Appendix 1

CDUP Letters from DLNR

LINDA LINGLE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

Office of Conservation and Coastal Lands
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

LAURA H. THIELEN
INTERIM CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

ALLAN A. SMITH
INTERIM DEPUTY DIRECTOR - LAND

KEN C. KAWAHARA
DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

AUG 10 2007

File No.: LA-3419

Mr. Charlie Karustis
TETRA TECH EC, INCORPORATED
737 Bishop Street, Suite 3020
Honolulu, HI 96813

Dear Mr. Karustis:

This is to inform you that on August 8, 2007, the Chairperson of the Board of Land and Natural Resources approved your client's application for the installation of one (1) metrological tower at site Number 6, and preliminarily approved installation of the remaining six (6) meteorological measurement towers on the Island of Lanai, TMK (2) 4-9-002:01, subject to the following conditions:

1. The applicant shall comply with all applicable statutes, ordinances, rules, and regulations of the Federal, State and County governments, and the applicable parts of Section 13-5-42, Hawaii Administrative Rules;

2. The applicant, its successors and assigns, shall indemnify and hold the State of Hawaii harmless from and against any loss, liability, claim or demand for property damage, personal injury or death arising out of any act or omission of the applicant, its successors, assigns, officers, employees, contractors and agents for any interference, nuisance, harm or hazard relating to or connected with the implementation of corrective measures to minimize or eliminate the interference, nuisance, harm or hazard;

3. The applicant shall comply with all applicable Department of Health administrative rules;

4. Where any interference, nuisance, or harm may be caused, or hazard established by the use the applicant shall be required to take measures to minimize or eliminate the interference, nuisance, harm, or hazard within a time frame and manner prescribed by the Chairperson;

5. Any work done on the land shall be initiated within one year of the approval of such use, and unless otherwise authorized be completed within three years of the approval. The applicant shall notify the Department in writing when construction activity is initiated and when it is completed;

6. The applicant shall obtain the approval of the "Post-Construction Monitoring Protocol for the Meteorological Towers at the Lanai Wind Farm, Lanai, Hawaii", prior to installing any tower;

7. Should an impact with flying wildlife occur, the applicant shall remove the tower(s) until such time as the tower(s) are covered by an Incidental Take License and accompanying (amended) Habitat Conservation Plan;

8. This approval permits the installation of one (1) meteorological tower at site No 6. Subsequent tower construction shall proceed only after review and approval by the Division of Forestry and Wildlife and the Office of Conservation and Coastal Lands, based on positive avian survey results and the successful actions of the applicant to mitigate potential avian impacts;

9. Before proceeding with any work authorized by the Board, the applicant shall submit four (4) copies of the construction and grading plans and specifications to the Chairperson or his authorized representative for approval for consistency with the conditions of the permit and the declarations set forth in the permit application. Three (3) of the copies will be returned to the applicant. Plan approval by the Chairperson does not constitute approval required from other agencies;

10. In issuing this permit, the Department has relied on the information and data that the applicant has provided in connection with this permit application. If, subsequent to the issuance of this permit, such information and data prove to be false, incomplete or inaccurate, this permit may be modified, suspended or revoked, in whole or in part, and/or the Department may, in addition, institute appropriate legal proceedings;

11. Should historic remains such as artifacts, burials or concentration of charcoal be encountered during construction activities, work shall cease immediately in the vicinity of the find, and the find shall be protected from further damage. The contractor shall immediately contact SHPD (692-8015), which will assess the significance of the find and recommend an appropriate mitigation measure, if necessary;

12. The applicant understands and agrees that this permit does not convey any vested rights or exclusive privilege;

13. Prior to construction, the applicant shall have a wildlife biologist survey the area within a 125-yard radius of each proposed tower to re-confirm the absence of notable wildlife (e.g. nesting birds). If sensitive wildlife or nesting activities are noted, the applicant shall coordinate with DOFAW to tailor the methods and timing of installation to minimize the risk of adverse impacts;

14. Best management practices for prevention of introducing exotic species to the site shall be observed;

15. Upon the end of the duration of data collection or the end of the equipment lifecycle or within three years, all equipment shall be removed and the land shall be restored to its original condition;

16. The applicant acknowledges that the approved work shall not hamper, impede or otherwise limit the exercise of traditional, customary or religious practices in the immediate area, to the extent such practices are provided for by the Constitution of the State of Hawaii, and by Hawaii statutory and case law;

17. Other terms and conditions as may be prescribed by the Chairperson; and

18. Failure to comply with any of these conditions shall render this Conservation District Use Permit null and void.

Please have the applicant acknowledge receipt of this permit, with the above noted conditions, in the space provided below. Please sign two copies, retain one, and return the other within thirty (30) days of the date of this letter.

Should you have any questions on any of these matters, please feel free to contact Michael Cain at 587-0048.

Aloha,

Samuel Lemmo, Administrator

Receipt acknowledged

____
Signature

____
Date

cc: Chairman's Office
Caste & Cooke Resorts, LLC
Maui Board Member
Maui Land Agent
County of Maui Planning Department
DOFAW
DOCARE
HPD
USFWS

LINDA LINGLE
GOVERNOR OF HAWAII

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LAND
STATE PARKS

STATE OF HAWAI`I
DEPARTMENT OF LAND AND NATURAL RESOURCES
Office of Conservation and Coastal Lands
POST OFFICE BOX 621
HONOLULU, HAWAI`I 96809

ref: OCCL:MC

CDUP LA-3419

SEP 27 2007

Timothy A. Hill, Executive Vice President
Castle & Cooke Lāna`i
PO Box 630310
Lāna`i City, HI 96763

Dear Mr. Hill,

SUBJECT: CONSERVATION DISTRICT USE PERMIT (CDUP) LA-3419
Clarification on Condition 7, Meteorological Towers
Northwest Lāna`i, Lahaina District, Maui
TMK (2) 4-9-02:01

The Office of Conservation and Coastal Lands (OCCL) has reviewed you request to clarify Condition (7) of CDUP LA-3419 for the Lāna`i Meteorological Towers.

Condition (7) reads:

Should an impact with flying wildlife occur, the applicant shall remove the tower(s) until such time as the tower(s) are covered by an Incidental Take License and an accompanying (amended) Habitat Conservation Plan.

Castle & Cooke Lāna`i point out that there is no mechanism to acquire an Incidental Take Permit for wildlife that is not covered by the Endangered Species Act. The applicant concludes that Condition (7) should only apply to state or federally listed threatened or endangered species.

OCCL concurs with this, and will interpret Condition (7) as applying to state or federally listed threatened or endangered species, namely but limited to the `ua`u, Hawaiian petrel (*Pterodroma sandwichensis*); the `a`o, Newell's Shearwater (*Puffinus newelli*); and the `ope`ape`a, Hawaiian hoary bat (*Lasiurus cinereus semotus*).

Should you have any questions please feel free to contact Michael Cain at 587-0048.

