite low in these areas.
- **Population trend and optimal growth rate.** The modeled population trend for the Hanalei to Kekaha area assumes a relatively steep rate of decline, based on the long-term trend from the

Waiakalua Stream radar site. Based on recent (and longer-term) radar trends from the other radar sites, the population trend is unlikely to be that steep for all breeding colonies in this area.

Raine and Rossiter (2020) have shown that the average trend in radar estimates have leveled out since 2010, indicating that after a very large population decline the population trend may now be relatively stable on an island-wide basis. For example, a regression of radar data including all 13 monitored sites was flat with no significant change during the last decade (2010–2020).

This pattern is consistent with data on the amounts of rescues of Hawaiian petrel (ʻuaʻu) from the SOS Program, which are relatively stable over a similar period (Ainley et al. submitted).

Therefore, based on these three data sources (radar signatures, SOS rescues, and acoustic call rates) the aggregate modeled population trend in the absence of minimization and mitigation is likely to be conservative, at least in terms of observed trends over the last decade. If the aggregate population trend is more positive (either a smaller negative number or a number close to zero for a stable population), then the effects of the HCP conservation strategy will result in a greater benefit to the island-wide metapopulation of Hawaiian petrel (ʻuaʻu) than what is estimated.

Also, the optimal rate of modeled population growth assumed in the model is much lower than has been estimated for the family Procellariidae (all petrels, prions and shearwaters) in published allometric and demographic modeling studies. The results of those studies are consistent with species in this seabird family having expected optimal rates of population growth closer to 6.8 percent per year (Dillingham et al. 2016) or 7.1 percent per year (Dillingham and Fletcher 2011), depending on the methods used. This model assumed an optimal rate of modeled population growth (i.e., in the absence of introduced predators, powerline strikes or light fallout mortality) of 2.0 percent per year.

- **Fallout from light attraction.** Currently a constant amount of 5.3 age-1 (fledglings) from the Hanalei to Kekaha subpopulation are assumed to die annually from fallout associated with KIUC streetlights. The estimated level of fallout includes correction factors for the proportion of grounded seabirds that go undetected, e.g., for KIUC streetlights, 89.6% of grounded Hawaiian petrel (ʻuaʻu) are assumed to go undetected (Appendix 5C: *Light Attraction Modeling*). Fallout, whether detected or not, is assumed to result in 100% mortality in the model. This assumption is conservative for three reasons: (1) The estimate for fallout is based on the number of expected streetlights and facility lights at the end of the permit term, not at the beginning. Fallout from light attraction is therefore likely overestimated at the start of the projections; (2) This assumes zero individuals rehabilitated by the SOS program survive; and, (3) Fallout mortality is modeled as a fixed number of fledglings lost, not a mortality rate. In other words, even when the Hanalei to Kekaha subpopulation is much smaller towards the end of 50 years, 5.3 fledglings (or the number of modeled fledglings, whichever is smaller) are still removed in the model from this area each year. Furthermore, the level of mortality from fallout is estimated to be less than five percent of the level of mortality estimated from powerline collisions. So, while fallout mortality is a contributing factor to metapopulation dynamics, it does not have as large of an effect on metapopulation trends as powerline collisions.
- **Conservation actions performed by others.** The population dynamics of the Kauaʻi metapopulation of Hawaiian petrel (ʻuaʻu) are modeled only assuming the full implementation of this HCP's conservation. Numerous federal, state, and local agencies and conservation organizations are either implementing or planning to implement additional conservation actions

separately from this HCP, which will benefit Hawaiian petrel (ʻuaʻu). Similarly, due to a lack of available estimates for reductions in predation rates resulting from barn owl control at the conservation sites, no attempt has been made to include the benefit of that form of predator control effort at the conservation sites. Because this model does not consider these other current or planned conservation action, the impacts of the taking of this HCP are conservative (i.e., overestimate effects).

5F.3.2 Potentially Optimistic Assumptions

Reasons the population dynamics model for Hawaiian petrel (ʻuaʻu) may be too optimistic (i.e., underestimates adverse effects or overstates benefits) include the following.

- **Total metapopulation size.** The estimate of the island-wide metapopulation may be too high, despite the integration of multiple indpendent data sources, and what are thought to be conservative assumptions by experts. If this is true, then impacts of the taking would be greater than predicted by the model. However, all else being equal, the *relative* effects of the HCP would be the same because the comparison is made with and without the HCP using the same initial abundance estimate and estimates of trends in relative abundance (i.e., positive trends in call rates from the conservation sites and negative trends in relative abundance from the radar survey). Also, if a smaller value for metapopulation abundance were used, the modeled trend would become inconsistent with long-term monitoring data, e.g., the modeled rate of decline in the Hanalei to Kekaha area would be even more negative compared to the lowest estimated rates of decline from the radar survey. Such a steep rate of decline, which would result from the estimated number of powerline collisions if abundance was indeed lower, would not be supported by the best available science on long-term trends in abundance.
- **Cat predation events.** The model is deterministic, which means that mortality and reproductive rates are assumed to be constant between years (with the exceptions of powerline collision minimization and the effects of immigration into social attraction sites). As such, interannual variation (stochasticity) in predation rates is not modeled even though the number of predations by cats can be variable between years. In particular, there have been instances of individual cats predating multiple nests during certain years before they have been caught. As such, a conservation site may have low predation mortality rates for a period of years, with an incursion of a single problem cat one year leading to a spike in predation mortality rates that year. Breeding pairs and chicks inside predator exclusion fences may be subject to such events in rare instances (i.e., before the cat incursion is caught on camera and additional control efforts can be deployed). Such events may also occur outside of conservation sites despite aggressive predator control techniques.

  The predation mortality rates used in the model are based on burrow monitoring data from multiple conservation sites over multiple years. The resulting estimate represents an average annual predation mortality rate under predator control that includes punctuated predation mortality events due to single cats. If the estimated predation mortality rate does not fully capture the extent or frequency of these predation events, for example because they are not observed during the burrow monitoring surveys (i.e., predations are occurring at burrows that are yet undiscovered and are not currently monitored), the model results with respect to the benefits of predator control at the conservation sites would be optimistic. However, independent acoustic monitoring data indicate that at least since 2014–2015, the extent of punctuated cat predation events has not resulted in negative trends in recruitment into the breeding colonies at the conservation sites—call rates have continued to increase and have doubled at many conservation sites under predator control efforts (Raine et al. 2022), despite such predation events having occured during the same time.

- **Carrying capacity.** There is no assumption in the model that Hawaiian petrel (ʻuaʻu) population growth in the conservation sites will be limited by carrying capacity during the 50-year permit term. If, in the future, population growth is limited by the carrying capacity of suitable nesting habitat, the model results would overestimate the long-term benefit of the conservation sites to the metapopulation. However, not only are carrying capacities difficult to estimate reliably for these large management areas, but estimates of predation rates prior to dedicated predator control in the conservation sites in combination with the assumed low rates of population recovery suggest that reaching carrying capacity in the adjacent management areas is not likely during the permit term.
- **Allee effects.** The model does not account for either compensatory, or depensatory, density dependence on the population growth rate. The former would account for higher expected population growth rates at lower population sizes, for example due to decreasing competition for resources. The latter, also known as “Allee” effects, arises in situations where population growth rates might be expected to decrease at lower abundance levels, for example due to difficulties finding a mate at low densities. Given that Hawaiian petrel (ʻuaʻu) is an endangered species with a low intrinsic rate of increase, there does not seem to be support for considering compensatory density dependence within the permit term. However, if modeled subpopulations that are predicted to be vulnerable to large declines (e.g., breeding colonies in the Hanalei to Kekaha area) experience Allee effects at lower densities in the future, the degree of the modeled declines there could be optimistic. There is no indication that Allee effects are occurring at recent abundance levels, at least at the broader scales monitored by the radar survey. Recent population trends from the radar data seem to be generally flattening out instead of showing accelerating rates of decline, but Allee effects are a possibility at smaller spatial scales in areas of the island without predator control.

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Appendix 6A

Adaptive Management Comparison Tables

Table 6A-1. Newell’s Shearwater (ʻaʻo) Powerline Collisions: Projected 5-year Rolling Averages

year	5-yr ave.	year	5-yr ave.	year	5-yr ave.	year	5-yr ave.	year	5-yr ave.
2027	1,763	2037	1,010	2047	583	2057	353	2067	235
2028	1,658	2038	956	2048	553	2058	337	2068	227
2029	1,554	2039	905	2049	525	2059	322	2069	220
2030	1,463	2040	856	2050	498	2060	309	2070	214
2031	1,386	2041	809	2051	473	2061	296	2071	209
2032	1,315	2042	765	2052	450	2062	284	2072	205
2033	1,250	2043	724	2053	428	2063	272	2073	203
2034	1,186	2044	685	2054	407	2064	262		
2035	1,125	2045	649	2055	388	2065	252		
2036	1,066	2046	615	2056	370	2066	243		

Table 6A-2. Hawaiian Petrel (ʻuaʻu) Powerline Collisions: Projected 5-year Rolling Averages

year	5-yr ave.	year	5-yr ave.	year	5-yr ave.	year	5-yr ave.	year	5-yr ave.
2027	878	2037	548	2047	370	2057	274	2067	225
2028	833	2038	525	2048	358	2058	268	2068	222
2029	790	2039	503	2049	346	2059	262	2069	219
2030	752	2040	483	2050	335	2060	256	2070	216
2031	717	2041	464	2051	325	2061	251	2071	214
2032	684	2042	446	2052	315	2062	245	2072	211
2033	654	2043	429	2053	306	2063	241	2073	209
2034	625	2044	413	2054	297	2064	236		
2035	598	2045	398	2055	289	2065	232		
2036	572	2046	384	2056	282	2066	229		

Table 6A-3. Newell’s Shearwater (ʻaʻo) Breeding Pairs: Projected 5-year Rolling Averages

year	5-yr ave.	year	5-yr ave.	year	5-yr ave.	year	5-yr ave.	year	5-yr ave.
2027	1,329	2037	1,657	2047	2,198	2057	2,828	2067	3,612
2028	1,349	2038	1,710	2048	2,256	2058	2,902	2068	3,697
2029	1,372	2039	1,765	2049	2,314	2059	2,976	2069	3,783
2030	1,395	2040	1,819	2050	2,372	2060	3,052	2070	3,869
2031	1,418	2041	1,871	2051	2,432	2061	3,128	2071	3,957
2032	1,447	2042	1,924	2052	2,493	2062	3,206	2072	4,045
2033	1,480	2043	1,977	2053	2,555	2063	3,285	2073	4,134
2034	1,514	2044	2,031	2054	2,619	2064	3,365		
2035	1,557	2045	2,086	2055	2,687	2065	3,446		
2036	1,606	2046	2,142	2056	2,756	2066	3,529		

Table 6A-4. Hawaiian Petrel (ʻuaʻu) Breeding Pairs: Projected 5-year Rolling Averages

year	5-yr ave.	year	5-yr ave.	year	5-yr ave.	year	5-yr ave.	year	5-yr ave.
2027	2,311	2037	2,460	2047	2,618	2057	2,787	2067	2,967
2028	2,325	2038	2,475	2048	2,635	2058	2,804	2068	2,985
2029	2,340	2039	2,491	2049	2,651	2059	2,822	2069	3,004
2030	2,355	2040	2,506	2050	2,668	2060	2,840	2070	3,023
2031	2,370	2041	2,522	2051	2,684	2061	2,857	2071	3,042
2032	2,385	2042	2,538	2052	2,701	2062	2,875	2072	3,061
2033	2,399	2043	2,554	2053	2,718	2063	2,893	2073	3,080
2034	2,414	2044	2,570	2054	2,735	2064	2,911		
2035	2,429	2045	2,586	2055	2,752	2065	2,930		
2036	2,445	2046	2,602	2056	2,769	2066	2,948		

Appendix 6B

KIUC Site Monitoring Protocols & Procedures for Protected Seabirds

KIUC

Site Monitoring Protocols & Procedures for Protected Seabirds



Table of Contents

1. Introduction & Site Monitoring
2. Protected Seabird Species
3. Seabird Recovery Reporting Form
4. Contents of Oppenheimer Seabird Recovery Kit
5. SOS Aid Stations
6. Backup paper processing

Section 1

Introduction & SiteMonitoring

(Electronic Inspection Log)

INTRODUCTION

KIUC has developed a variety of support materials to assist its employees in executing the requirements of site monitoring, recovery, and reporting of protected seabirds that are found downed, injured, or dead at KIUC facilities. This manual includes information and guidance about the following:

1. Site monitoring protocol for all KIUC personnel
2. Threatened and endangered seabird species
3. Recovery and reporting process when dealing with a downed, injured, or dead seabird
4. KIUC Oppenheimer Seabird Recovery Kit
5. Location of SOS Aid Stations

SITE MONITORING

ALL PERSONNEL will report any downed seabirds they encounter during their daily work routine immediately to the Operations Shift Supervisor/Designee or Warehouse Supervisor/Designee for recovery and reporting.