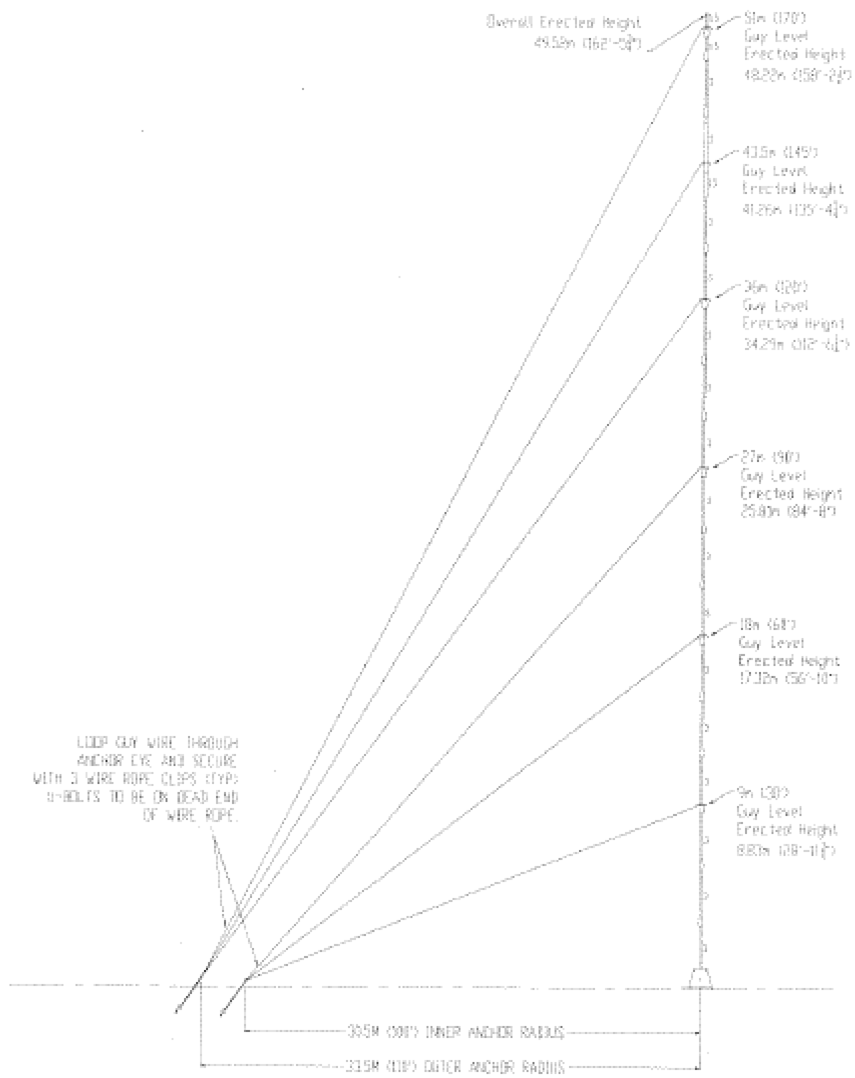
Sincerely,

Samuel J. Lemmo, Administrator
Department of Land and Natural Resources

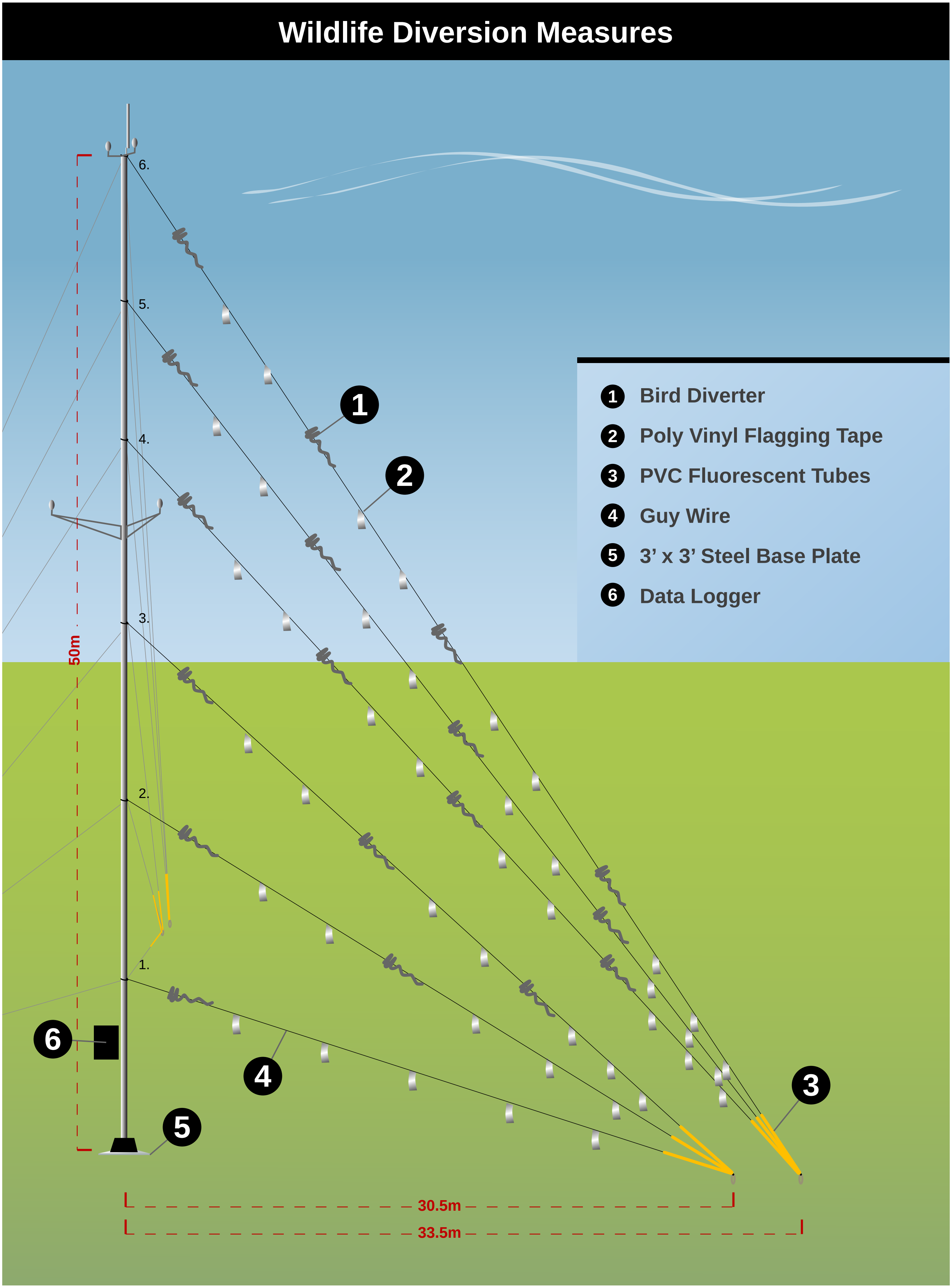
cc: *DLNR – Chair, DOFAW*
Charlie Karustris, Tetra Tech, Inc., 737 Bishop Street, Suite 3020 Honolulu, HI 96813
USFWS

Appendix 2

Example of a Typical Met Tower and Wildlife Diversion Measures



Appendix 2. Drawing of a 50 m tall tower assembly


Wildlife Diversion Measures
1 Bird Diverter
2 Poly Vinyl Flagging Tape
3 PVC Fluorescent Tubes
4 Guy Wire
5 3’ x 3’ Steel Base Plate
6 Data Logger
6.
5.
4.
3.
2.
1.
50m
30.5m
33.5m

Appendix 3

Radar Survey Report

RADAR AND AUDIOVISUAL STUDIES OF HAWAIIAN PETRELS NEAR PROPOSED METEOROLOGICAL TOWERS AND WIND TURBINES ON NORTHWESTERN LANA'I ISLAND, MAY–JULY 2007

FINAL REPORT

Prepared for

KC Environmental, Inc.
P.O. Box 1208
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and

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Portland, OR 97201

Prepared by

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October 2007

Printed on recycled paper.

EXECUTIVE SUMMARY

- We used radar and audio-visual methods to collect data on the movements, behavior, and flight altitudes of the endangered Hawaiian Petrel (*Pterodroma sandwichensis*), threatened Newell's (Townsend's) Shearwater (*Puffinus auricularis newelli*), and endangered Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) at nine sites total on Lana'i Island in May–July 2007. We conducted sampling at 3 sites during 15 nights of sampling in late May–early June ("late spring" sampling period) and at 7 sites, including 1 site that was sampled during the previous period, during 35 nights of sampling in late June–early July ("summer" sampling period). The objectives of the study were to: (1) conduct surveys of endangered seabirds and bats in the vicinity of the proposed wind-resource area (WRA); and (2) obtain information to help assess use of the area by these species.
- We recorded 170 radar targets that fit our criteria for petrels and shearwaters during the 15 nights of sampling in late spring 2007. Of these targets, we recorded 37 at the Western site, 73 at the Central site, and 60 at the Eastern site. This pattern of fewer targets in the western portion of the study area also was seen in summer 2007: out of 427 probable petrel targets, we recorded 11 at Lower Ka'ena, 42 at Lower Polihua, 43 at Garden of the Gods (all in the western WRA), 70 at Lower Awalua, 83 at Central, 50 at Upper Lapaiki (all in the central WRA), and 128 at Lower Kuahua (in the eastern WRA). Movement rates also reflected this pattern of fewer petrels in the western portion of the study area.
- In late spring, mean movement rates of landward-flying targets ranged from 0.24–1.96 targets/h in the evening to 0 targets/h during the morning, whereas seaward rates ranged from 1.92–3.48 targets/h in the evening to 0.96–3.68 targets/h in the morning. In summer, mean movement rates of landward-flying targets ranged from 0.0–3.56 targets/h in the evening to 0.0–0.12 targets/h during the morning, whereas seaward rates ranged from 0.48–3.56 targets/h in the evening to 0.60–4.92 targets/h in the morning.
- The overall mean movement rates that we observed on radar at Lana'i tended to be much lower than did rates observed during similar radar studies on Kaua'i and East Maui and were slightly lower than rates on West Maui; however, Lana'i movement rates were similar to rates on Hawai'i.
- We sampled only one location (Central) in both late spring and summer; movement rates at that site were similar between the two periods.
- Seaward movement rates (west or northwest, away from the colony) were higher than landward rates (east or southeast, toward the colony) for all sites, times of day (evening and morning), and sampling periods; however, rates did vary among hours within evening and morning periods. In addition, landward rates in the evening always were equal to or greater than landward rates in the morning, and morning rates usually were 0 targets/h. In contrast, seaward rates did not show a consistent difference between evening and morning. The only sites at which evening rates of seaward-flying targets were higher were the two farthest-inland sites, both of which were located along the east–west spine of the island.
- During audio-visual sampling, we recorded 33 Hawaiian Petrels and 2 unidentified petrels/shearwaters. Petrels were visually observed at all sites except for the Western site. For instance, in late spring, we recorded 5 petrels, with 0 at the Western site, 3 at the Central site, and 2 at the Eastern site. In summer, we recorded 30 petrels, with 1 at Lower Ka'ena, 2 at Lower Polihua, 3 at Garden of the Gods, 6 at Lower Awalua, 6 at Central, 2 at Upper Lapaiki, and 10 at Lower Kuahua.
- The mean (± SE) flight altitude of Hawaiian Petrels and unidentified petrels/shearwaters observed from all sites, times of day, and sampling periods was 47 ± 8 m agl. The mean flight altitude of Hawaiian Petrels and unidentified petrels/shearwaters flying in a landward direction was 34 ± 9 m agl, whereas

the mean seaward flight altitude was higher (71 ± 15 m agl).

- In addition to Hawaiian Petrels, we recorded one Hawaiian Hoary Bat during 485 sampling sessions (i.e., a rate of 0.005 bats/h). Thus, bats were present in the proposed WRA, but they occurred there in very low densities.
- Based on flight-altitude data from Lana'i, we estimate that 64% of the birds flying through this area are flying at altitudes low enough to interact with proposed met towers (i.e., ≤50 m agl) and that 94% of the birds flying through this area are flying at altitudes low enough to interact with proposed wind turbines (i.e., ≤125 m agl).
- To determine risk, we used petrel movement rates, petrel flight altitudes, and dimensions and characteristics of the proposed met towers and proposed wind turbines to generate an estimate of exposure risk. We corrected that estimate by the fatality probability (i.e., the probability of death if a bird does collide with a structure) and a range of estimates for avoidance rates to estimate the annual fatality that could be expected at the proposed met towers and wind turbines.
- Based on data from summer 2007, we estimate annual movement rates of ~983; ~3,660; ~3,365; ~6,046; ~7,629; ~4,278; and ~11,250 Hawaiian Petrels within 1.5 km of the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites, respectively.
- We estimated annual fatality rates for the proposed met tower associated with each site by assuming that 0%, 50%, 95%, or 99% of all Hawaiian Petrels flying near a proposed met tower or wind turbine will see and avoid the tower. Based on these scenarios, annual fatality rates for proposed met towers near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites would be 0.1–6.7, 0.3–25.0, 0.2–23.0, 0.4–41.3, 0.5–52.1, 0.3–29.2, and 0.8–76.8 Hawaiian Petrels/tower, respectively. Based on the same set of assumptions about possible avoidance rates, annual fatality rates for proposed wind turbines near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites are estimated to be 0.02–2.2, 0.1–8.2, 0.1–7.5, 0.1–13.5, 0.1–17.0, 0.1–9.5, and 0.2–25.1 Hawaiian Petrels/turbine, respectively. We caution, however, that these assumptions for avoidance rates are not based on empirical data and do not consider effects of potential deterrents (such as white flagging) that might reduce fatality rates.

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ACKNOWLEDGMENTS

The funding for this research came from Castle and Cooke LLC. At KC Environmental, we thank Charlie Fein for project management and Tom Kekona for help with logistics and the audio-visual sampling. At TetraTech EC, Charlie Karustis and Alicia Oller provided thoughtful questions and expertise on wind energy and George Redpath provided logistical assistance. At ABR, Todd Mabee provided field help and report review; Mike Davis, Adam Harris, and Hanna Mounce provided field help; Tom DeLong provided fiscal support; Susan Cooper, John Rose, John Shook, and Delee Spiesschaert helped with logistics; and Pam Odom produced the report.

INTRODUCTION

Castle and Cooke Resorts is interested in developing a windfarm in the western half of Lana'i Island, Hawaii (Fig. 1). As part of the siting and permitting process, Castle and Cooke wanted to obtain initial information on endangered seabirds and bats in the proposed development area. Ornithological radar and night-vision techniques have been shown to be successful in studying these species on Kaua'i (Cooper and Day 1995, 1998; Day and Cooper 1995, Day et al. 2003b), Maui (Cooper and Day 2003), Moloka'i (Day and Cooper 2002), and Hawai'i (Reynolds et al. 1997, Day et al. 2003a), so ABR was hired to survey seabirds and bats in the area with similar techniques. This report summarizes the results of a radar and audio-visual study of seabirds conducted during May–July 2007. The objectives of the study were to: (1) conduct surveys of endangered seabirds and bats in the vicinity of the proposed wind-resource area; and (2) obtain information to help assess use of the area by these species.

BACKGROUND

Two nocturnal seabird species occur on Lana'i Island: the endangered Hawaiian Petrel (*Pterodroma sandwichensis*), which nests there, and the threatened Newell's (Townsend's) Shearwater (*Puffinus auricularis newelli*), which appears to occur there in very small numbers but whose breeding status is unknown. The Hawaiian Petrel ('Ua'u) and the Newell's Shearwater ('A'o) are tropical Pacific seabirds that nest only on the Hawaiian Islands (American Ornithologists' Union 1998). Both species are Hawaiian endemics whose populations have declined significantly in historical times: they formerly nested widely over all of the Main Hawaiian Islands but now are restricted in most cases to scattered colonies in more inaccessible locations (Ainley et al. 1997b, Simons and Hodges 1998). The main exception is Kaua'i Island, which has no introduced Indian Mongooses (*Herpestes auropunctatus);* there, colonies are still widespread and populations are substantial in size, although Newell's Shearwaters have declined there substantially since the early 1990s (Day et al. 2003b). Because of their low overall population numbers and restricted breeding distributions, both of these species are protected under the Endangered Species Act.

The Hawaiian Petrel nests on most of the Main Islands but is known to nest primarily on Maui (Richardson and Woodside 1954, Banko 1980a; Simons 1984, 1985; Simons and Hodges 1998, Cooper and Day 2003), Kaua'i (Telfer et al. 1987, Gon 1988, Day and Cooper 1995; Ainley et al. 1997a, 1997b; Day et al. 2003b), and, to a lesser extent, Hawai'i (Banko 1980a, Conant 1980, Hu et al. 2001, Day et al. 2003a) and Lana'i (Shallenberger 1974; Hirai 1978a, 1978b; Conant 1980). Recent information from Moloka'i (Day and Cooper 2002) also suggests breeding. Probably several thousand Hawaiian Petrels occur on Kaua'i and Maui (Harrison et al. 1984, Harrison 1990, Day and Cooper 1995, Spear et al. 1995, Ainley et al. 1997a, Simons and Hodges 1998, Day et al. 2003b; Day and Cooper, unpubl. data), and the colony on Lana'i is now considered to be "large" (J. Penniman, State of Hawaii Department of Land and Natural Resources, Division of Fish and Wildlife [DOFAW], in litt. 15 June 2007), possibly being even larger than the colony on Maui.

The Newell's Shearwater breeds on several of the Main Islands, with the largest numbers clearly occurring on Kaua'i (Telfer et al. 1987, Day and Cooper 1995, Ainley et al. 1997b, Day et al. 2003b). These birds also nest on Hawai'i (Reynolds and Richotte 1997, Reynolds et al. 1997, Day et al. 2003a), almost certainly nest on Moloka'i (Pratt 1988, Day and Cooper 2002), probably nest on Maui (Cooper and Day 2003), and may still nest on O'ahu (Sincock and Swedberg 1969, Banko 1980b, Conant 1980, Pyle 1983; but see Ainley et al. 1997b). Although there have been a few recent records of Newell's Shearwaters on Lana'i, there is no evidence of nesting at this time (J. Penniman, DOFAW, pers. comm.). Several tens of thousands of Newell's Shearwaters are estimated to nest on Kaua'i (Harrison et al. 1984, Harrison 1990, Day and Cooper 1995, Spear et al. 1995, Ainley et al. 1997b, Simons and Hodges 1998, Day et al. 2003b; Day and Cooper, unpubl. data), which is the world center of abundance of this species. Finally, although Banko (1980a) listed no historical or recent records of this species on Lana'i, a downed Newell's Shearwater was found in Lana'i City on