DESIGNEE FOR EACH RESPECTIVE FACILITY shall watch for downed seabirds as they conduct their routine plant inspections throughout the year.
During the seabird fallout season (September 15 - December 15), searches targeted specifically at finding downed seabirds will be conducted as per the table in Figure 1, 7 days a week. The results of daily inspections conducted during the seabird season shall be recorded on the Electronic Seabird Weekly Inspection Log (see next page). Any downed seabirds shall be recovered and reported following the established protocols detailed in the KIUC Seabird Recovery Reporting Form under Section 3 of this manual. **In the event that a scheduled search cannot be conducted due to an operational emergency, the Operations Shift Supervisor or Designee will conduct the survey as soon as possible. A notation should be made on the inspection log accordingly.**

Figure 1:

	FREQUENCY		
FACILITY	3 to 4 hours after sunset	1 hour before sunrise	weekends & holidays
PAGS	x	x	x*
Kapaia GS	x	x	

** note : On Saturdays, Sundays and company holidays, PAGS will conduct an additional search for downed seabirds between 7:00 AM and 8:00 AM.*

ELECTRONIC SEABIRD INSPECTION LOG

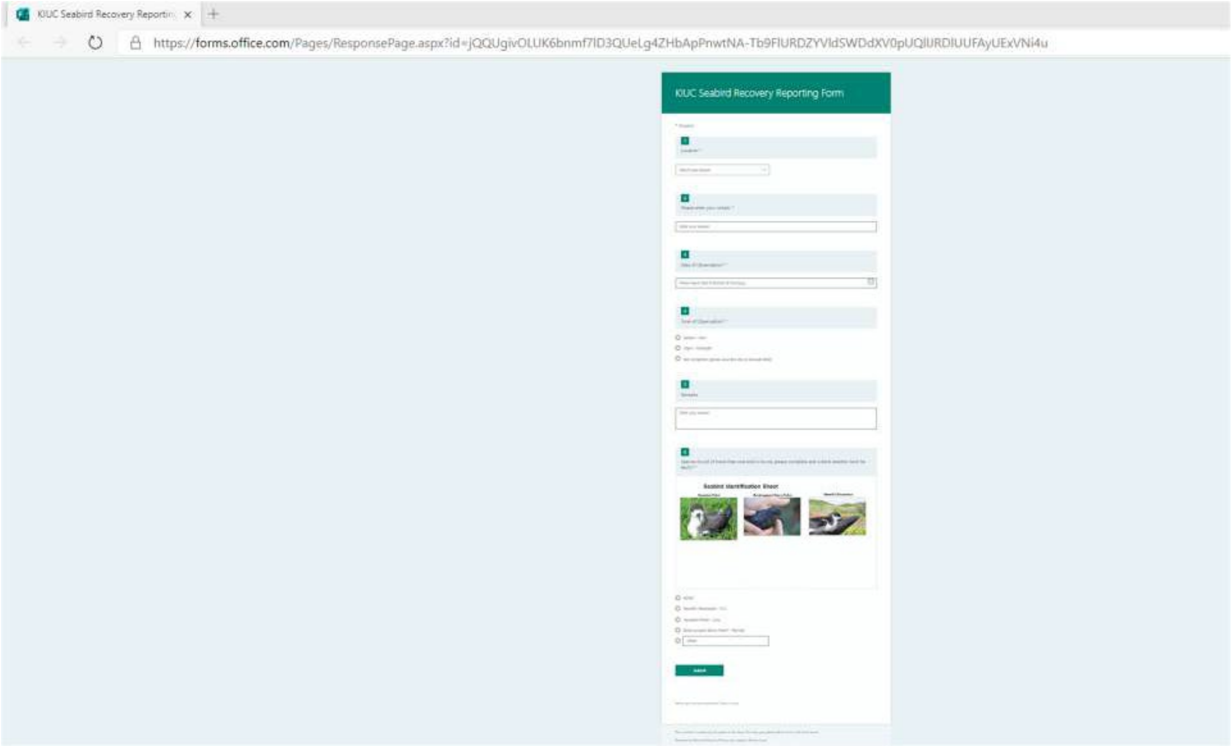
KIUC has developed an electronic inspection log to make the process more efficient. Using Microsoft Forms and the below link, anyone can get to and submit an inspection using a desktop computer, smart phone, or tablet.

Link to the electronic seabird inspection log can be found here:

[KIUC Seabird Recovery Reporting Form]

or by copy/paste the below into your browser:

https://forms.office.com/Pages/ResponsePage.aspx?id=jQQUgivOLUK6bnmf7lD3QUeLg4ZHbApPnwtNA-Tb9FlURDZYVldSWDdXV0pUQllJRDlUUFAyUExVNi4u



Please coordinate with your team to ensure your inspection frequencies are met for your respective facility. If ever in doubt if an inspection occurred or not, it's best to submit one again anyway (better to double up rather than missing an inspection).

A weekly report will be run and distributed to the teams so all submissions to date can be reviewed, corrected, and/or actioned. Please contact Chris Yuh for any issues or questions about the form (cyuh@kiuc.coop; 808-246-8281; 808-679-2388).

As a last resort backup, the paper documents from previous seasons can be found in Section 6.

Section 2

Protected Seabird Species

PROTECTED SEABIRD SPECIES

Why is KIUC taking special precautions with respect to protected seabirds?

KIUC's electrical transmission and distribution system is largely above ground and consists of poles and wires that extend from 25 to more than 100 feet above ground. The overhead wires and poles occupy airspace through which birds fly, and collisions between birds and these facilities have been reported. Covered facilities, which include the Port Allen and Kapaia Generating Stations, are of less concern, but there is potential for take.

In addition to collisions, urban lights, including KIUC's covered facility lights and streetlights KIUC owns and operates on behalf ofthe County of Kaua'i, State of Hawai'i, and private entities, can attract and/or disorient fledglingsof these species making their first flights to sea. Birds that become disoriented by these lights can exhaust themselves by flying around the lighted areas before eventually landing, and can also collide with obstacles such as power lines, utility poles, buildings, and other tall structures. The protected seabirds have very limited ability to resume flight from flat surfaces, therefore once on the ground they are highly subject to predation by dogs, cats, and other mammals, and to injury and death by vehicles, other human activity, or due to dehydration or starvation.

Studies indicate that KIUC's existing facilities have affected three species of seabirds that are protected by the Federal Endangered Species Act (ESA), the Hawai'i Endangered Species Act, and other federal and state laws and regulations. All three species are also listed by the State of Hawai'i as threatened or endangered species. The species are:

- the Federally listed endangered **Hawaiian Petrel** (*Pterodroma sandwichensis*);
- the Federally listed threatened **Newell's Shearwater** (*Puffinus newelli*); and
- the Federally listed endangered **Band-rumped Storm-Petrel** (*Oceanodroma castro*).

These species nest and breed in certain inland locations on the island but spend most of their lives at sea. They generally travel between land and sea during hours of darkness or near-darkness.

What are the legal implications?

There are significant legal implications if any of these birds are harmed, or the protected seabird protocols are not followed. Violations of the Federal ESA may include civil fines of up to $25,000 per incident, and criminal fines of up to $50,000, and up to one year imprisonment per incident. Violations of the state law include fines of up to $10,000 per species, up to one year imprisonment, or both.

Why do the seabirds fallout/What happens to them if they do?

- Nocturnally flying seabirds can be attracted to lights. This is particularly true of fledgling birds on their way to sea for the first time.
- The lights appear to confuse seabirds, leading them to collide with structures or simply circle until they land on the ground too tired to continue flying.
- Once on the ground they cannot take off again and will die from starvation, dehydration or be killed by predators if not rescued.

When is the seabird fallout season?

Adult seabirds arrive on the island as early as late March to find their mates and establish their nesting sites. These seabirds typically fly inland to their nests from sunset to about 3 hours after sunset and fly out to sea to forage for food during the 3 hours before sunrise. The potential for downings occurs during these flights. If downed, the seabirds will then attempt to seek places to hide at first light to escape from predators. Typical hiding places include under vegetation, in stairwells, under building materials, and under equipment including parked vehicles.

The vast majority of seabird fallout is by fledglings and occurs between September 15 and December 15 each year. However, adults and juveniles are typically present on Kaua‘i from mid-April onward.

Newell’s Shearwater - ‘a‘o.

- Listed as a threatened species by both the U.S. and State of Hawai‘i
- Ninety percent (90%) of the population nests on Kaua‘i. Also breeds on Maui, Hawai‘i, and possibly Moloka‘i
- The Newell’s Shearwater has an almost black head, upper wings and tail, and is white below. It has a thin narrow bill. Legs and feet are grey/black. Newell’s are 12-14 inches long, and have a wingspan of 30 inches.

Hawaiian Petrel - ‘u‘au.

- Listed as an endangered species by both the U.S. and State of Hawai‘i
- Breeding populations exist on Kaua‘i, Maui, Lana‘i, and Hawai‘i
- The Hawaiian Petrel has a dark gray head, wings, and tail, and a white forehead and belly. It has a stout grayish-black bill that is hooked at the tip. Its legs are pinkish with black and pink feet. This bird measures 16-17 inches in length and has a wing span of 35-37 inches.

Band-rumped Storm Petrel - ʻakeʻake.

- Listed as an endangered species by both the U.S. and State of Hawaiʻi
- Breeding populations exist on Kauaʻi, Lehua Island, Hawaiʻi and possibly on Maui.

The Band-rumped Storm-Petrel is an overall blackish-brown bird with an evenly-cut white rump band and slightly forked tail. It has a dark bill with a tube on top. This bird measures 8-9 inches in length and has a wing span of 17-18 inches.

Section 3

Seabird Recovery ReportingForm

ELECTRONIC SEABIRD RECOVERY REPORTINGFORM

As part of this year's process improvements, the seabird recovery form can also be logged using our electronic form. Using Microsoft Forms and the below link, anyone can get to and submit a recovery form using a desktop computer, smart phone, or tablet.

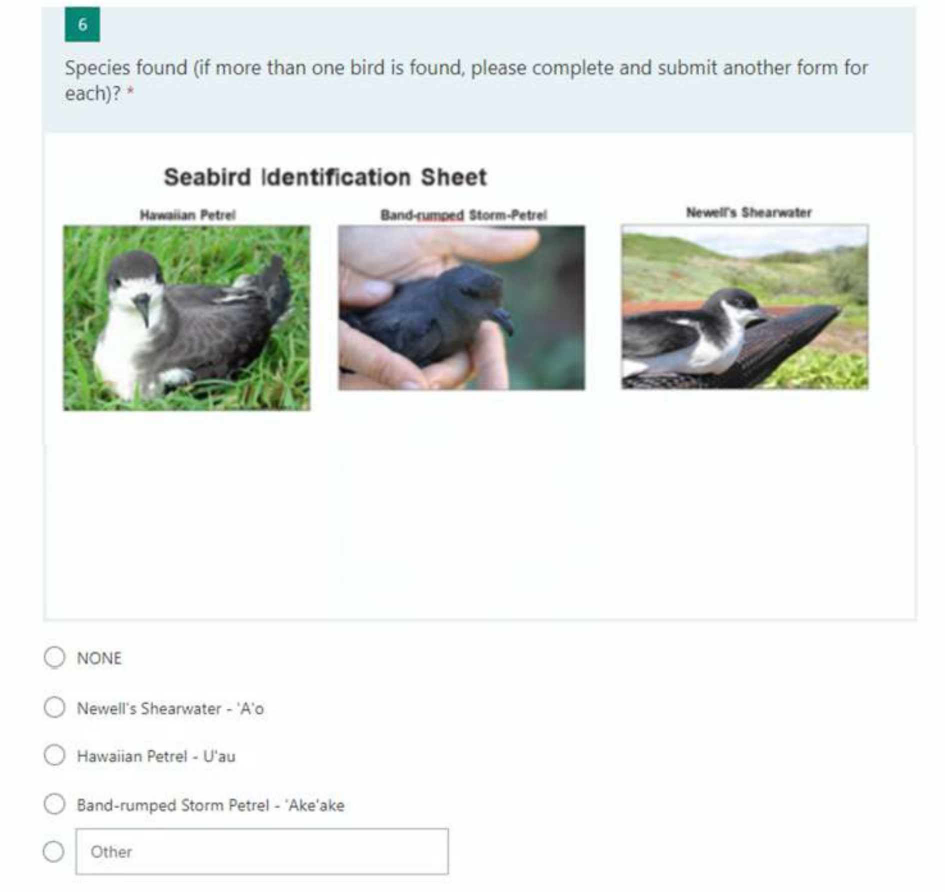
Link to the electronic seabird recovery form can be found using the SAME link to the seabird inspection log and found here:

KIUC Seabird Recovery Reporting Form

or by copy/paste the below into your browser:

https://forms.office.com/Pages/ResponsePage.aspx?id=jQQUgivOLUK6bnmf7lD3QUeLg4ZHbApPnwtNA-Tb9FlURDZYVldSWDdXV0pUQllJRDlUUFAyUExVNi4u

If your answer to question 6 is anything other than "NONE," then you will be prompted to fill out the electronic seabird recovery reporting form.



6

Species found (if more than one bird is found, please complete and submit another form for each)? *

○ NONE

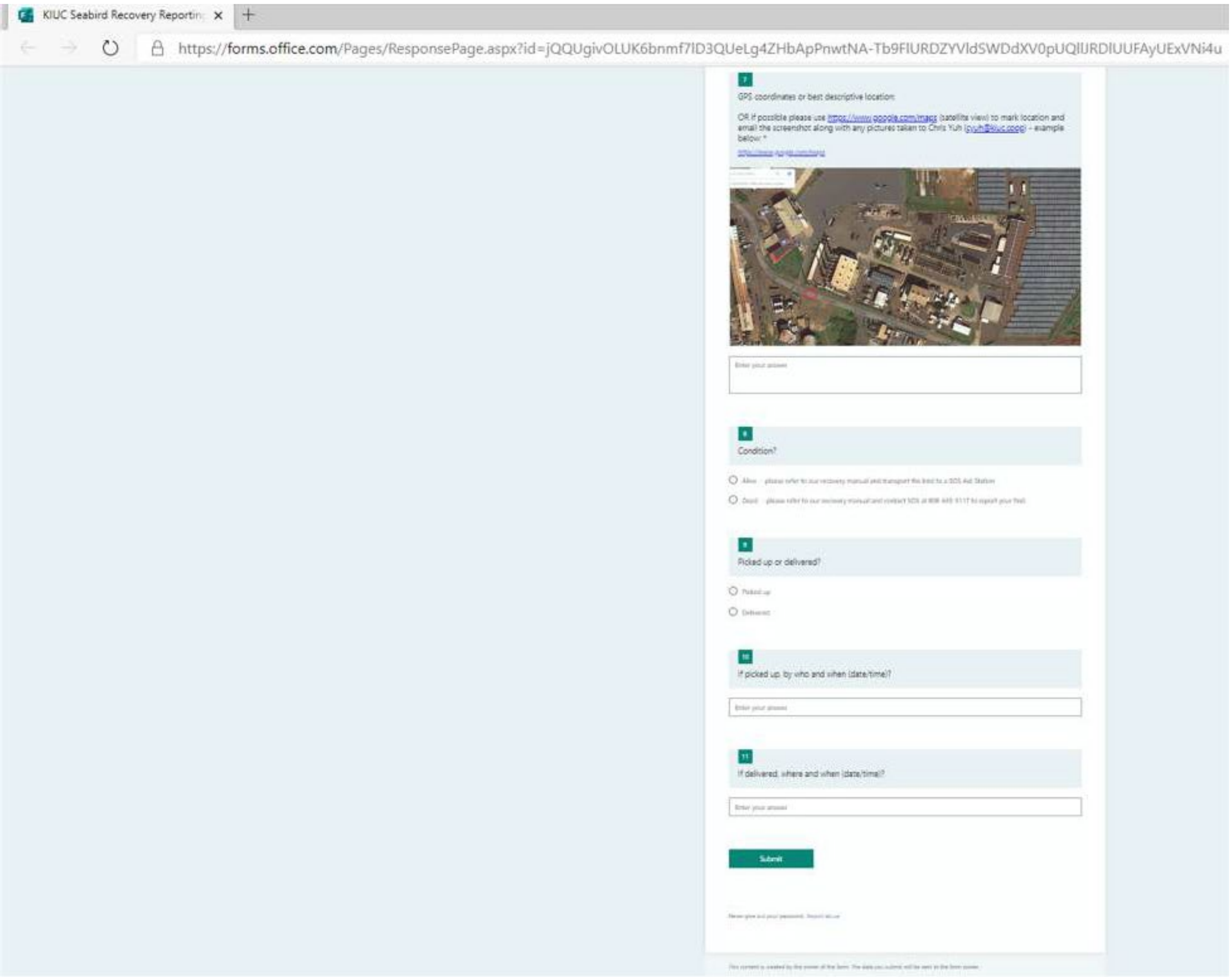
○ Newell's Shearwater - 'A'o

○ Hawaiian Petrel - U'au

○ Band-rumped Storm Petrel - 'Ake'ake

○ Other

You will then be required to answer an additional set of questions regarding the endangered species you found.



7

GPS coordinates or best descriptive location:

OR if possible please use https://www.google.com/maps (satellite view) to mark location and email the screenshot along with any pictures taken to Chris Yuh (cyuh@kiuc.coop) - example below: *

Enter your answer

8

Condition?

○ Alive

○ Dead

9

Picked up or delivered?

○ Picked up

○ Delivered

10

If picked up, by who and when (date/time)?

Enter your answer

11

If delivered, where and when (date/time)?

Enter your answer

As a last resort backup, the paper documents from previous seasons can be found in Section 6.

<u>If you encounter a living seabird:</u>

1. Before touching the downed seabird take at least one photograph of the scene showing the bird as it was found.
2. If possible please use https://www.google.com/maps (satellite view) to mark location the map and save the screenshot OR on the back side of the paper recovery reporting form, mark an “X” on the facility map to indicate where the seabird was found.
3. Deploy the KIUC Oppenheimer Seabird Recovery Kit.
4. Put on protective gloves.
5. Carefully wrap the bird in the clean towel from your kit and gently place it in the recovery box.
6. Transport the bird to the nearest SOS Aid Station.
7. Place the bird in the SOS Aid Station.
8. Call SOS at 635-5117 and report that seabird has been dropped off.
9. If seabird is dropped off after hours, leave a message with SOS providing all details and follow-up with a telephone call during business hours.
10. Fill in the Shearwater Aid Station log and provide Chris Yuh’s contact information.
11. Contact Chris Yuh (cyuh@kiuc.coop, 808-246-8281 or 808-679-2388).
12. Completely fill out the *Electronic KIUC Seabird Recovery Reporting Form* OR manually fill out the paper version.

13. Submit all pictures, screenshots, and/or the paper reporting form to Chris Yuh.

If you encounter a dead seabird:

1. Take at least one photograph of the scene showing the carcass as it was found.
2. If possible please use https://www.google.com/maps (satellite view) to mark location the map and save the screenshot OR on the back side of the paper recovery reporting form, mark an "X" on the facility map to indicate where the seabird was found.
3. Put on protective gloves.
4. Carefully place the carcass in two (2) Ziploc bags.
5. Place in refrigerator.
6. Contact SOS at 635-5117 and wait for further instructions (if after hours, leave a message with details and follow-up during business hours).
7. Contact Chris Yuh (cyuh@kiuc.coop, 808-246-8281 or 808-679-2388).
8. Completely fill out the *Electronic KIUC Seabird Recovery Reporting Form* OR manually fill out the paper version.
9. Submit all pictures, screenshots, and/or the paper reporting form to Chris Yuh.

Section 4

Contents of OppenheimerSeabird Recovery Kit

CONTENTS OF OPPENHEIMER SEABIRD RECOVERY KIT

To assist KIUC employees in fulfilling the conditions of its permits, it is equipping all KIUC vehicles and designated facilities with a package of materials which will help them deal with cases of downed, injured or dead protected species. Known as an *Oppenheimer Seabird Recovery Kit*, this kit is kept in their service vehicles and at selected KIUC facilities for use by employees as needed. As part of the Seabird Protection Training Program, all KIUC employees have been trained in how to use the contents of the kit to help them follow policies and procedures regarding the handling and reporting of downed, injured, or dead protected species they may encounter in the course of their duties.

Each *Oppenheimer Seabird Recovery Kit* includes the following five items:

Folded Cardboard Carrier**.** This carrier is a collapsible cardboard box, approximately 18 inches long, 10 inches wide, and 12 inches deep. This is large enough to accommodate any of the Covered Species. It can be folded to allow for carrying in service vehicles and can be quickly deployed whenever necessary.

Nitrile Gloves**.** A pair of Nitrile gloves, which are to be worn whenever a KIUC employee needs to handle a seabird. These gloves prevent contamination of the bird and protect the employee.

Cloth Towel**.** A clean towel, such as a generic automotive cleanup towel, approximately 12 inches square. Once the employee has donned the Nitrile gloves, he/she may use this towel to gently wrap the bird and place it in the cardboard carrier described above. This helps prevent any further harm to the bird as it is transported to a recovery location.

Seabird Recovery Reporting Form**.** This document is to be filled out by the KIUC employee(s) in the process of recovering a seabird. It contains fields for relevant information, such as the date, time, and location of the recovery, as well as GPS coordinates, species, status at time of recovery (i.e. living or dead), and the person/organization to which the bird was delivered. The form also summarizes the procedure which the employee is to follow at the time of recovery and reporting.

Seabird Identification Photographs**.** Correctly identifying seabirds can be challenging, and KIUC employees are not expected to be able to do so with total accuracy. To assist them in the sometimes difficult process of accurately reporting species information, photographs of the three threatened or endangered covered species (i.e., Newell's Shearwater, Hawaiian Petrel, and Band-rumped Storm-Petrel) have been included on the back side of the *Seabird Recovery Reporting Form*. Detailed information is also located in this manual under the "Protected Seabird Species" section.

It is suggested that the items listed above are inserted into the collapsed carrier and then kept in a plastic trash bag for ease of storage in service vehicles and to keep them clean and free of any possible contaminants.

Ziploc Bags**.** Two 2-gallon-sized Ziploc bags are to be used in the event a dead seabird is found at the facility. The double-bagged carcass should then be placed into a refrigerator until further instructions are received from SOS.

Section 5

SOS Aid Stations

SOS AID STATIONS

After initiating the proper recovery procedures, the downed seabird can be transported to one of the SOS Aid Stations located below:

North

- Hanalei Fire Station
- Hanalei Liquor Store
- North Shore Pharmacy Parking Lot *(formerly North Shore Medical Center)*

Central-East

- Kaiʻakea Fire Station
- Kapaʻa Fire Station
- Kauaʻi Humane Society
- Līhuʻe Fire Station

West

- Hanapēpē Fire Station
- Kalāheo Fire Station
- Port Allen Chevron
- Waimea Fire Station

South

- Koloa Fire Station

Contact Number for SOS: 635-5117

Photograph of SOS Aid Station

Section 6

Backup Paper Docs

2020 Seabird Fallout Season

KIUC Facility Site Monitoring - Weekly Inspection Log

Facility:

Week Starting: ________________________

Week Ending: ________________________

		DATE	INSPECTION DONE BY	START TIME	BIRDS FOUND (Y/N)*	ALIVE / DEAD	IF YES, LOCATION
Monday	Sunrise-8AM						
	10PM-Midnight						
Tuesday	Sunrise-8AM						
	10PM-Midnight						
Wednesday	Sunrise-8AM						
	10PM-Midnight						
Thursday	Sunrise-8AM						
	10PM-Midnight						
Friday	Sunrise-8AM						
	10PM-Midnight						
Saturday	Sunrise-8AM						
	10PM-Midnight						
Sunday	Sunrise-8AM						
	10PM-Midnight						

* If a seabird is found, immediately follow established protocol specified on the *KIUC Seabird Recovery Reporting Form*.

IF A SCHEDULED SEARCH CANNOT BE CONDUCTED DUE TO AN OPERATIONAL EMERGENCY, PLEASE NOTE ON LOG.

KIUC SEABIRD RECOVERY REPORTING FORM

DATE:		**TIME:**		**RESPONDER:**	
LOCATION:					
GPS LOCATION:					
SPECIES:					**ALIVE / DEAD**
PHOTO REFERENCE #S:					
AGENCY PICKUP – WHO:					
PICK UP OR DELIVERY:					
IF DELIVERY WHERE:					
REMARKS:					

If you encounter a living seabird:

1. Before touching the downed seabird take at least one photograph of the scene showing the bird as it was found.
2. If possible please use https://www.google.com/maps (satellite view) to mark location the map and save the screenshot OR on the back side of the paper recovery reporting form, mark an "X" on the facility map to indicate where the seabird was found.
3. Deploy the KIUC Oppenheimer Seabird Recovery Kit.
4. Put on protective gloves.
5. Carefully wrap the bird in the clean towel from your kit and gently place it in the recovery box.
6. Transport the bird to the nearest SOS Aid Station.
7. Place the bird in the SOS Aid Station.
8. Call SOS at 635-5117 and report that seabird has been dropped off.
9. If seabird is dropped off after hours, leave a message with SOS providing all details and follow-up with a telephone call during business hours.
10. Fill in the Shearwater Aid Station log and provide Chris Yuh's contact information.
11. Contact Chris Yuh (cyuh@kiuc.coop, 808-246-8281 or 808-679-2388).
12. Completely fill out the *Electronic KIUC Seabird Recovery Reporting Form* OR manually fill out the paper version.
13. Submit all pictures, screenshots, and/or the paper reporting form to Chris Yuh.

If you encounter a dead seabird:

1. Take at least one photograph of the scene showing the carcass as it was found.
2. If possible please use https://www.google.com/maps (satellite view) to mark location the map and save the screenshot OR on the back side of the paper recovery reporting form, mark an "X" on the facility map to indicate where the seabird was found.
3. Put on protective gloves.
4. Carefully place the carcass in two (2) Ziploc bags.
5. Place in refrigerator (continued next page).

6. Contact SOS at 635-5117 and wait for further instructions (if after hours, leave a message with details and follow-up during business hours).
7. Contact Chris Yuh (cyuh@kiuc.coop, 808-246-8281 or 808-679-2388).
8. Completely fill out the *Electronic KIUC Seabird Recovery Reporting Form* OR manually fill out the paper version.
9. Submit all pictures, screenshots, and/or the paper reporting form to Chris Yuh.