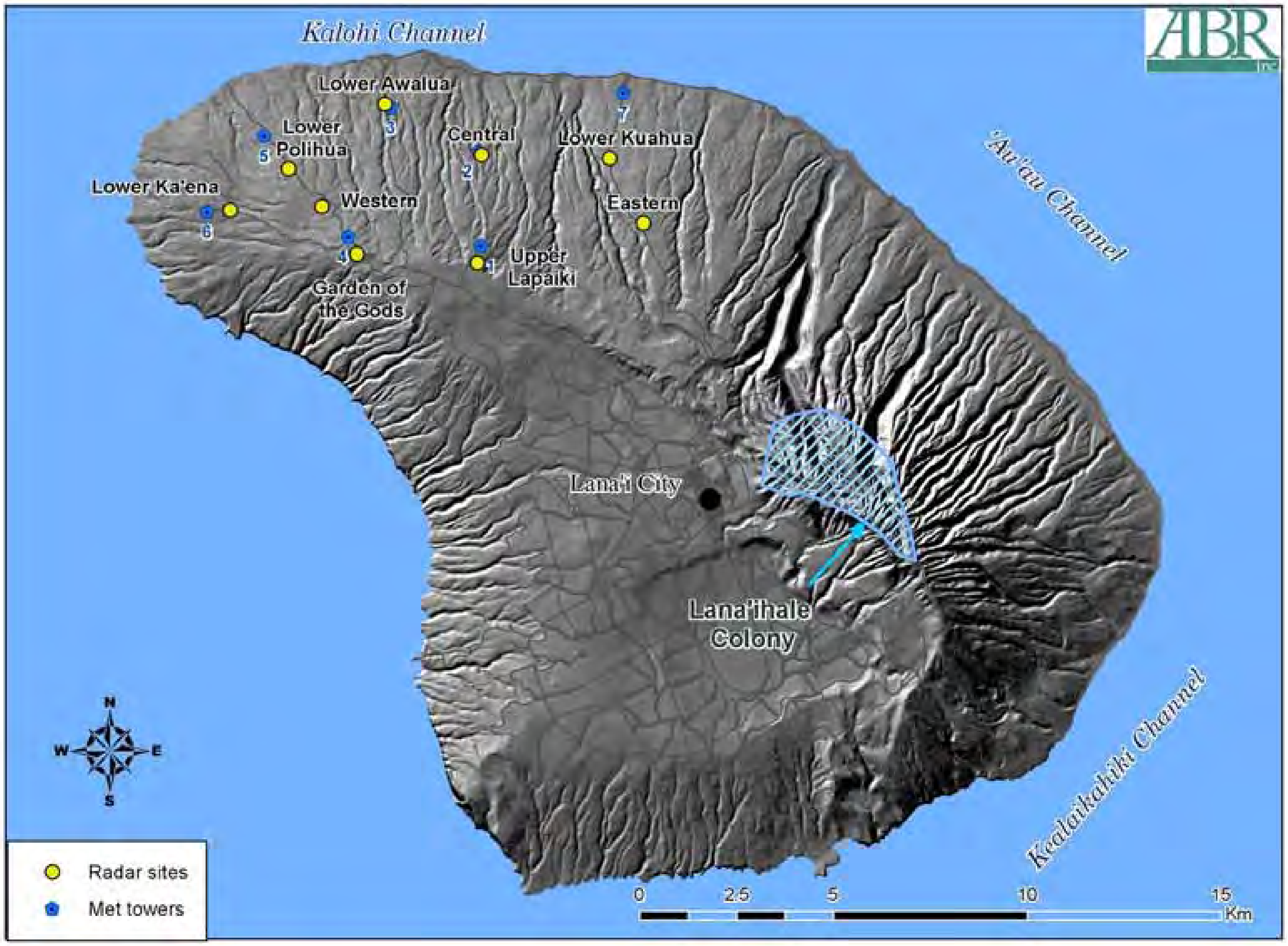

Figure 1. Location of radar-sampling sites and proposed met towers on Lana'i Island, Hawai'i, late spring and summer 2007. Information on the location of the nesting colony of Hawaiian Petrels is from J. Penniman (State of Hawaii DLNR, DOFAW, pers. comm..).

10 October 1983 (Pyle 1984a); the date of the record suggests that the bird was a juvenile. Because this city is located several kilometers inland, it is doubtful that the lights attracted this bird from the ocean; hence, it probably was produced on the island.

HISTORY OF HAWAIIAN PETRELS ON LANA'I

Hawaiian Petrels have been known on Lana'i for many years. Although Munro (1960) had stated that introduced pigs (*Sus scrofus*) and cats (*Felis catus*) had exterminated this species on Lana'i, a nesting population of Hawaiian Petrels still survives there. This island is the only Main Island other than Kauai that is mongoose-free, which may explain the long-term persistence of the species on Lana'i. Shallenberger (1974) reported a Hawaiian Petrel at ~820 m elevation above Kaiholena Gulch on Lana'ihale (the highest point on the island) on 26 October 1973; the bird was attracted to lights set up for insect collecting on a foggy night, suggesting from that fact and the date of the record that it may have been a juvenile.

A colony of ~100 Hawaiian Petrels was found at Kunoa Gulch, along the Munro Trail, on 23 June 1976; this colony was located at ~850 m elevation in the mountain forest (Hirai 1978a, 1978b) and was located just on the other side of the ridge from the Kaiholena Gulch mentioned above. Hirai (1978b) saw Hawaiian Petrels at this site again on 29 May 1977 and suggested that scattered Hawaiian Petrels heard calling at scattered locations along the Munro Trail in June 1976 might represent either adults flying to the one known nesting colony or scattered nesting attempts. Birds also were recorded on Lana'ihale in the summers of 1978 (Pyle 1978) and 1980 (Ralph and Pyle 1980), suggesting breeding.

One Hawaiian Petrel was found downed in the lights of Lana'i City on 5 November 1980 (Pyle and Ralph 1981), with the light-attraction and the date of the record suggesting that the bird was a juvenile; the authors indicated that this species is now "seen and heard by the hundreds each spring" in the mountains of Lana'i. A Hawaiian Petrel fledgling also was picked up at Lana'i City on 8 November 1986 (Pyle 1987); the author indicated that fledglings had been found at this location in previous years, perhaps referring to the 1980 record.

Hawaiian Petrels again were seen and heard in "good numbers" in the mountains of Lana'i in the summer of 1981, and an injured Hawaiian Petrel was found in the Palawai Basin on 19 May 1981 (Pyle and Ralph 1981). Observers also heard five pairs vocalizing and saw six single Hawaiian Petrels before dark at a probable nesting location at Lana'ihale on 24 June 1982 (Pyle 1982).

Hawaiian Petrels also were seen and heard near a small weather station at ~2,000 ft (~610 m) on Lana'ihale on 12 June 1983 (Pyle 1983). At least 50 Hawaiian Petrels were seen or heard near this station again on 26 May 1984; this count was considered low because observation conditions were so poor (Pyle 1984b).

Recent research on Lana'i has indicated that the population of Hawaiian Petrels there is large—probably being even larger than that on Maui (J. Penniman, DOFAW, *in litt*.). The belief is that the Lana'ihale colony was able to survive until protection of the nesting habitat, especially 'uluhe ferns (*Dicranopteris linearis*), from ungulates allowed regrowth of the habitat to a point where the colony could expand. That restoration of habitat appears to have allowed the colony to grow dramatically in the past 20 yr.

HAWAIIAN HOARY BATS

The Hawaiian Hoary Bat (*Lasiurus cinereus semotus*), or 'Ope'ape'a, is the only terrestrial mammal native to Hawaii. It is classified as endangered at both the federal and state levels, primarily because so little is known about its status and population trends. It is a nocturnal species that does not roost communally during the daytime; instead, it roosts solitarily within the forest. This bat occupies a wide variety of habitats, from sea level to >13,000 ft (Baldwin 1950, Fujioka and Gon 1988, Fullard 1989, David 2002). It also occurs on all of the Main Islands, including Lana'i (Baldwin 1950, van Riper and van Riper 1982, Tomich 1986, Fullard 1989, Kepler and Scott 1990, Hawaii Heritage Program 1991, David 2002).

Recent data from Appalachian ridge tops in the eastern US (Erickson 2004, Kerns 2004) have indicated that substantial kills of bats, including Hoary Bats, sometimes occur at windpower projects. Most of the bat fatalities documented at windfarms to date have been of migratory species during seasonal periods of dispersal and migration in late summer and fall. Several hypotheses have been posited, but none have been tested, to explain the cause(s) of these fatalities (Arnett 2005, Kunz et al. 2007). Because of this recent mortality of migratory Hoary Bats at windfarms on the US mainland, there was interest in collecting preliminary visual data on Hawaiian Hoary Bats during this study, even though the Hawaiian subspecies is non-migratory.