Seabird Identification Sheet

Hawaiian Petrel


Brenda Zaun, USFWS

Newell's Shearwater

Band-rumped Storm-Petrel

SOS Aid Station Locations

North

Hanalei Fire Station
Hanalei Liquor Store
North Shore Pharmacy
Parking Lot *(formerly N. Shore Medical Center)*

Central-East

Kaiʻakea Fire Station
Kapaʻa Fire Station
Kauaʻi Humane Society
Līhuʻe Fire Station

West

Hanapēpē Fire Station
Kalāheo Fire Station
Port Allen Chevron
Waimea Fire Station

South

Koloa Fire Station

Kauaʻi Island Utility Cooperative

Revised 11/2022

Appendix 7A

Cost Model

Kauaʻi Island Utility Cooperative Habitat Conservation Plan
Cost Model

Prepared by ICF

Introduction

This model estimates the cost of implementing the Kauaʻi Island Utility Cooperative (KIUC) Habitat Conservation Plan (HCP) in fulfillment of its terms and conditions. The goal of the cost model is to demonstrate that costs to KIUC over the 50-year HCP permit term have been reasonably and conservatively estimated in a manner that is transparent and reproducable. The table of contents, below, describes and links to each interconnected component of the model.

To briefly summarize the model design and function: The annual costs of the HCP are estimated within a series of distinct cost categories across the 50-year HCP permit term. Sources, assumptions, and calculations for estimating costs within each category are provided on the group of sheets listed under "HCP Implementation Cost Estimates," below. The model also recognizes costs incurred by KIUC for early implementation of certain conservation actions from 2020 through 2022, prior to issuance of the HCP permit, on the group of sheets listed under "Early Implementation Costs," below. Wherever possible, cost estimates are based on actual costs or detailed cost estimates for the same or similar activities that would be implemented for the HCP. Where this information was not available, cost were estimated based on reasonable assumptions and best professional judgement of the HCP preparation team. The sheets listed under "Assumptions and Parameters," below, identify global parameters and assumptions applied to the model. Certain fundamental assumptions and parameters can be updated dynamically throughout the model. Lastly, the sheets listed under "Summary Tables and Charts," below, draw from each individual cost category calculation sheet to present the aggregated costs of the HCP in tabular and graphic formats.

Chapter 7 of the HCP, "Plan Implementation," provides additional description of plan implementation and summary of HCP costs.

Cost Summary Table

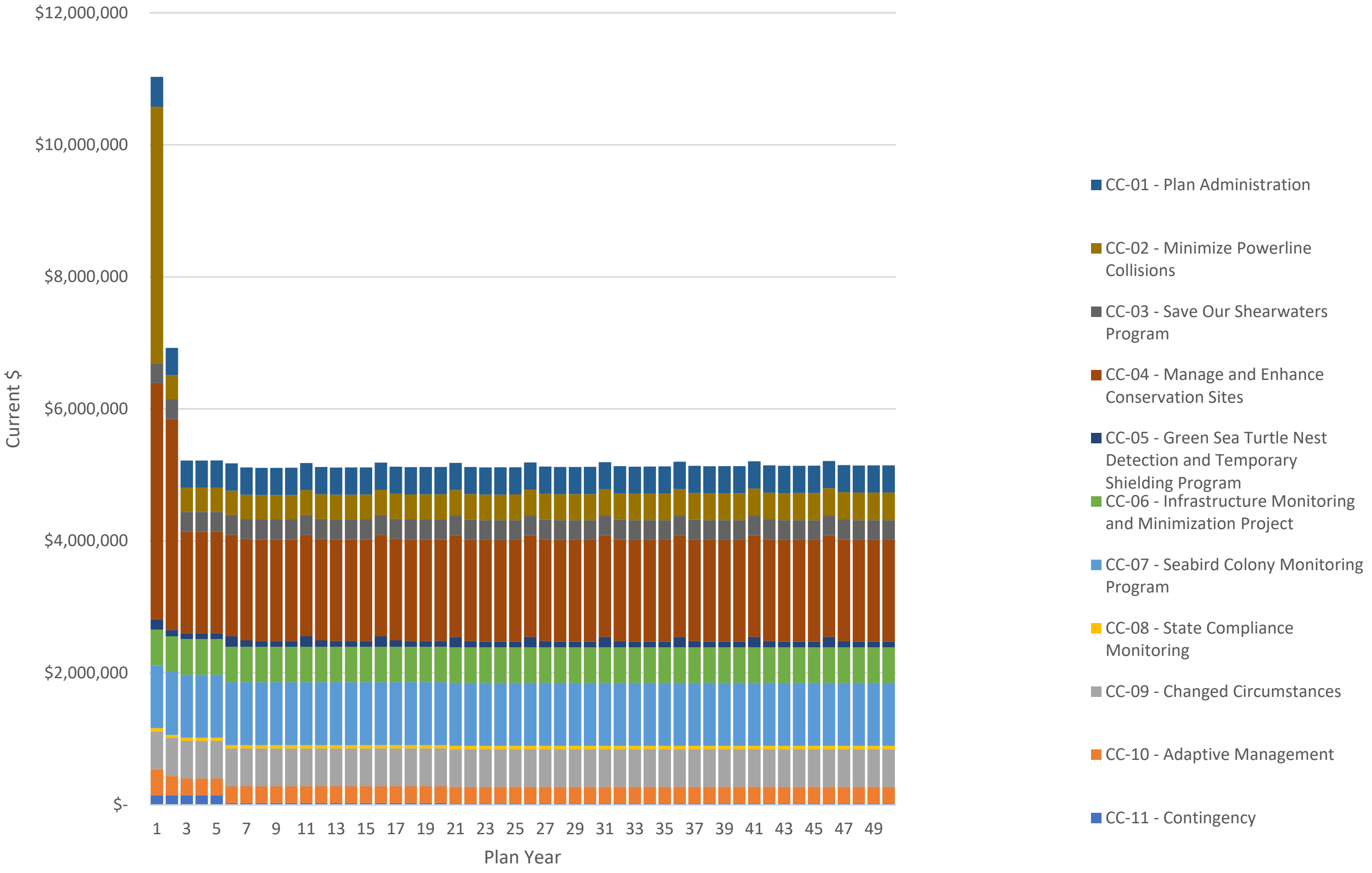
Table showing KIUC HCP implementation cost estimates by category and plan year

				Permit period (calendar years)																
Cost categories	**Avg. annual cost during permit period**	**Avg. annual cost: 2025-2072**	**Early implementation period: 2020–2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028–2032**	**2033–2037**	**2038–2042**	**2043–2047**	**2048–2052**	**2053–2057**	**2058–2062**	**2063–2067**	**2068–2072**	**Total: 2025-2072**	**50-year total**	**% of total cost by category**
Plan Administration	$413,300	$412,500	N/A	$452,500	$412,500	$412,500	$412,500	$412,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$19,800,000	$20,665,000	7.8%
Minimize Powerline Collisions	$460,133	$390,791	$19,757,870	$3,885,544	$363,141	$364,270	$365,399	$366,527	$1,849,564	$1,877,777	$1,905,991	$1,934,204	$1,962,418	$1,990,631	$2,018,845	$2,047,058	$2,075,272	$18,757,954	$23,006,640	8.7%
Save Our Shearwaters Program	$300,000	$300,000	$744,344	$300,000	$300,000	$300,000	$300,000	$300,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$14,400,000	$15,000,000	5.7%
Manage and Enhance Conservation Sites	$1,612,144	$1,538,202	$9,015,764	$3,576,627	$3,196,868	$1,538,202	$1,538,202	$1,538,202	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$73,833,709	$80,607,204	30.4%
Green Sea Turtle Nest Detection and Temporary Shielding Program	$104,100	$103,119	-	$158,900	$96,400	$88,400	$88,400	$88,400	$520,500	$520,500	$520,500	$520,500	$520,500	$520,500	$520,500	$520,500	$520,500	$4,949,700	$5,205,000	2.0%
Infrastructure Monitoring and Minimization Project	$539,911	$539,911	$2,746,125	$539,911	$539,911	$539,911	$539,911	$539,911	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$25,915,722	$26,995,544	10.2%
Seabird Colony Monitoring Program	$952,993	$952,993	$2,347,023	$952,993	$952,993	$952,993	$952,993	$952,993	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$45,743,662	$47,649,648	18.0%
State Compliance Monitoring	$50,000	$50,000	N/A	$50,000	$50,000	$50,000	$50,000	$50,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$2,400,000	$2,500,000	0.9%
Changed Circumstances	$572,934	$572,934	N/A	$572,934	$572,934	$572,934	$572,934	$572,934	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$27,500,812	$28,646,679	10.8%
Adaptive Management	$257,375	$253,744	N/A	$394,862	$294,183	$252,345	$252,373	$252,401	$1,266,354	$1,267,060	$1,267,765	$1,268,470	$1,269,176	$1,269,881	$1,270,586	$1,271,292	$1,271,997	$12,179,700	$12,868,745	4.9%
Contingency	$34,995	$30,378	N/A	$145,813	$145,813	$145,813	$145,813	$145,813	$145,813	$145,813	$145,813	$97,209	$97,209	$97,209	$97,209	$97,209	$97,209	$1,458,135	$1,749,762	0.6%
Total	**$5,297,884**	**$5,144,571**	**$34,611,125**	**$11,030,084**	**$6,924,744**	**$5,217,368**	**$5,218,525**	**$5,219,682**	**$25,614,930**	**$25,643,849**	**$25,672,768**	**$25,653,082**	**$25,682,001**	**$25,710,920**	**$25,739,838**	**$25,768,757**	**$25,797,676**	**$246,939,395**	**$264,894,222**	**100.0%**

Sources and notes: All costs are reported in current $ (year 2021). See individual cost category tabs for explanation of estimates. Average annual cost and total costs are reported separately for years 2025-2072 to omit high, one-time capital costs during years 2023 and 2024.

Cost Summary Chart

Chart showing KIUC HCP implementation cost estimates by category and plan year



Sources and notes: All costs are reported in current $ (year 2021). See individual cost category tabs for explanation of estimates.

General Assumptions

Assumptions for plan start year, permit term, cost base year, and future inflation

Source $: Cost expressed in dollar value from year it was paid
Current $: Cost expressed in dollars adjusted for purchasing power based on annual Consumer Price Index data
It is assumed that all cost components will increase over time due to inflation. To simplify the presentation, all costs are expressed in current $ (year 2021), allowing comparisons between costs today and costs later in the permit term. KIUC will pay all costs associated with HCP implementation, including inflation, even if those costs are above the costs estimated here.

Plan start year
2023

Plan end year
2072

Permit term (years)
50

Current $ Year
2021

Inflation

Plan year	Calendar year
	2021
	2022
1	2023
2	2024
3	2025
4	2026
5	2027
6	2028
7	2029
8	2030
9	2031
10	2032
11	2033
12	2034
13	2035
14	2036
15	2037
16	2038
17	2039
18	2040
19	2041
20	2042
21	2043
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24	2046
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26	2048
27	2049
28	2050
29	2051
30	2052
31	2053
32	2054
33	2055
34	2056
35	2057
36	2058
37	2059
38	2060
39	2061
40	2062
41	2063
42	2064
43	2065
44	2066
45	2067
46	2068
47	2069
48	2070
49	2071
50	2072

Consumer Price Index Conversions

Historical consumer price index data used to convert costs to current dollars

CPI for All Urban Consumers (CPI-U)
Original Data Value

Series Id:	CUURS49FSA0,CUUSS49FSA0
Not Seasonally Adjusted	
Series Title:	All items in Urban Hawaii, all urban consumers, not seasonally adjusted
Area:	Urban Hawaii
Item:	All items
Base Period:	1982-84=100
Years:	2010 to 2020

Historical consumer price index (CPI) data used to convert costs from previous years (source $) to current $.

Source: U.S. Bureau of Labor Statistics. 2021. Accessed January 21, 2021.

🟦 = calculated by ICF
🟥 = add or replace with actual values when available

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	HALF1	HALF2	Annual Inflation Rate	Covert to current year cost
2010													234.869	233.822	235.916		126.376%
2011													243.622	241.902	245.342	3.727%	121.835%
2012													249.474	248.646	250.303	2.402%	118.978%
2013													253.924	253.202	254.646	1.784%	116.892%
2014													257.589	255.989	259.190	1.443%	115.229%
2015													260.165	257.848	262.482	1.000%	114.088%
2016													265.283	264.038	266.528	1.967%	111.887%
2017											274.346		272.014	270.738	273.290	2.537%	109.119%
2018	273.909		275.408		276.359		277.389		279.113		279.700		277.078	275.196	278.960	1.862%	107.124%
2019	279.005		280.263		282.271		281.928		282.106		282.248		281.585	280.666	282.503	1.627%	105.410%
2020	283.683		285.321		285.834		285.725		287.529		286.872		286.008	285.086	286.931	1.571%	103.780%
2021	287.634		290.361		296.559		298.820		301.891		302.332		296.818	292.475	301.161	3.780%	100.000%
2022	304.988		312.158		317.207		319.197		321.799				296.818	312.137		0.000%	100.000%
2023													296.818			0.000%	100.000%
2024													296.818			0.000%	100.000%
2025													296.818			0.000%	100.000%

Early Implementation Costs: Summary

Costs for early implementation of conservation measures and other actions from 2020 to 2022

Early Implementation Cost Summary (source $)

Category	2020	2021	2022	TOTAL
Minimize Powerline Collisions	**$5,250,352**	**$6,307,575**	**$8,001,500**	**$19,559,426**
Save Our Shearwaters Program	**$245,028**	**$245,028**	**$245,028**	**$735,083**
Manage and Enhance Conservation Sites	**$1,165,593**	**$1,441,853**	**$6,364,263**	**$8,971,709**
Site 10	*$26,869*	*$31,713*	*$2,364,609*	*$2,423,191*
Upper Limahuli Preserve	*$529,805*	*$465,235*	*$2,821,996*	*$3,817,036*
Pihea, Pōhākea, North Bog	*$608,919*	*$712,851*	-	*$1,321,770*
Hanakoa, Hanakāpīʻai	-	*$232,055*	-	*$232,055*
Pihea, Pōhākea, North Bog, Hanakoa, Hanakāpīʻai	-	-	*$1,151,099*	
Pōhākea PF	-	-	*$26,558*	*$26,558*
Infrastructure Monitoring and Minimization Project	**$595,145**	**$1,052,501**	**$1,075,985**	**$2,723,630**
Seabird Colony Monitoring Program	**$351,089**	**$976,918**	**$1,005,746**	**$2,333,753**
TOTAL	**$7,607,207**	**$10,023,874**	**$16,692,521**	**$34,323,602**

Early Implementation Cost Summary (current $)

Category	2020	2021	2022	TOTAL
Minimize Powerline Collisions	**$5,448,795**	**$6,307,575**	**$8,001,500**	**$19,757,870**
Save Our Shearwaters Program	**$254,289**	**$245,028**	**$245,028**	**$744,344**
Manage and Enhance Conservation Sites	**$1,209,648**	**$1,441,853**	**$6,364,263**	**$9,015,764**
Site 10	*$27,885*	*$31,713*	*$2,364,609*	*$2,424,207*
Upper Limahuli Preserve	*$549,830*	*$465,235*	*$2,821,996*	*$3,837,061*
Pihea, Pōhākea, North Bog	*$631,934*	*$712,851*	-	*$1,344,784*
Hanakoa, Hanakāpīʻai	-	*$232,055*	-	*$232,055*
Pihea, Pōhākea, North Bog, Hanakoa, Hanakāpīʻai	-	-	*$1,151,099*	*$1,151,099*
Pōhākea PF	-	-	*$26,558*	*$26,558*
Infrastructure Monitoring and Minimization Project	**$617,639**	**$1,052,501**	**$1,075,985**	**$2,746,125**
Seabird Colony Monitoring Program	**$364,359**	**$976,918**	**$1,005,746**	**$2,347,023**
TOTAL	**$7,894,730**	**$10,023,874**	**$16,692,521**	**$34,611,125**

Sources and notes

Minimize Powerline Collisions: See following page for cost estimation methods.

Save our Shearwaters: Save Our Shearwaters Program 2020

Manage and Enhance Conservation Sites: Hallux Ecosystem Restoration LLC 2020a, 2020b, 2021a, 2021b; National Tropical Botanical Garden 2020, 2021; Archipelago Research and Conservation 2021a; Conservation Fencing LLC 2021

Regional Feral and Free-Roaming Cat Management Program: Hallux Ecosystem Restoration LLC 2021b

Infrastructure Monitoring and Minimization Project: Kauaʻi Endangered Seabird Recovery Project 2020a; Archipelago Research and Conservation 2021b, 2021c

Seabird Colony Monitoring Program: Kauaʻi Endangered Seabird Recovery Project 2020b, 2020c, 2020d; Archipelago Research and Conservation 2021b, 2021c, 2021d

See the References tab for more detailed information about the cited sources.

Early Implementation Costs: Implement Powerline Collisions Minimization Projects

Costs for early implementation of powerline collisions minimization measures

Number of Spans with Powerline Collision Minimization Projects Completed or Planned (2020–2022)

Minimization type(s)	Number of spans minimized, 2020	Number of spans minimized, 2021	Number of spans minimized, 2022
69kV removal, Static wire removal	-	-	29
Diverter installation (LED)	-	49	62
Diverter installation (LED), Static wire removal	-	4	-
Diverter installation (Reflective)	24	333	474
Diverter installation (Reflective), Static wire removal	109	134	76
Reconfiguration, Static wire removal	45	-	-
Static wire removal	43	249	164
Underground	-	-	2
Total	**221**	**769**	**807**

Estimated Costs of Early Implementation Powerline Collision Minimization Projects (2020-2022)

Minimization type(s)	Estimated cost per span (current $)	Estimated total cost, 2020 (source $)	Estimated total cost, 2021 (source $)	Estimated total cost, 2022 (source $)
69kV removal, Static wire removal	$4,868	-	-	$146,508
Diverter installation (LED)	$30,210	-	$1,480,290	$1,943,813
Diverter installation (LED), Static wire removal	$32,644	-	$130,576	-
Diverter installation (Reflective)	$8,061	$200,776	$2,684,313	$3,965,330
Diverter installation (Reflective), Static wire removal	$10,495	$1,187,192	$1,406,330	$827,767
Reconfiguration, Static wire removal	$80,379	$3,753,766	-	-
Static wire removal	$2,434	$108,618	$606,066	$414,263
Underground	$339,093	-	-	$703,819
Total		**$5,250,352**	**$6,307,575**	**$8,001,500**

Sources and notes

Number of spans with powerline collisions minimization projects completed or planned: ICF 2022

Average cost per span for powerline collision minimization activities: Yuh 2021a, 2021b

See the References tab for more detailed information about the cited sources.

Implementation Costs: Plan Administration

Staffing, legal support, database administration, and annual reporting

Plan Adminsitration Costs

Type	Average annual cost (source $)	Source $ year	Average annual cost (current $)
Program Management	$385,000	2021	$385,000
Legal Support	$25,000	2021	$25,000
Database Administration and Software License Fees	$2,500	2021	$2,500
Additional Cost to Prepare 1st KIUC Annual Report	$40,000	2021	$40,000
Annual Total (Plan Year 1)			**$452,500**
Annual Total (Plan Years 2-50)			**$412,500**

Sources and notes

All plan administration cost assumptions developed through coordination between ICF and the Joule Group. Program management costs are based on current support provided by the Joule Group and additional tasks anticipated to implement the long-term HCP.

Implementation Costs: Implement Powerline Collision Minimization Projects (Conservation Measure 1)

Collision reduction through static wire removal, diverter installation, and reconfiguration

Estimated Costs of Planned Powerline Collision Minimization Projects for Existing Powerlines (Plan Year 1)

Minimization type	Number of spans minimized, 2023	Estimated cost per span (source $)	Estimated cost, plan year 1 (source $)	Source $ year	Estimated cost, plan year 1 (current $)
69kV removal, Static wire removal	-	$4,868	-	2021	-
Diverter installation (LED)	12	$30,210	$362,520	2021	$362,520
Diverter installation (LED), Static wire removal	-	$32,644	-	2021	-
Diverter installation (Reflective)	307	$8,061	$2,474,727	2021	$2,474,727
Diverter installation (Reflective), Static wire removal	64	$10,495	$671,680	2021	$671,680
Reconfiguration, Static wire removal	-	$80,379	-	2021	-
Static wire removal	6	$2,434	$14,604	2021	$14,604
Underground	-	$339,093	-	2021	-
Total	**389**		**$3,523,531**		**$3,523,531**

Estimated Costs of Reflective Diverter Installations on New Powerlines (Plan Years 1-50)

Year	Number of spans minimized per plan year	Estimated cost per span (source $)	Estimated cost per plan year (source $)	Source $ year	Estimated cost per plan year (current $)
Plan Years 1-50 (2023-2072)	7	$8,061	$56,427	2021	$56,427

Estimated Costs of Reflective Diverter Replacement (Plan Years 1-50)

Year	Number of spans minimized per plan year	Estimated cost per span (source $)	Estimated cost per plan year (source $)	Source $ year	Estimated cost per plan year (current $)
Plan Year 1 (2023)	28.4	$8,061	$228,932	2021	$228,932
Plan Years 2-50 (2024-2072)	0.14	$8,061	$1,129	2021	$1,129

Estimated Costs of LED Diverter Replacement (Plan Years 1-50)

Year	Number of spans replaced per plan year	Estimated cost per span (source $)	Estimated cost per plan year (source $)	Source $ year	Estimated cost per plan year (current $)
Plan Years 1-50 (2023-2072)	2.5	$30,210	$75,525	2021	$75,525

Sources and notes

Number of spans with powerline collision minimization projects planned: ICF 2022

Average cost per span for powerline collision minimization activities: Yuh 2021a, 2021b

New diverter installations per plan year: Assumes 7 new spans installed each year would be equipped with reflective diverters.

Reflective diverter replacements per plan year: There will be an estimated 1,419 spans with reflective diverters installed by Plan Year 1 (2023). Per previous note, an estimated 7 new spans would be equipped with reflective diverters each successive plan year. Cost estimate assumes reflective diverters would be replaced on 2% of all spans in system each year.

LED diverter replacements per plan year: There will be an estimated 127 spans with LED diverters installed by Plan Year 1 (2023). Cost estimate assumes LED diverters would be replaced on 2% of all spans in system each year.

See the References tab for more detailed information about the cited sources.

Implementation Costs: Fund the Save Our Shearwaters Program (Conservation Measure 3)

Ongoing contribution to fund a share of the Save our Shearwater Program's annual budget

SOS Program Costs and Contributions During Plan Implementation

Total SOS program annual costs	Funds contributed by KIUC annually	Proportion of annual SOS program costs funded by KIUC
$300,000	$300,000	100%

Sources and notes

Kauaʻi Island Utility Cooperative 2020

The $300,000 annual contribution will be held constant until issuance of the 50-year permit, at which time the annual contribution will increase with an inflation index.

See the References tab for more detailed information about the cited sources.

Implementation Costs: Manage and Enhance Seabird Breeding Habitat and Colonies at Conservation Sites (Conservation Measure 4)

Perform various combinations of predator and weed controls at conservation sites

Summary of Estimated Annual Costs by Conservation Site

Conservation Sites	Annual Cost Plan Year 1 (current $)	Annual Cost Plan Year 2 (current $)	Annual Cost Plan Year 3 (current $)	Annual Cost Plan Year 4 (current $)	Annual Cost Plan Years 5-50 (current $)
Site 10	$864,485	$801,400	$29,267	$29,267	$29,267
Upper Limahuli Preserve	$1,285,160	$1,011,103	$124,570	$124,570	$124,570
Pihea, Pōhākea, North Bog, Hanakoa, Hanakāpīʻai (Hono O Nā Pali Natural Area Reserve)	$1,148,276	$1,148,276	$1,148,276	$1,148,276	$1,148,276
Pōhākea PF	$21,884	$21,884	$21,884	$21,884	$21,884
Honopū	$166,357	$166,357	$166,357	$166,357	$166,357
Honopū PF	$90,465	$47,848	$47,848	$47,848	$47,848
Total	**$3,576,627**	**$3,196,868**	**$1,538,202**	**$1,538,202**	**$1,538,202**

Site 10

Site 10 - Estimated Annual Predator Control Costs

Item	Units	Estimated unit cost (source $)	Source $ year	Estimated unit cost (current $)	Total cost (current $)
Personnel Subtotal					**$10,800**
Predator control staff labor	*1*	*$10,800*	*2022*	*$10,800*	*$10,800*
Materials and Supplies Subtotal					**$6,432**
Trapping Supplies	*1*	*$2,000*	*2022*	*$2,000*	*$2,000*
Ammunition	*1*	*$100*	*2022*	*$100*	*$100*
CO2 Cannisters	*66*	*$3*	*2022*	*$3*	*$197*
Automatic Lure Pumps	*90*	*$9*	*2022*	*$9*	*$810*
AA Batteries (Game Cameras)	*200*	*$1*	*2022*	*$1*	*$260*
AA Batteries (Owl hunting gear)	*50*	*$1*	*2022*	*$1*	*$65*
Assumed Annual Cost for Miscellaneous Items, Repairs, Replacements (one-time purchases)	*1*	*$3,000*	*2022*	*$3,000*	*$3,000*
Direct Procurement, Communications, Services, etc. Subtotal					**$16,052**
Transmitting Cameras Verizon Data	*9*	*$240*	*2022*	*$240*	*$2,160*
Camera Repair	*3*	*$30*	*2022*	*$30*	*$90*
MBTA Permit Application	*1*	*$100*	*2022*	*$100*	*$100*
Helicopter Services	*13*	*$1,054*	*2022*	*$1,054*	*$13,702*
Direct Contractor Costs					**$33,284**
General Excise Tax (4.7120%)					**$1,568**
Annual Total (Plan Year 1 (2023))					**$34,853**
Annual Total (Plan Years 3-30 (2025-2072)-cost reduced to 25% of plan year 1 cost after predator fencing and predator eradication					**$8,713**

Sources and notes

Hallux Ecosystem Restoration LLC 2021b. Plan year 2 (2024) is limited to predator eradication, which is costed out seperately, below.

See the References tab for more detailed information about the cited sources.

Site 10 - Estimated Annual Weed Control Costs

Annual Total (Plan Years 1-30 (2023-2072))	**$20,000**

Sources and notes

Koke'e Resource Conservation Program 2021

See the References tab for more detailed information about the cited sources.

Site 10 - Estimated Predator Fence Installation and Maintenance Costs

Total fence length (meters) = 182

Item	**Unit**	**Estimated cost per unit (source $)**	**Source $ year**	**Estimated cost per unit (current $)**	**Total cost (current $)**
Fence Installation					
Labor	*1*	*49,001*	*2014*	*56,463*	$56,463
Helicopter/Ground Transportation	*1*	*1,000,000*	*2022*	*1,000,000*	$1,000,000
Predator Eradication	*1*	*$500,000*	*2022*	*$500,000*	$500,000
Infrastructure at Site	*1*	*$30,000*	*2014*	*$34,569*	$34,569
Annual Total (Plan Year 1 (2023))					*$809,632*
Annual Total (Plan Year 2 (2024))					*$781,400*
Fence Maintenance (Plan Years 3-30 (2025-2072)					
Annual Fence Maintenance (cost per meter)	182	$2.64	2014	$3.04	$554

Sources and notes

Young and VanderWerf 2014, 2016. Fence materials assumed to be purchased in 2022; material costs included in early implementation costs. Fence labor cost from source reduced to 3.4% of original value due to decision to decrease fence length from 5,300 meters to 182 meters in 2022.