STUDY AREA

The proposed windfarm is located in the western half of Lana'i (Fig. 1). This proposed windfarm would include seven 50-m-high meteorological (met) towers (Fig. 1). Each tower would be anchored by six guy wires in each of four directions. All guy wires would be marked with an alternating array of spiral vibration dampers and strips of reflective tape at ~5-m intervals. Each of the ~270 proposed Vestas V90 wind turbines would have a generating capacity of ~1.5 MW, for a total installed capacity of ~400 MW. The currently proposed monopole towers would be ~80 m in height, and each turbine would have three rotor blades. The length of each rotor blade and hub would be ~45 m, thus, the total maximal height of a proposed turbine would be ~125 m at the top of the rotor-swept area.

The Island of Lana'i was formed by a single volcano. The highest point of the island, Lana'ihale, is 3,370 ft (1,027 m) above sea level (asl) and receives ~30–35 in (~75–90 cm) of annual precipitation (Carlquist 1980). There is a large colony of Hawaiian Petrels on the ridge encompassing Lana'ihale (Fig. 1), and native vegetation such as 'ohia trees (*Metrosideros polymorpha*) and 'uluhe ferns dominate the valleys and slopes of Lana'ihale. These two plant species also form the preferred nesting habitat for Newell's Shearwaters (Sincock and Swedberg 1969, Ainley et al. 1997b). In addition to the vegetation, the steepness of the slopes surrounding Lana'ihale suggests suitable nesting habitat in the area for both petrels and shearwaters (Hirai 1978b), as it does on Kaua'i (T. Telfer, DOFAW [retired] pers. comm.) and Maui (Brandt et al. 1995).

In contrast to the top of Lana'ihale, the Wind Resource Area (WRA) in the western half of Lana'i is lower and drier and does not contain any known petrel colonies. Elevations in the WRA range from sea level to ~1,600 ft (~500 m) asl, and the area receives only ~10–20 in (~25–50 cm) of annual precipitation (Carlquist 1980). For many years, the area was used as a cattle ranch and pineapple plantation. The proposed WRA is situated in a highly-eroded area of sloping scrubland, barren areas, and grasslands. The dominant "shrubs" in the area include the non-native kiawe (*Prosopis pallida*), verbena (*Lantana camara*), bull thistle (*Circium vulgare*), and 'ilima (*Sida fallax*; Redpath 2007). The open grasslands include alien invasive species such as buffel grass (*Cenchrus ciliaris*) and native grass species such as pili grass (*Heteropogon contortus*). At the lowest elevations along the coast, kiawe is prevalent and grows to ~5 m in height.

METHODS

DATA COLLECTION

We collected data on the movements, behavior, and flight altitudes of Hawaiian Petrels at nine sites total on Lana'i Island in 2007 (Fig. 1): at 3 sites during 15 nights of sampling in late May–early June ("late spring" sampling period) and at 7 sites, including 1 site that was sampled during the late-spring period, during 35 nights of sampling in late June–early July ("summer" sampling period; Tables 1 and 2). We sampled with ornithological radar and visual equipment for 3 h in the evening and ~2 h in the morning; these two periods correspond to the evening and morning peaks of movement of these birds (Day and Cooper 1995). During sampling, we collected radar and audio-visual data concurrently so that we could use the radar to help the visual observer locate birds for identification and data collection. In return, the visual observer provided information to the radar operator on the identity and flight altitude of individual targets (whenever possible). For the purpose of recording data, a calendar day began at 0700 and ended at 0659 the following morning; that way, an evening and the following morning were classified as occurring on the same day.

Table 1. Radar and audio-visual sampling effort on Lana'i Island, Hawai'i, late spring 2007.

		Sampling type	
Date	Study site	Radar	Audio-visual
26 May	Western	1900–2200; 0400–0630	1900–2200; 0400–0630
27 May	Eastern	1900–2200; 0400–0630	1900–2200; 0400–0630
28 May	Central	1900–2200; 0400–0600	1900–2200; 0400–0600
29 May	Western	1900–2200; 0400–0600	1900–2200; 0400–0600
30 May	Eastern	1900–2200; 0400–0600	1900–2200; 0400–0600
31 May	Central	1900–2200[1]; 0400–0600	1900–2200; 0400–0600
1 June	Western	1900–2200; 0400–0600	1900–2200; 0400–0600
2 June	Eastern	1900–2200; 0400–0600	1900–2200; 0400–0600
3 June	Central	1900–2200; 0400–0600	1900–2200; 0400–0600
4 June	Western	1900–2200[2]; 0400–0600	1900–2200; 0400–0600
5 June	Eastern	1900–2200; 0400–0600	1900–2200; 0400–0600
6 June	Central	1900–2200; 0400–0600	1900–2200; 0400–0600
7 June	Western	1900–2200; 0400–0600	1900–2200; 0400–0600
8 June	Eastern	1900–2200; 0400–0600	1900–2200; 0400–0600
9 June	Central	1900–2200; 0400–0600	1900–2200; 0400–0600

[1] One radar session cancelled because of equipment problems.
[2] Parts of two radar sessions cancelled because of rain.

The ornithological radars used in this study were Furuno Model 1510 X-band radars transmitting at 9.410 GHz through a slotted wave guide with a peak power output of 12 kW; a similar radar unit is described in Cooper et al. (1991). Each radar's antenna face was tilted upward by ~10–15°, and we operated the radars at a range setting of 1.5 km and a pulse-length of 0.07 μsec.

Radar operators had to deal with two issues at each site: ground clutter and shadow zones. Whenever energy is reflected from the ground, surrounding vegetation, and other objects that surround the radar unit, a ground-clutter echo appears on the radar's display screen. Because ground clutter can obscure targets of interest (e.g., birds and bats), we attempted to minimize it by picking optimal sampling locations. Ground clutter was minor at all nine sites and, in our opinion, did not cause us to miss any targets. Shadow zones are areas of the screen where birds were likely to be flying at an altitude that would put them behind a hill, row of vegetation, etc., where they could not be detected. Shadow zones at all sampling sites were minimal; however, because of the unusually low flight altitudes of petrels in this area (see below), it is likely that some birds flew within these zones, especially those toward the edge of the radar screen, and thus were not detected by radar.

We sampled for six 25-min counts during the period 1900–2200 and for four 25-min counts during the period 0400–0600 (Tables 1 and 2). Each 25-min sampling period was separated by a 5-min break for collecting weather data and for switching observers. We attempted to collect data only for petrel-like targets, following methods developed by Day and Cooper (1995). Thus, to help eliminate species other than those of interest (e.g., slowly-flying birds, insects), we recorded data only for those targets flying ≥30 mi/h (≥50 km/h; corrected in real-time for wind speed and direction, per methods described below) and removed otherwise-countable targets (based on target velocity and flight characteristics) identified by visual observers as those of other bird species.

We also conducted audio-visual sampling for birds and bats concurrently with the radar sampling, to help identify targets observed on radar and to obtain flight-altitude information. During

Table 2. Radar and audio-visual sampling effort on Lana'i Island, Hawai'i, summer 2007.

		Sampling type	
Date	Study site	Radar	Audio-visual
21 June	Lower Kuahua	1900–2200; 0400–0630	1900–2200; 0400–0600
22 June	Lower Ka'ena	1900–2200; 0400–0630	1900–2200; 0400–0600
	Upper Lapaiki	1900–2200; 0400–0600	1900–2200; 0400–0600
23 June	Lower Awalua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Garden of the Gods	1900–2200; 0400–0600	1900–2200; 0400–0600
24 June	Lower Polihua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Central	1900–2200; 0400–0600	1900–2200; 0400–0600
25 June	Lower Kuahua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Lower Ka'ena	1900–2200; 0400–0600	1900–2200; 0400–0600
26 June	Upper Lapaiki	1900–2200; 0400–0600	1900–2200; 0400–0600
	Garden of the Gods	1900–2200; 0400–0600	1900–2200[1]; 0400–0600[1]
27 June	Lower Awalua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Central	1900–2200; 0400–0600	1900–2200; 0400–0600
28 June	Lower Polihua	1900–2200; 0400–0630	1900–2200; 0400–0600
	Lower Kuahua	1900–2200; 0400–0630	1900–2200; 0400–0600
29 June	Lower Ka'ena	1900–2200; 0400–0600	1900–2200; 0400–0600
	Upper Lapaiki	1900–2200; 0400–0600	1900–2200; 0400–0600
30 June	Garden of the Gods	1900–2200; 0400–0600	1900–2200; 0400–0600
	Lower Awalua	1900–2200; 0400–0600	1900–2200; 0400–0600
1 July	Central	1900–2200; 0330–0600	1900–2200; 0400–0600
	Lower Polihua	1900–2200; 0400–0600	1900–2200; 0400–0600
2 July	Lower Kuahua	1900–2200; 0330–0600	1900–2200; 0400–0600
	Lower Ka'ena	1900–2200; 0400–0600	1900–2200; 0400–0600
3 July	Garden of the Gods	1900–2200[1]; 0400–0600	1900–2200; 0400–0600
	Upper Lapaiki	1900–2200[1]; 0400–0600[1]	1900–2200[1]; 0400–0600[1]
4 July	Central	1900–2200; 0330–0600	1900–2200; 0400–0600
	Lower Awalua	1900–2200; 0400–0630	1900–2200; 0400–0600
5 July	Lower Kuahua	1900–2200; 0330–0630	1900–2200; 0400–0600
	Lower Polihua	1900–2200; 0400–0600	1900–2200; 0400–0600
6 July	Upper Lapaiki	1900–2200; 0400–0600	1900–2200; 0400–0600
	Lower Ka'ena	1900–2200; 0400–0600	1900–2200; 0400–0600
7 July	Lower Awalua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Garden of the Gods	1900–2200; 0400–0600	1900–2200; 0400–0600
8 July	Lower Polihua	1900–2200; 0400–0600	1900–2200; 0400–0600
	Central	1900–2200; 0330–0600	1900–2200; 0400–0600