See the References tab for more detailed information about the cited sources.

Upper Limahuli Preserve

Upper Limahuli Preserve - Estimated Annual Predator and Weed Control Costs

Item	**Units**	**Estimated unit cost (source $)**	**Source $ year**	**Estimated unit cost (current $)**	**Total cost (current $)**
Salaries and Fringe Subtotal					**$317,874**
Salaries and Fringe	*1*	*$317,874*	*2022*	*$317,874*	*$317,874*
Helicopter Subtotal					**$59,285**
Helicopter Rental: Basic four-passenger trip (round t rip)	*1*	*$59,285*	*2022*	*$59,285*	*$59,285*
Equipment, Supplies, and Safety Subtotal					**$81,219**
Communications and monitoring equipment	*1*	*$26,420*	*2022*	*$26,420*	*$26,420*
Fence and shelter maintenance	*1*	*$4,000*	*2022*	*$4,000*	*$4,000*
Field and safety equipment (traps, firearms, camping gear, PPE)	*1*	*$20,305*	*2022*	*$20,305*	*$20,305*
Training (safety, preadator and weed control techniques)	*1*	*$10,494*	*2022*	*$10,494*	*$10,494*
Food and other expendables	*1*	*$20,000*	*2022*	*$20,000*	*$20,000*
Direct Contractor Cost					**$458,378**
NTGB Administrative fee of 5%					**$22,919**
Base Contract Total					**$481,297**
Assumed Cost for Miscellaneous Items (one-time purchases)					**$15,000**
Annual Total (Plan Year 1 (2023))					**$496,297**
Annual Total (Plan Year 2 (2024) - cost reduced by 50% of plan year 1 cost to account for weed control only while predator eradication is implemented)					**$248,148**
Annual Total (Plan Years 3-30 (2025-2072) - cost reduced to 25% of plan year 1 cost after predator fencing and predator eradication					**$124,074**

Sources and notes

Archipelago Research and Conservation 2021e.

See the References tab for more detailed information about the cited sources.

Upper Limahuli Preserve - Estimated Predator Fence Installation and Maintenance Costs

Total fence length (meters) = 163

Item	Unit	Estimated cost per unit (source $)	Source $ year	Estimated cost per unit (current $)	Total cost (current $)
Fence Installation					
Labor	*1*	*44,969*	*2014*	$51,817.42	$51,817
Helicopter/Ground Transportation	*1*	*1,000,000*	*2022*	$1,000,000.00	$1,000,000
Predator Eradication	*1*	*$500,000*	*2022*	$500,000.00	$500,000
Annual Total (Plan Year 1 (2023))					*$788,863*
Annual Total (Plan Year 2 (2024))					*$762,954*
Fence Maintenance (Plan Years 3-30 (2025-2072))					
Annual Fence Maintenance (cost per meter)	163	$2.64	2014	$3.04	$496

Sources and notes

Young and VanderWerf 2014, 2016. Fence materials assumed to be purchased in 2022; material costs included in early implementation costs. Fence labor cost from source reduced to 2.8% of original value due to decision to decrease fence length from 5,800 meters to 163 meters in 2022.

See the References tab for more detailed information about the cited sources.

Pihea, Pōhākea, North Bog, Hanakoa, Hanakāpīʻai (Hono O Nā Pali Natural Area Reserve)

Pihea, Pōhākea, North Bog, Hanakoa, Hanakāpīʻai (Hono O Nā Pali Natural Area Reserve) - Estimated Annual Predator Control Costs

Item	Units	Estimated unit cost (source $)	Source $ year	Estimated unit cost (current $)	Total cost (current $)
Personnel Subtotal					**$509,000**
Personnel Salaries and Fringe	*1*	*$509,000*	*2022*	*$509,000*	*$509,000*
Training Subtotal					**$9,000**
First Aid Training	*10*	*$300*	*2022*	*$300*	*$3,000*
Firearms training	*10*	*$200*	*2022*	*$200*	*$2,000*
Off-island travel	*8*	*$500*	*2022*	*$500*	*$4,000*
Materials and Supplies Subtotal					**$104,430**
Automatic Rat and Mouse Traps	*100*	*$150*	*2022*	*$150*	*$15,000*
Automatic Lure Pumps	*2550*	*$9*	*2022*	*$9*	*$22,950*
CO2 Canisters	*1900*	*$4*	*2022*	*$4*	*$7,600*
Trapping Supplies	*1*	*$8,000*	*2022*	*$8,000*	*$8,000*
Ammunition	*2*	*$200*	*2022*	*$200*	*$400*
Firearm maintenance	*1*	*$1,000*	*2022*	*$1,000*	*$1,000*
Bait and Lures	*5*	*$500*	*2022*	*$500*	*$2,500*
Staff Field Gear Replacements	*10*	*$850*	*2022*	*$850*	*$8,500*
Propane Refills	*8*	*$35*	*2022*	*$35*	*$280*
Propane Tank Replacement	*2*	*$50*	*2022*	*$50*	*$100*
Office supplies	*1*	*$2,000*	*2022*	*$2,000*	*$2,000*
First-aid kit restocking	*8*	*$30*	*2022*	*$30*	*$240*
AA Batteries (Game Cameras and Headlamps)	*2040*	*$1*	*2022*	*$1*	*$2,652*
AA Batteries (Owl Hunting Gear)	*300*	*$1*	*2022*	*$1*	*$390*
Weatherport Consumables	*1*	*$2,550*	*2022*	*$2,550*	*$2,550*
Flight Helmet Repair/Replace	*1*	*$1,200*	*2022*	*$1,200*	*$1,200*
Camping Gear Replacement	*1*	*$3,568*	*2022*	*$3,568*	*$3,568*
Assumed Annual Cost for Miscellaneous Items, Repairs, Replacements (one-time purchases)	*1*	*$25,500*	*2022*	*$25,500*	*$25,500*
Direct Procurement, Communications, Services, etc. Subtotal					**$124,174**
Transmitting Cameras Verizon Data	*19*	*$240*	*2022*	*$240*	*$4,560*
Satellite Communication Services	*12*	*$72*	*2022*	*$72*	*$864*
Vehicle Repair & Maintenance	*1*	*$5,000*	*2022*	*$5,000*	*$5,000*
Gas	*1*	*$6,000*	*2022*	*$6,000*	*$6,000*
Miscellaneous Shipping	*1*	*$2,000*	*2022*	*$2,000*	*$2,000*
Camera Repair	*15*	*$50*	*2022*	*$50*	*$750*
Helicopter Services	*1*	*$105,000*	*2022*	*$105,000*	*$105,000*
Direct Contractor Cost					**$746,604**
Contractor Overhead Cost					**$350,000**
General Excise Tax (4.7120%)					**$51,672**
Annual Total (Plan Years 1-30 (2023-2072))					**$1,148,276**

Sources and notes

Hallux Ecosystem Restoration LLC 2021b. See the References tab for more detailed information about the cited sources.

Pōhākea PF

Pōhākea PF - Estimated Annual Predator Control Costs

Item	Units	Estimated unit cost (source $)	Source $ year	Estimated unit cost (current $)	Total cost (current $)
Personnel Subtotal					**$4,000**
Predator control staff labor	*1*	*$4,000*	*2022*	*$4,000*	*$4,000*
Materials and Supplies Subtotal					**$12,240**
Automatic Rat and Mouse Traps	*15*	*$150*	*2022*	*$150*	*$2,250*
Automatic Lure Pumps	*15*	*$9*	*2022*	*$9*	*$135*
CO2 Canisters	*15*	*$4*	*2022*	*$4*	*$60*
Victors (12 units)	*3*	*$35*	*2022*	*$35*	*$105*
Transmitting Game Camera Replacements	*5*	*$660*	*2022*	*$660*	*$3,300*
Transmitting Camera Plans	*60*	*$5*	*2022*	*$5*	*$300*
Track Tunnels and Ink Plates	*20*	*$10*	*2022*	*$10*	*$200*
Cage Traps	*10*	*$160*	*2022*	*$160*	*$1,600*
Gear Storage Box	*1*	*$500*	*2022*	*$500*	*$500*
AA Batteries	*120*	*$2*	*2022*	*$2*	*$240*
SD Cards	*10*	*$5*	*2022*	*$5*	*$50*
Misc. Trapping Gear and Supplies	*1*	*$1,000*	*2022*	*$1,000*	*$1,000*
Bait	*1*	*$500*	*2022*	*$500*	*$500*
Assumed Annual Cost for Miscellaneous Items, Repairs, Replacements (one-time purchases)	*1*	*$2,000*	*2022*	*$2,000*	*$2,000*
Direct Procurement, Communications, Services, etc. Subtotal					**$5,270**
Helicopter Hours	*5*	*$1,054*	*2022*	*$1,054*	*$5,270*
Direct Contractor Costs					**$21,510**
Contractor Overhead Costs (30%)					**$6,453**
General Excise Tax (4.7120%)					**$1,318**
Annual Total (2022 - included as early implementation cost)					**$29,281**
Annual Total (Plan Years 1-30 (2023-2072)- cost reduced to 25% of early implementation cost after predator fencing and predator eradication complete)					**$7,320**

Sources and notes

Hallux Ecosystem Restoration LLC. 2021b. Any additional costs associated with training and transportation for Pōhākea PF are assumed to be covered under Hono O Nā Pali NAR costs.

See the References tab for more detailed information about the cited sources.

Pōhākea PF - Estimated Annual Social Attraction Site Costs

Item	Units	Estimated unit cost (source $)	Source $ year	Estimated unit cost (current $)	Total cost (current $)
Social Attraction Equipment Subtotal					**$470**
Average annual social atttraction equipment replacement cost	*1*	*$470*	*2022*	*$470*	*$470*
Social Attraction Monitoring Subtotal					**$2,867**
Reconyx cameras (HP2X) replacement	*5*	*$437*	*2022*	*$437*	*$2,185*
Reconyx cameras thunderbolt mounting block replacement	*5*	*$19*	*2022*	*$19*	*$95*
Reconyx cameras (HP2X) replacement shipping	*1*	*$347*	*2022*	*$347*	*$347*
2 Reconyx SD cards per camera 32 GB	*10*	*$12*	*2022*	*$12*	*$120*
Batteries (lithium)	*120*	*$1*	*2022*	*$1*	*$120*
Transportation Subtotal					**$4,100**
Helicopter (sling loads of boxes and sand)	*1.6*	*$1,025*	*2022*	*$1,025*	*$1,640*
Helcopter (transport digging crew - 6 pax)	*2.4*	*$1,025*	*2022*	*$1,025*	*$2,460*
Direct Contractor Costs					**$7,437**
Contractor Overhead Costs (30%)					**$2,231**
General Excise Tax (4.7120%)					**$456**
Annual Total (Plan Years 1-30 (2023-2072))					**$10,124**

Sources and notes

Archipelago Research and Conservation. 2021f. All costs associated with staff time for social attraction at Pōhākea PF are assumed to be covered in other existing budgets. All costs associated with predator eradication and social attraction equipment installation are assumed to be complete (and funded by other entities) and are not included in this cost estimate.

See the References tab for more detailed information about the cited sources.

Pōhākea PF - Estimated Annual Weed Control Costs

Annual Total (Plan Years 1-30 (2023-2072))	**$4,000**

Sources and notes

Costs for Pōhākea PF were estimated based on a proportion of Site 10 costs. Other weed control equipment and materials purchased for use at Site 10 are assumed to be reusable at Pōhākea PF.

See the References tab for more detailed information about the cited sources.

Pōhākea PF - Estimated Predator Fence Maintenance Costs

Total fence length (meters) = 145

Item	Meters	Estimated cost per meter (source $)	Source $ year	Estimated cost per meter (current $)	Total cost (current $)
Annual Fence Maintenance Cost (Plan Years 1-30 (2023-2072))	145	$2.64	2014	$3.04	$440

Sources and notes

Young and VanderWerf 2014. KIUC is not responsible for predator fence installation at Pōhākea PF.

See the References tab for more detailed information about the cited sources.

Honopū

Honopū - Estimated Annual Predator Control Costs

Item	Units	Estimated unit cost (source $)	Source $ year	Estimated unit cost (current $)	Total cost (current $)
Personnel Subtotal					**$117,450**
Personnel Salaries and Fringe	*1*	*$117,450*	*2021*	*$117,450*	*$117,450*
Training Subtotal					**$1,000**
First Aid Training	*1*	*$300*	*2021*	*$300*	*$300*
Firearms training	*1*	*$200*	*2021*	*$200*	*$200*
Off-island travel	*1*	*$500*	*2021*	*$500*	*$500*
Materials and Supplies Subtotal					**$8,380**
Automatic Lure Pumps	*375*	*$9*	*2021*	*$9*	*$3,375*
CO2 Canisters	*300*	*$4*	*2021*	*$4*	*$1,200*
Trapping Supplies	*1*	*$2,000*	*2021*	*$2,000*	*$2,000*
Ammunition	*1*	*$100*	*2021*	*$100*	*$100*
Firearm maintenance	*1*	*$500*	*2021*	*$500*	*$500*
Bait	*1*	*$500*	*2021*	*$500*	*$500*
Propane refills	*2*	*$35*	*2021*	*$35*	*$70*
First-aid kit restocking	*1*	*$50*	*2021*	*$50*	*$50*
AA Batteries (Game Cameras)	*450*	*$1*	*2021*	*$1*	*$585*
AA Batteries (Owl Hunting Gear)	*60*	*$1*	*2021*	*$1*	*$78*
Direct Procurement, Communications, Services, etc. Subtotal					**$23,680**
Transmitting Cameras Verizon Data	*4*	*$240*	*2021*	*$240*	*$960*
Vehicle Repair & Maintenance	*1*	*$1,000*	*2021*	*$1,000*	*$1,000*
Gas	*1*	*$300*	*2021*	*$300*	*$300*
Miscellaneous Shipping	*1*	*$300*	*2021*	*$300*	*$300*
Camera Repair	*4*	*$30*	*2021*	*$30*	*$120*
Helicopter Services	*1*	*$20,000*	*2021*	*$20,000*	*$20,000*
Assumed Cost for Miscellaneous Items (one-time purchases)	*1*	*$1,000*	*2021*	*$1,000*	*$1,000*
Direct Contractor Cost					**$150,510**
General Excise Tax (4.7120%)					**$7,092**
Annual Total (Plan Years 1-50 (2023-2072))					**$157,602**

Sources and notes

Archipelago Research and Conservation 2021a

See the References tab for more detailed information about the cited sources.

Honopū - Estimated Ungulate Fence Maintenance Costs

Total fence length (meters) = 5,065

Item	**Meters**	**Estimated cost per meter (source $)**	**Source $ year**	**Estimated cost per meter (current $)**	**Total cost (current $)**
Annual Fence Maintenance Cost (Plan Years 1-50 (2023-2072))	5,065	$1.50	2014	$1.73	$8,755

Sources and notes
Costs to maintain the existing ungulate fence at Honopū. Assumed $1.50 per meter (in 2014 $), less than maintenance costs for predator fence.

See the References tab for more detailed information about the cited sources.

Honopū PF

Honopū PF - Estimated Annual Predator Control Costs

Item	**Units**	**Estimated unit cost (source $)**	**Source $ year**	**Estimated unit cost (current $)**	**Total cost (current $)**
Personnel Subtotal					**$500**
Predator control staff labor	*1*	*$500*	*2022*	*$500*	*$500*
Materials and Supplies Subtotal					**$552**
Trapping Supplies	*1*	*$500*	*2022*	*$500*	*$500*
Ammunition	*1*	*$20*	*2022*	*$20*	*$20*
CO2 Canisters	*2*	*$3*	*2022*	*$3*	*$6*
Automatic Lure Pumps	*2*	*$9*	*2022*	*$9*	*$18*
AA Batteries (Game Cameras)	*4*	*$1*	*2022*	*$1*	*$5*
AA Batteries (Owl Hunting Gear)	*2*	*$1*	*2022*	*$1*	*$3*
Direct Procurement, Communications, Services, etc. Subtotal					**$510**
Transmitting Cameras Verizon Data	*2*	*$240*	*2022*	*$240*	*$480*
Camera Repair	*1*	*$30*	*2022*	*$30*	*$30*
Direct Contractor Costs					**$1,562**
General Excise Tax (4.7120%)					**$74**
Annual Total (Plan Years 2-50 (2024-2072))					**$1,635**
Predator Eradication (Plan Year 1 (2023) - assumed to be 50 times greater than annual predator control cost)					**$81,769**

Sources and notes
Costs for Honopū PF were estimated based on a proportion of Honopū costs. All costs associated with training and transportation for Honopū PF are assumed to be covered under Honopū costs.

See the References tab for more detailed information about the cited sources.

Honopū PF - Estimated Annual Social Attraction Site Costs

Item	Units	Estimated unit cost (source $)	Source $ year	Estimated unit cost (current $)	Total cost (current $)
Personnel Subtotal					**$25,367**
Personnel Labor	*1*	*$25,367*	*2022*	*$25,367*	*$25,367*
Social Attraction Monitoring					**$7,204**
Speaker System Repairs	*1*	*$500*	*2022*	*$500*	*$500*
Artificial Burrow Repairs	*1*	*$500*	*2022*	*$500*	*$500*
Reconyx cameras (HP2X) replacements	*3*	*$414*	*2022*	*$414*	*$1,380*
Reconyx cameras thunderbolt mounting block replacements	*3*	*$20*	*2022*	*$20*	*$67*
Reconyx cameras (HP2X) shipping	*1*	*$250*	*2022*	*$250*	*$250*
Reconyx camera repairs	*1*	*$250*	*2022*	*$250*	*$250*
2 Reconyx SD cards per camera 32 GB	*6*	*$13*	*2022*	*$13*	*$75*
Lithium AA batteries (3 sets per camera)	*27*	*$15*	*2022*	*$15*	*$396*
Song meters SM4 replacements	*1*	*$805*	*2022*	*$805*	*$1,073*
Song Meter - D batteries	*10*	*$1*	*2022*	*$1*	*$9*
32GB SD cards for SM2/4	*4*	*$13*	*2022*	*$13*	*$50*
Miscellaneous Field Equipment	*1*	*$500*	*2022*	*$500*	*$500*
Song Meter analysis - Contracted to Conservation Metrics	*1*	*$2,154*	*2022*	*$2,154*	*$2,154*
Direct Contractor Costs					**$32,571**
Contractor Overhead Costs (10%)					**$3,257**
General Excise Tax (4.7120%)					**$1,688**
Annual Total (Plan Years 2-50 (2024-2072))					**$37,516**

Sources and notes

Archipelago Research and Conservation 2021g. All costs associated with training and transportation for Honopū PF are assumed to be covered under Honopū costs.

See the References tab for more detailed information about the cited sources.

Honopū PF - Estimated Annual Weed Control Costs

Annual Total (Plan Years 1-50 (2023-2072))	**$6,500**

Sources and notes

Costs for Pōhākea PF were estimated based on a proportion of Site 10 costs. Other weed control equipment and materials purchased for use at Site 10 are assumed to be reusable at Pōhākea PF.

See the References tab for more detailed information about the cited sources.

Honopū PF - Estimated Predator Fence Maintenance Costs

Total fence length (meters) = 722

Item	Meters	Estimated cost per meter (source $)	Source $ year	Estimated cost per meter (current $)	Total cost (current $)
Annual Fence Maintenance Cost (Plan Years 1-50 (2023-2072))	722	$2.64	2014	$3.04	$2,197

Sources and notes

Young and VanderWerf 2014. KIUC is not responsible for predator fence installation at Honopū PF.

See the References tab for more detailed information about the cited sources.

Implementation Costs: Implement a Green Sea Turtle Nest Detection and Temporary Shielding Program (Conservation Measure 5)

Implement a nest detection and shielding program for green sea turtle

Nest Detection and Shielding Program Costs by Plan Year

Note: Sequence repeats through plan year 50

Item	Quantity	Estimated unit cost (source $)	Source $ year	Estimated unit cost (current $)	Annual cost, plan year 1 (current $)	Annual cost, plan year 2 (current $)	Annual cost, plan year 3-5 (current $)
Personnel Subtotal					**$86,400**	**$82,400**	**$74,400**
Personnel Salaries and Fringe	*1*	*$82,400*	*2021*	*$82,400*	*$86,400*	*$82,400*	*$74,400*
Materials and Supplies Subtotal					**$63,500**	**$5,000**	**$5,000**
Drone (Mavic Pro 2 or similar)	*1*	*$4,000*	*2021*	*$4,000*	*$4,000*		
Drone Materials (iPad, chargers, software, laptop, storage)	*1*	*$7,500*	*2021*	*$7,500*	*$7,500*		
Light Mitigation Structure Materials	*1*	*$2,000*	*2021*	*$2,000*	*$2,000*		
Vehicle (Ford F-150 base model)	*1*	*$50,000*	*2021*	*$50,000*	*$50,000*		
Miscellaneous annual material and repair costs.	*1*	*$5,000*	*2022*	*$5,000*		*$5,000*	*$5,000*
Travel Subtotal					**$9,000**	**$9,000**	**$9,000**
Project Coordinator (fuel cost/reimbursement)	*1*	*$4,000*	*2021*	*$4,000*	*$4,000*	*$4,000*	*$4,000*
Volunteer Network (fuel cost/reimbursement)	*1*	*$5,000*	*2021*	*$5,000*	*$5,000*	*$5,000*	*$5,000*
GRAND TOTAL					**$158,900**	**$96,400**	**$88,400**

Sources and notes

Department of Land and Natural Resources, Division of Aquatic Resources 2020

See the References tab for more detailed information about the cited sources.

Implementation Costs: Implement Infrastructure Monitoring and Minimization Project

Monitor seabird and water bird collision rates at KIUC powerlines

Infrastructure Monitoring and Minimization Project Costs by Plan Year

Item	Quantity	Estimated unit cost (source $)	Source $ year	Estimated unit cost (current $)	Annual cost (current $)
Personnel Subtotal					**$288,192**
Personnel Salaries and Fringe	1	$288,192	2021	$288,192	$288,192
Equipment and Supplies Subtotal					**$150,349**
Estimated Annual Misc. Expenses	*1*	*$750*	*2022*	*$750*	*$750*
SONG METERS					
Song meters - SM4 (replacements every 5 years)	*8.5*	*$825*	*2021*	*$825*	*$7,013*
Song Meter - D batteries	*546*	*$1*	*2021*	*$1*	*$502*
Microphone for SM4 (replacements)	*19.2*	*$50*	*2021*	*$50*	*$960*
32GB SD cards for SM2/4 (replacements)	*38.4*	*$13*	*2021*	*$13*	*$482*
Song meters - shipping	*9.5*	*$42*	*2021*	*$42*	*$394*
Song meter repairs ($147 per unit, including postage - $22 out, $25 return post, repair cost $100)	*9.5*	*$147*	*2021*	*$147*	*$1,397*
Analysis of song meter data by Conservation Metrics - all UMP work	*1*	*$115,761*	*2021*	*$115,761*	*$115,761*
CAMERAS					
Reconyx HP2X - replacements	*0.6*	*$414*	*2021*	*$414*	*$248*
Reconyx Repair (avg cost per camera to repair, including shipping)	*0.6*	*$60*	*2021*	*$60*	*$36*
Lithium AA batteries (3 sets per camera)	*108*	*$1*	*2021*	*$1*	*$138*
T post camera mount - replacements	*0.6*	*$20*	*2021*	*$20*	*$12*
SanDisk 32GB SDHC Memory Card (replacements)	*2*	*$13*	*2021*	*$13*	*$25*
FIELD EQUIPMENT					
Garmin GPS Unit (replacements)	*1.5*	*$550*	*2021*	*$550*	*$825*
iPad (replacements)	*1*	*$300*	*2021*	*$300*	*$300*
Ipad Cases (replacements)	*1.5*	*$45*	*2021*	*$45*	*$68*
Handheld Camera	*2*	*$210*	*2021*	*$210*	*$420*
Handheld Camera (replacements)	*0.5*	*$210*	*2021*	*$210*	*$105*
Helicopter Helmet	*1.5*	*$1,660*	*2021*	*$1,660*	*$2,490*
Helicopter Helmet (replacemets)	*1*	*$1,660*	*2021*	*$1,660*	*$1,660*
CWU-27/P Flight Suit	*1.5*	*$238*	*2021*	*$238*	*$357*
CWU-27/P Flight Suit (replacements)	*1*	*$238*	*2021*	*$238*	*$238*
USNV PVS-7 GEN III Auto-Gated Nightvision Goggles (replacements)	*1*	*$3,695*	*2021*	*$3,695*	*$3,695*
MSR Hubba NX 1 Tent & footprint	*1*	*$410*	*2021*	*$410*	*$410*
MSR Hubba NX 1 Tent & footprint (replacements)	*1*	*$410*	*2021*	*$410*	*$410*
Field Equipment (new gear for each new staff member, includes first aid training NOLS)	*1*	*$3,300*	*2021*	*$3,300*	*$3,300*

Field Equipment (replacement gear for existing staff members)	*2*	*$825*	*2021*	*$825*	*$1,650*
Field Equipment (annual group gear purchases)	*1*	*$750*	*2021*	*$750*	*$750*
IMMP-SPECIFIC MONITORING EQUIPMENT					
Near Infrared Lights (replacements)	*0.6*	*$3,200*	*2021*	*$3,200*	*$1,920*
Near Infrared Lights (annual small repairs)	*1*	*$250*	*2021*	*$250*	*$250*
Honda Generator (replacements)	*0.6*	*$1,000*	*2021*	*$1,000*	*$600*
Light shields, mallets , cables, locks (annual)	*1*	*$100*	*2021*	*$100*	*$100*
NV portable Cameras (replacements)	*0.75*	*$500*	*2021*	*$500*	*$375*
Weather station	*0.5*	*$2,000*	*2021*	*$2,000*	*$1,000*
Weather station (replacements)	*0.2*	*$2,000*	*2021*	*$2,000*	*$333*
Heli sling gear (Replacements)	*0.13*	*$1,000*	*2021*	*$1,000*	*$125*
Miscelanious supplies- pegs, ropes, tapes, wood, rain guards, etc	*1*	*$1,250*	*2021*	*$1,250*	*$1,250*
Transportation Subtotal					**$30,200**
Helicopter	*10*	*$1,040*	*2021*	*$1,040*	*$10,400*
Equipment (3 vehicles) Charge	*18*	*$1,100*	*2021*	*$1,100*	*$19,800*
Subtotal					*$468,741*
Contractor Overhead (10%)					*$46,874*
General Excise Tax (4.712%)					*$24,296*
GRAND TOTAL					**$539,911**

Sources and notes
Archipelago Research and Conservation 2021c

See the References tab for more detailed information about the cited sources.