[1] One or more sessions cancelled because of rain or other factors.

this sampling, we used 10× binoculars during crepuscular periods and used PVS-7 night-vision goggles during nocturnal periods to look for targets that were detected on the radar. The magnification of these Generation 3 goggles was 1×, and their performance was enhanced with the use of a 3-million-Cp floodlight that was fitted with an IR filter to avoid blinding and/or attracting these nocturnal birds. During our audio-visual sampling, we also used a Pettersson D-100 heterodyne bat detector to conduct acoustic surveys for bats. During acoustic sampling, we set the bat detector to detect calls in the peak range for Hawaiian Hoary Bats (25–30 KHz) and recorded the number of calls heard during each 25-min session. The bat detector was placed ~0.5 m above ground level and was oriented vertically, so that it sampled the airspace directly overhead.

During the summer study period, we also conducted acoustic surveys to investigate the possibility that some petrels could be nesting away from the main colony and within the WRA. On 15 nights between 22 June and 8 July, one observer (T. Kekona, KC Environmental, Makawao, HI) listened at specific locations along all roads within the proposed WRA for vocalizations typically heard in petrel breeding areas. Survey points were established every ~0.5 mi (~0.8 km) along each of eight roads, resulting in 50 total sampling points. Acoustic surveys were conducted between 1930 and 2300, during which time the observer listened for 10 min at each of as many points as possible along one or more road transects. Each point was visited 2–3 times during the study, with the sampling order of points along each road changed between visits. A hand-held digital audio recorder with a customized hand-held microphone and adjustable pre-amp (built by Bill Evans, Old Bird, Inc., Ithaca, NY) was used to record potential petrel vocalizations. The microphone was designed to eliminate wind noise (<3 KHz), and the pre-amp both allowed the sensitivity of the microphone to be modified to maximize the detection of petrel calls and boosted the signal sent to the audio recorder.

Before each 25-min sampling session, we also collected a series of environmental and weather data, including wind speed (to the nearest 1 mi/h [1.6 km/h]) and wind direction (to the nearest 1°). If the wind speed was >10 mi/h (>16 km/h) and the ground speed of the target was near the 30-mi/h cutoff speed and in such a direction that the target was encountering either a headwind or tailwind, we factored in wind speed to help determine whether those marginal targets made the 30-mi/h cutoff for a petrel target. Following Mabee et al. (2006), airspeeds (i.e., groundspeed corrected for wind speed and relative direction) of surveillance-radar targets were computed with the formula:

$$V_a = \sqrt{V_g^{\,2} + V_w^{\,2} - 2V_g V_w \cos\theta}\,,$$

where V_a = airspeed, V_g = target groundspeed (as determined from the radar flight track), V_w = wind velocity, and θ is the angular difference between the observed flight direction and the direction of the wind vector.

In addition to wind speed and wind direction, we recorded the following standardized weather and environmental data:

- percent cloud cover (to the nearest 5%);
- cloud ceiling height, in meters above ground level (agl; in several height categories);
- visibility (maximal distance we could see, in categories);
- light condition (daylight, crepuscular, or nocturnal, and with or without precipitation)
- precipitation type; and
- moon phase/position (lunar phase and whether the moon was above or below the horizon in the night sky).
- For each appropriate radar target, we recorded a large suite of data:
- species (if known);
- number of organisms (if known);
- time;
- direction of flight (to the nearest 1°);
- transect crossed (the four cardinal points—000°, 090°, 180°, or 270°; also used in reconstructing flight paths);

- tangential range (the minimal distance to the target when it passed closest to the lab; used in reconstructing actual flight paths, if necessary);
- flight behavior (straight, erratic, circling);
- velocity (to the nearest 5 mi/h [8 km/h]); and
- flight altitude (if known).

We also plotted the flight path of each bird target on a transparent overlay of the radar screen for later digitizing into a GIS.

For each bird (or bat) seen during night-vision sampling, we recorded:

- time;
- species (to the lowest practical taxonomic unit [e.g., Hawaiian Petrel, unidentified petrel/shearwater]);
- number of organisms in the target;
- flight direction (the eight ordinal points); and
- flight altitude (meters agl).

For any birds detected during auditory sampling, we recorded species, number of call bouts, direction of call, and approximate distance.

DATA ANALYSIS

We entered all radar and audio-visual data into Microsoft Excel databases. Data files were checked visually for errors after each night's sampling, then were checked electronically for irregularities at the end of the field season, prior to data analyses. All data summaries and analyses were conducted with SPSS 14.0 statistical software (SPSS 2005). For quality assurance, we cross-checked results of the SPSS analyses with hand-tabulations of small subsets of data whenever possible.

We tabulated counts of numbers of targets recorded during each sampling session, then converted those counts to estimates of movement rates of birds (radar targets/h), based on the number of minutes sampled; some sampling time was lost to rain or other factors, so we had to standardize estimates by actual sampling effort. To calculate movement rates, we divided the number of targets recorded during a sampling session by the number of minutes actually sampled during that session, then multiplied that number (expressed as targets/min) by 60 min/h to estimate the movement rate (targets/h) for that session. We then used all of the estimated movement rates across sampling sessions at a site to calculate the mean ± 1 standard error (SE) nightly movement rate by site, by time period (evening, morning), and by flight direction (landward, seaward). Note that data from 0530 to 0600 were excluded from all analyses for the late spring study because of severe contamination of the radar data from non-petrel species such as Common Mynas (*Acridotheres tristis*). Further, only known petrel/shearwater targets or unknown targets with appropriate speeds (i.e., with appropriate target size, flight characteristics, and groundspeeds ≥30 mi/h) were included in data analyses of movement rates, flight directions, and flight behavior; all other species were excluded from those analyses.

We calculated the mean flight direction for all targets seen on radar. We also classified general flight directions of each radar target as inland, seaward, or "other" and summarized those directional categories by site, date, and time of day. To categorize the general flight direction of each target, we defined a landward flight as a radar target flying toward the Lana'ihale petrel colony and within 75° of either side of the approximate outer boundaries of that colony (Table 3). Targets flying in the opposite directions were considered seaward targets (again, with a 75° buffer). For each site, the few remaining flight vectors that were somewhat perpendicular to the direction to the colony were classified as landward or seaward based on their direction relative to the coastline.

We summarized the audio-visual data in terms of species, number, and flight direction. We also tabulated data on minimal flight altitudes of petrels recorded during the visual sampling and used those data for the vertical component in our fatality models (see below).

EXPOSURE AND FATALITY INDICES

To describe potential risk to Hawaiian Petrels within the area potentially occupied by the proposed met towers or wind turbines, we developed Exposure Indices (estimated number of times that a petrel would pass within the airspace

Table 3. Information on met tower covered, time period sampled, and criteria for landward and seaward categories of petrel flight directions at each site, Lana'i Island, Hawai'i, during late spring (LS) and summer (S) 2007.

Site	Met tower(s) covered	Sampling period[1]	Flight direction: Landward	Flight direction: Seaward
Lower Ka'ena	6, 8	S	015–194°	195–014°
Lower Polihua	5	S	045–224°	225–044°
Western	4	LS	045–224°	225–044°
Garden of the Gods	4	S	020–199°	200–019°
Lower Awalua	3	S	050–229°	230–049°
Central	2	LS; S	050–229°	230–049°
Upper Lapaiki	1	S	030–209°	210–029°
Lower Kuahua	7	S	070–249°	250–069°
Eastern	none	LS	055–234°	235–054°

[1] MY–JN = late spring (LS); JN–JL = summer (S).

occupied by the proposed met towers and their guy wires or pass by the proposed wind turbines each night). The Exposure Index for proposed met towers is equal to the number of target/km expected to be flying at or below met-tower height (i.e., ≤50 m agl) each night; this index is calculated by multiplying movement rates from surveillance radar by the percentage of seabirds with flight altitudes ≤50 m agl (maximal height of the proposed met towers). The Exposure Index for proposed wind turbines is more complex and comprises (1) the number of target/km flying at or below turbine height (i.e., ≤125 m agl) each night (calculated by multiplying movement rates from surveillance radar by the percentage of petrels with flight altitudes ≤125 agl [maximal height of the rotor-swept area]); and (2) the turbine area that petrels would encounter when approaching turbines from the side (parallel to the plane of rotation) or from the front (perpendicular to the plane of rotation).