Implementation Costs: Implement Seabird Colony Monitoring Program

Monitor seabird breeding colonies at ten sites

Seabird Colony Monitoring Program Costs by Plan Year (Detail)

Conservation Sites

Item	Quantity	Estimated unit cost (source $)	Source $ year	Estimated unit cost (current $)	Annual cost (current $)
Personnel Subtotal					**$536,891**
Personnel Salaries and Fringe	*1*	*$536,891*	*2022*	*$536,891*	*$536,891*
Equipment and Supplies Subtotal					**$230,933**
Estimated Annual Misc. Expenses	*1*	*$15,000*	*2022*	*$15,000*	*$15,000*
SONG METERS					
Song meters - SM4 - replacements every 5 years, 75 units	*15*	*$805*	*2022*	*$805*	*$12,075*
Microphone for SM4 (replacements every 5 years, 2 mics per unit, 75 units)	*30*	*$50*	*2022*	*$50*	*$1,500*
32GB SD cards for SM2/4 (replacements every 3 years, 4 SD cards per unit, 75 units)	*100*	*$13*	*2022*	*$13*	*$1,254*
Wildlife Acoustics - shipping	*1*	*$400*	*2022*	*$400*	*$400*
*Song Meter - D batteries (5 sites - 10 units*4*3)*	*600*	*$1*	*2022*	*$1*	*$554*
*Song Meter - D batteries (ULP - 14 units*4*3)*	*168*	*$1*	*2022*	*$1*	*$155*
*Song Meter - D batteries (UMV - 8 units*4*3)*	*96*	*$1*	*2022*	*$1*	*$105*
Song meter repairs ($147 per unit, including postage - $22 out, $25 return post, repair cost $100)	*14.4*	*$147*	*2022*	*$147*	*$2,117*
Analysis of song meter data by Conservation Metrics - all 7 sites NESH/HAPE/BAOW	*1*	*$127,014*	*2022*	*$127,014*	*$127,014*
RECONYX CAMERAS					
Reconyx HP2X - replace each unit (n=210) every 5 years	*42*	*$414*	*2022*	*$414*	*$17,388*
T post camera mount (replacements)	*42*	*$20*	*2022*	*$20*	*$840*
Reconyx - shipping	*1*	*$850*	*2022*	*$850*	*$850*
Lithium AA batteries (3 sets per camera)	*630*	*$15*	*2022*	*$15*	*$9,233*
SanDisk 32GB SDHC Memory Card (replacements)	*140*	*$13*	*2022*	*$13*	*$1,756*
Reconyx Repair (avg cost per camera to repair, including shipping)	*82*	*$60*	*2022*	*$60*	*$4,920*
MISC. FIELD GEAR					
Garmin Inreach Explorer +	*2*	*$450*	*2022*	*$450*	*$900*
Garmin Inreach Explorer + (replacements)	*1*	*$450*	*2022*	*$450*	*$450*
Garmin GPS Unit (replacements)	*4*	*$550*	*2022*	*$550*	*$2,200*
iPad (replacements)	*2.7*	*$300*	*2022*	*$300*	*$800*
Handheld Camera (replacements)	*4*	*$210*	*2022*	*$210*	*$840*
Helicopter Helmet	*2*	*$1,660*	*2022*	*$1,660*	*$3,320*

Helicopter Helmet (replacemets)	1.2	$1,660	2022	$1,660	$1,992
CWU-27/P Flight Suit	2	$238	2022	$238	$476
CWU-27/P Flight Suit (replacements)	1.6	$238	2022	$238	$381
USNV PVS-7 GEN III Auto-Gated Nightvision Goggles	1	$3,695	2022	$3,695	$3,695
USNV PVS-7 GEN III Auto-Gated Nightvision Goggles (replacements)	1.3	$3,695	2022	$3,695	$4,927
Tent & footprint (replacements)	2.7	$410	2022	$410	$1,093
Field Equipment (new field gear for each new staff member, includes first aid training NOLS)	3	$3,300	2022	$3,300	$9,900
Field Equipment (replacement gear for existing staff members)	4	$825	2022	$825	$3,300
Field Equipment (annual group gear purchases)	1	$1,500	2022	$1,500	$1,500
WEATHERPORT MAINTENANCE					
Buckets	4	$7	2022	$7	$28
Wood Shavings	4	$20	2022	$20	$80
Water filter Repair	4	$40	2022	$40	$160
Water Filter Replacement	3.0	$317	2022	$317	$951
Transportation Subtotal					**$26,400**
Equipment (3 vehicles) Charge	24	$1,100	2022	$1,100	$26,400
Subtotal					$794,224
Contractor Overhead (10%)					$79,422
General Excise Tax (4.712%)					$41,166
GRAND TOTAL (for 7 conservation sites)[1]					**$914,813**

Nā Pali Coast Sites

Item	Quantity	Estimated unit cost (source $)	Source $ year	Estimated unit cost (current $)	Annual cost (current $)
Personnel Subtotal					**-**
Covered under conservation site monitoring budget, above.	*0*	*-*	*2022*	*-*	*-*
Equipment and Supplies Subtotal					**$33,147**
Song meters - SM4 - replacements every 5 years, 20 units	*4*	*$805*	*2022*	*$805*	*$3,220*
32GB SD cards for SM2/4 (replacements, 2 per unit)	*40*	*$21*	*2022*	*$21*	*$828*
*Song Meter - D batteries (20 units*4)*	*80*	*$1*	*2022*	*$1*	*$74*
Supplies for building new deployment boxes	*1*	*$500*	*2022*	*$500*	*$500*
Analysis of song meter data by Conservation Metrics - 20 units, 3 species (NESH, BANP, BAOW), 3 months per unit	*1*	*$22,376*	*2022*	*$22,376*	*$22,376*
Helicopter - (3 hrs to deploy song meters, 3 hrs to receover song meters)	*6*	*$1,025*	*2022*	*$1,025*	*$6,150*
Subtotal					*$33,147*
Contractor Overhead (10%)					*$3,315*
General Excise Tax (4.712%)					*$1,718*
GRAND TOTAL					**$38,180**

Sources and notes

Archipelago Research and Conservation 2021c. Seabird costs for Pōhākea PF and Honopū PF costs are accounted for in social attraction monitoring. Helicopter costs are covered under management and enhancement of conservation sites.

See the References tab for more detailed information about the cited sources.

Implementation Costs: Fund State Compliance Monitoring

Funds monitoring of endangered species by the State of Hawaii

State Compliance Monitoring Costs by Plan Year

Type	Average annual cost (source $)	Source $ year	Average annual cost (current $)
Program Management	$50,000	2022	$50,000

Sources and notes

ICF 2022. KIUC has included a total of $50,000 annually to fund endangered species monitoring by the State of Hawaii.

See the References tab for more detailed information about the cited sources.

Implementation Costs: Changed Circumstances, Adaptive Management, and Contingency

Funds to address changed circumstances, adaptive management, and contingencies with plan implementation

Estimated Costs to Account for Changed Circumstances

Funding for changed circumstances is calculated as a percentage of the annual cost to manage and enhance conservation sites, using parameters below. These funds will accrue throughout the permit term.

Changed circumstance	Cost assumption	2023	2024	2025	2026	2027	2028–2032	2033–2037	2038–2042	2043–2047	2048–2052	2053–2057	2058–2062	2063–2067	2068–2072	50-year total
Severe Weather	Total cost of $15,275,229, divided equally across the 50-year permit term, of replacing all reflective ($8,061 × 1,419 spans) and LED ($30,210 × 127 spans) diverters once due to severe weather.	$305,505	$305,505	$305,505	$305,505	$305,505	$1,527,523	$1,527,523	$1,527,523	$1,527,523	$1,527,523	$1,527,523	$1,527,523	$1,527,523	$1,527,523	$15,275,229
Severe Weather	Annual cost of $200,000 to cover replacement of two predator fences during permit term.	$200,000	$200,000	$200,000	$200,000	$200,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$10,000,000
Loss of Accessibility To or Destruction of Conservation Sites/Escape of Domesticated Animals	Annual cost of $60,000 (approximately 1% of Plan Year 1 cost to manage conservation sites) to compensate for termporary loss of accessibility to or temporary or permanent destruction of conservation sites, as well as escape of domesticated animals.	$60,000	$60,000	$60,000	$60,000	$60,000	$300,000	$300,000	$300,000	$300,000	$300,000	$300,000	$300,000	$300,000	$300,000	$3,000,000
Invasive Species	Annual cost of $3,500 to purchase additional predator control equipment.	$3,500	$3,500	$3,500	$3,500	$3,500	$17,500	$17,500	$17,500	$17,500	$17,500	$17,500	$17,500	$17,500	$17,500	$175,000
Vandalism	Annual cost to repair vandalism to predator fencing ($100) plus vandalism to turtle nesting light mitigation structures ($2,240).	$2,340	$2,340	$2,340	$2,340	$2,340	$11,700	$11,700	$11,700	$11,700	$11,700	$11,700	$11,700	$11,700	$11,700	$117,000
Destruction of Green Sea Turtle Nests	Annual cost of $1,589 (approximately 1% of Plan Year 1 cost to detect and shield nests) to compensate for destruction of green sea turtle nests.	$1,589	$1,589	$1,589	$1,589	$1,589	$7,945	$7,945	$7,945	$7,945	$7,945	$7,945	$7,945	$7,945	$7,945	$79,450
Changed Circumstances Total		**$572,934**	**$572,934**	**$572,934**	**$572,934**	**$572,934**	**$2,864,668**	**$2,864,668**	**$2,864,668**	**$2,864,668**	**$2,864,668**	**$2,864,668**	**$2,864,668**	**$2,864,668**	**$2,864,668**	**$28,646,679**

Estimated Adaptive Management and Contingency Costs

Funding for adaptive management is calculated as a percentage of the annual costs for each cost category, as listed below. Percentages vary based on the degree of uncertainty within each cost category. Contingencies are based on a percentage of the average annual total cost for plan implementation from years 2025-2072. Plan years 2023 and 2024 are omitted from the annual average due to their high, one-time capital costs. Contingencies are assessed each year but do not accrue.

		Cost by Category During Permit period (calendar years)														
Cost categories	**Percentage of annual and 5-year total costs allocated to contingency**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028–2032**	**2033–2037**	**2038–2042**	**2043–2047**	**2048–2052**	**2053–2057**	**2058–2062**	**2063–2067**	**2068–2072**	**50-year total**
Plan Administration	**0.0%**	$452,500	$412,500	$412,500	$412,500	$412,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$2,062,500	$20,665,000
Minimize Powerline Collisions	**2.5%**	$3,885,544	$363,141	$364,270	$365,399	$366,527	$1,849,564	$1,877,777	$1,905,991	$1,934,204	$1,962,418	$1,990,631	$2,018,845	$2,047,058	$2,075,272	$23,006,640
Save Our Shearwaters Program	**2.5%**	$300,000	$300,000	$300,000	$300,000	$300,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$15,000,000
Manage and Enhance Conservation Sites	**2.5%**	$3,576,627	$3,196,868	$1,538,202	$1,538,202	$1,538,202	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$7,691,011	$80,607,204
Green Sea Turtle Nest Detection and Temporary Shielding Program	**5.0%**	$158,900	$96,400	$88,400	$88,400	$88,400	$520,500	$520,500	$520,500	$520,500	$520,500	$520,500	$520,500	$520,500	$520,500	$5,205,000
Infrastructure Monitoring and Minimization Project	**12.5%**	$539,911	$539,911	$539,911	$539,911	$539,911	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$2,699,554	$26,995,544
Seabird Colony Monitoring Program	**12.5%**	$952,993	$952,993	$952,993	$952,993	$952,993	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$4,764,965	$47,649,648
State Compliance Monitoring	**12.5%**	$50,000	$50,000	$50,000	$50,000	$50,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$2,500,000
Changed Circumstances	**0.0%**	$572,934	$572,934	$572,934	$572,934	$572,934	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$2,864,668	$28,646,679
Adaptive Management Total		**$394,862**	**$294,183**	**$252,345**	**$252,373**	**$252,401**	**$1,266,354**	**$1,267,060**	**$1,267,765**	**$1,268,470**	**$1,269,176**	**$1,269,881**	**$1,270,586**	**$1,271,292**	**$1,271,997**	**$12,868,745**
Contingency % of Average Cost Years 2025-2072		**3%**	**3%**	**3%**	**3%**	**3%**	**3%**	**3%**	**3%**	**2%**	**2%**	**2%**	**2%**	**2%**	**2%**	
Contingency Total		**$145,813**	**$145,813**	**$145,813**	**$145,813**	**$145,813**	**$145,813**	**$145,813**	**$145,813**	**$97,209**	**$97,209**	**$97,209**	**$97,209**	**$97,209**	**$97,209**	**$1,749,762**