We consider these estimates to be indices because they are based on several simplifying assumptions. The assumptions for this specific project include: (1) a worst-case scenario that the entire met-tower area encompassed by the outermost guy wires is solid, so there is no way that a petrel could fly through it without hitting a wire or pole; (2) a similar worst-case scenario for wind turbines, with the entire disk created by the rotor-swept area assumed to be a solid; (3) that there are minimal (i.e., side profile) and maximal (i.e., front profile, including the entire rotor-swept area) areas occupied by the proposed wind turbines relative to the flight directions of petrels; and (4) a worst-case scenario in which the rotor blades turn constantly (i.e., we used the entire rotor-swept area, not just the area of the blades themselves, to help calculate total turbine area). Note that our Exposure Indices estimate how many times petrels would be exposed to proposed met towers or turbines, not the number of birds that would actually collide with met towers or turbines: some unknown proportion of petrels would detect and avoid these structures, and, in the case of wind turbines, some could pass through the blades without collision. In addition, the Exposure Index calculates the number of exposure incidents, not the number of individuals—i.e., the index takes into account the fact that a single individual could be exposed to towers or turbines multiple times while crossing the WRA.

The Exposure Index is used to estimate daily numbers of birds flying within the airspace occupied by turbines or the proposed met towers and their guy wires. To calculate a Fatality Index, we expand those estimates for a 270-d year that birds are present on this island (late March through late December; J. Penniman, DOFAW, pers. comm.) and, hence, will be exposed to the proposed met towers and wind turbines. The fatality model then combines these estimates of interaction rates with the fatality probability to estimate fatality rates under a worst-case scenario of no collision avoidance (Fig. 2). Finally, it presents possible levels of fatality based on possible levels of collision avoidance by these birds.

RESULTS

RADAR-BASED OBSERVATIONS

MOVEMENT RATES

We recorded 170 targets that fit our criteria for petrels and shearwaters during the 15 nights of sampling in late spring 2007. Of those targets, we recorded 37 at the Western site, 73 at the Central site, and 60 at the Eastern site (Table 4). This pattern of fewer targets in the western portion of the study area also was seen in summer 2007: out of 427 probable petrel targets, we recorded 11 at Lower Ka'ena, 42 at Lower Polihua, 43 at Garden of the Gods (all in the western WRA), 70 at Lower Awalua, 83 at Central, 50 at Upper Lapaiki (all in the central WRA), and 128 at Lower Kuahua (in the eastern WRA; Table 5). Movement rates also reflected this pattern of fewer petrel targets in the western portion of the study area and more in the eastern portion of it, in both the evening and the morning (Figs. 3 and 4).

In late spring, mean movement rates of landward-flying targets ranged from 0.24–1.96 targets/h in the evening to 0 targets/h during the morning, whereas seaward rates ranged from 1.92–3.48 targets/h in the evening to 0.96–3.68 targets/h in the morning (Table 6). In summer, mean movement rates of landward-flying targets ranged from 0.0–3.56 targets/h in the evening to 0.0–0.12 targets/h during the morning, whereas seaward rates ranged from 0.48–3.56 targets/h in the evening to 0.60–4.92 targets/h in the morning. We sampled only one location (Central) in both late spring and summer; movement rates at that site were fairly similar between the two periods.

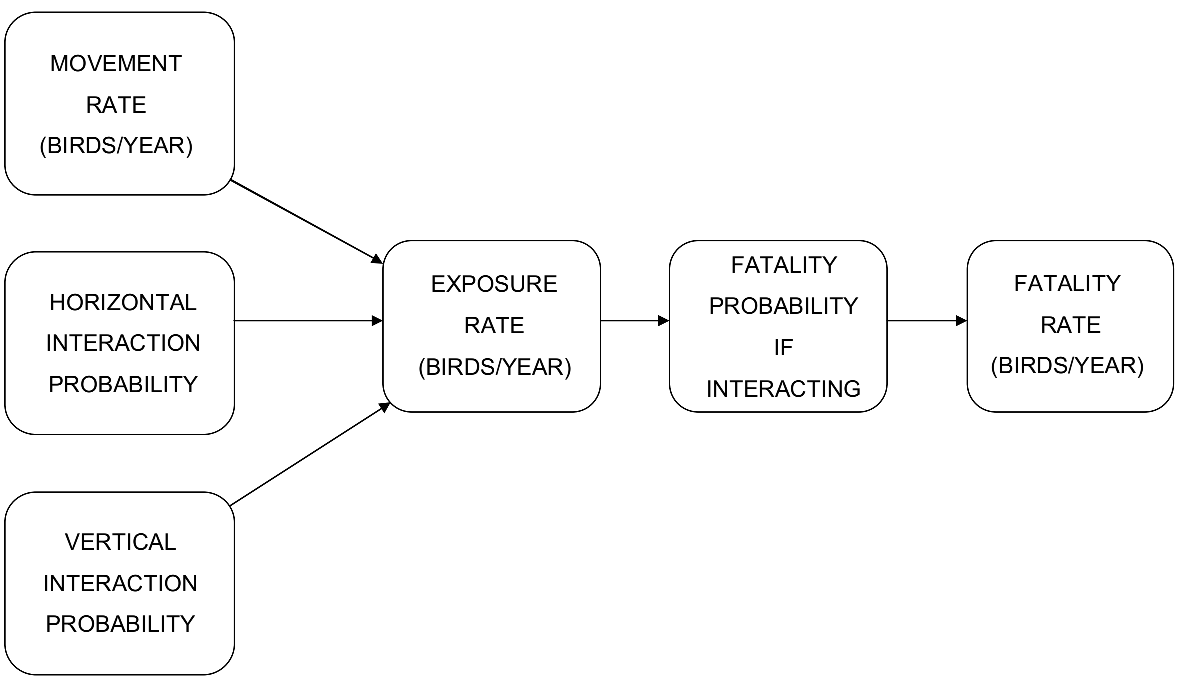

Figure 2. Major variables used in estimating possible fatality of Hawaiian Petrels at proposed met towers and wind turbines on Lana'i Island, Hawai'i. See Tables 13 and 14 for details on calculations.

Table 4. Number of probable Hawaiian Petrel targets observed on surveillance radar at Lana'i Island, Hawai'i, in late spring 2007, by study site, date, time of day, and flight direction. *n* = number of sampling sessions.

		Evening (1900–2200)		Morning (0400–0530)	
Site	Date	Landward (*n*)	Seaward (*n*)	Landward (*n*)	Seaward (*n*)
Western	26 May	1 (6)	4 (6)	0 (3)	3 (3)
	29 May	0 (6)	0 (6)	0 (3)	1 (3)
	1 June	0 (6)	3 (6)	0 (3)	1 (3)
	4 June	0 (6)	1 (6)	0 (3)	3 (3)
	7 June	2 (6)	16 (6)	0 (3)	2 (3)
	Total	3 (30)	24 (30)	0 (15)	10 (15)
Central	28 May	0 (6)	4 (6)	0 (3)	1 (3)
	31 May	1 (5)	4 (5)	0 (3)	2 (3)
	3 June	0 (6)	4 (6)	0 (3)	4 (3)
	6 June	5 (6)	13 (6)	0 (3)	10 (3)
	9 June	2 (6)	17 (6)	0 (3)	6 (3)
	Total	8 (29)	42 (29)	0 (15)	23 (15)
Eastern	27 May	4 (6)	2 (6)	0 (3)	1 (3)
	30 May	11 (6)	7 (6)	0 (3)	1 (3)
	2 June	1 (6)	5 (6)	0 (3)	1 (3)
	5 June	2 (6)	4 (6)	0 (3)	0 (3)
	8 June	6 (6)	14 (6)	0 (3)	3 (3)
	Total	24 (30)	32 (30)	0 (15)	6 (15)

At all sites, times of the day, and sampling periods, mean seaward movement rates always were higher than landward rates were (Table 6). The one exception was at Lower Kuahua, where evening movement rates in summer were identical between landward and seaward targets. In addition, landward rates in the evening always were equal to or greater than landward rates in the morning, and morning rates usually were 0 targets/h. In contrast, seaward rates did not show a consistent difference between evening and morning. It appears, however, that the only sites at which evening rates of seaward-flying targets were higher (Garden of the Gods and Upper Lapaiki) were the two farthest-inland sites, both of which were located along the east–west spine of the island (Fig. 1).

FLIGHT DIRECTION

The flight-direction data also reflected the pattern of higher seaward counts than landward counts. In spring 2007, most probable petrel targets were flying toward the west or northwest (i.e., away from the Lana'ihale colony) in both the evening (Fig. 5) and the morning (Fig. 6). At the Western site, however, an appreciable number also were heading toward the southwest in the evening.

The flight-direction pattern seen in summer 2007 was similar to that seen in late spring 2007: most probable petrel targets were heading toward the west or northwest, away from the colony, in both the evening and the morning (Figs. 7 and 8). In addition, targets were seen heading toward the colony only in the evening. However, the only site at which a substantial number of evening targets was heading southeasterly, toward the colony, was at Lower Kuahua, which was that site located closest to the colony (Fig. 7). In addition, a substantial number of targets at the Upper Lapaiki site were heading in a southerly direction.

We were able to collect flight-path data on a subset of 11 targets that were seen concurrently by the radar and verified as a petrel by audio-visual

Table 5. Number of probable Hawaiian Petrels observed on surveillance radar at Lana’i Island, Hawai’i, in summer 2007, by study site, date, time of day, and flight direction. *n* = number of sampling sessions.

		Time of day			
		Evening (1900–2200)		Morning (0400–0600)	
Site	Date	Landward (*n*)	Seaward (*n*)	Landward (*n*)	Seaward (*n*)
Lower Ka'ena	22 June	0 (6)	1 (6)	0 (4)	3 (4)
	25 June	0 (6)	0 (6)	0 (4)	0 (4)
	29 June	0 (6)	2 (6)	0 (4)	1 (4)
	2 July	0 (6)	1 (6)	0 (4)	1 (4)
	6 July	0 (6)	2 (6)	0 (4)	0 (4)
	Total	0 (30)	6 (30)	0 (20)	5 (20)
Lower Polihua	24 June	1 (6)	0 (6)	0 (4)	4 (4)
	28 June	0 (6)	1 (6)	0 (4)	0 (4)
	1 July	1 (6)	1 (6)	0 (4)	3 (4)
	5 July	2 (6)	6 (6)	0 (4)	1 (4)
	8 July	2 (6)	12 (6)	0 (4)	8 (4)
	Total	6 (30)	20 (30)	0 (20)	16 (20)
Garden of Gods	23 June	0 (6)	9 (6)	0 (4)	4 (4)
	26 June	0 (6)	9 (6)	0 (4)	3 (4)
	30 June	1 (6)	3 (6)	0 (4)	2 (4)
	3 July	0 (5)	8 (5)	0 (4)	0 (4)
	7 July	0 (6)	4 (6)	0 (4)	0 (4)
	Total	1 (29)	33 (29)	0 (20)	9 (20)
Lower Awalua	23 June	1 (6)	5 (6)	0 (4)	5 (4)
	27 June	0 (6)	6 (6)	1 (4)	2 (4)
	30 June	3 (6)	10 (6)	0 (4)	4 (4)
	4 July	1 (6)	9 (6)	0 (4)	5 (4)
	7 July	1 (6)	6 (6)	0 (4)	11 (4)
	Total	6 (30)	36 (30)	1 (20)	27 (20)
Central	24 June	4 (6)	10 (6)	0 (4)	9 (4)
	27 June	0 (6)	4 (6)	0 (4)	3 (4)
	1 July	2 (6)	5 (6)	0 (4)	7 (4)
	4 July	2 (6)	8 (6)	0 (4)	10 (4)
	8 July	1 (6)	8 (6)	0 (4)	11 (4)
	Total	9 (30)	35 (30)	0 (20)	40 (20)
Upper Lapaiki	22 June	2 (6)	5 (6)	0 (4)	4 (4)
	26 June	2 (6)	1 (6)	0 (4)	3 (4)
	29 June	4 (6)	5 (6)	0 (4)	2 (4)
	3 July	1 (5)	3 (5)	0 (2)	0 (2)
	6 July	5 (6)	11 (6)	0 (4)	2 (4)
	Total	14 (29)	25 (29)	0 (18)	11 (18)
Lower Kuahua	21 June	11 (6)	5 (6)	1 (4)	6 (4)
	25 June	2 (6)	8 (6)	0 (4)	7 (4)
	28 June	0 (6)	2 (6)	0 (4)	0 (4)
	2 July	13 (6)	12 (6)	0 (4)	17 (4)
	5 July	17 (6)	16 (6)	0 (4)	11 (4)
	Total	43 (30)	43 (30)	1 (20)	41 (20)

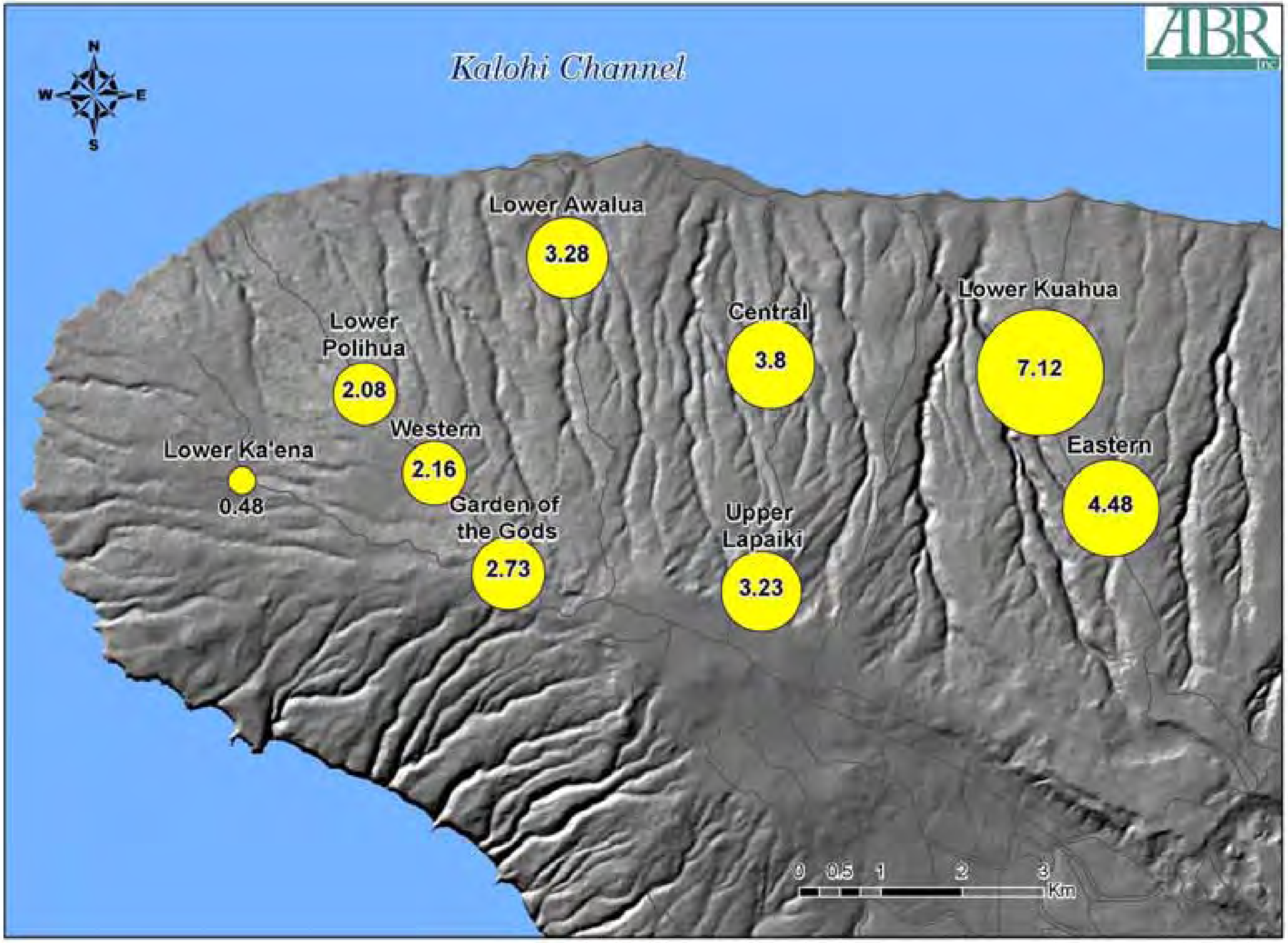

Figure 3. Geographic variation in mean movement rates (targets/h) of all probable Hawaiian Petrel targets observed during evening radar sampling at each site on Lana'i Island, Hawai'i, late spring and summer 2007. Sizes of circles are proportional to mean movement rate; numbers in/near circles are actual mean rates.

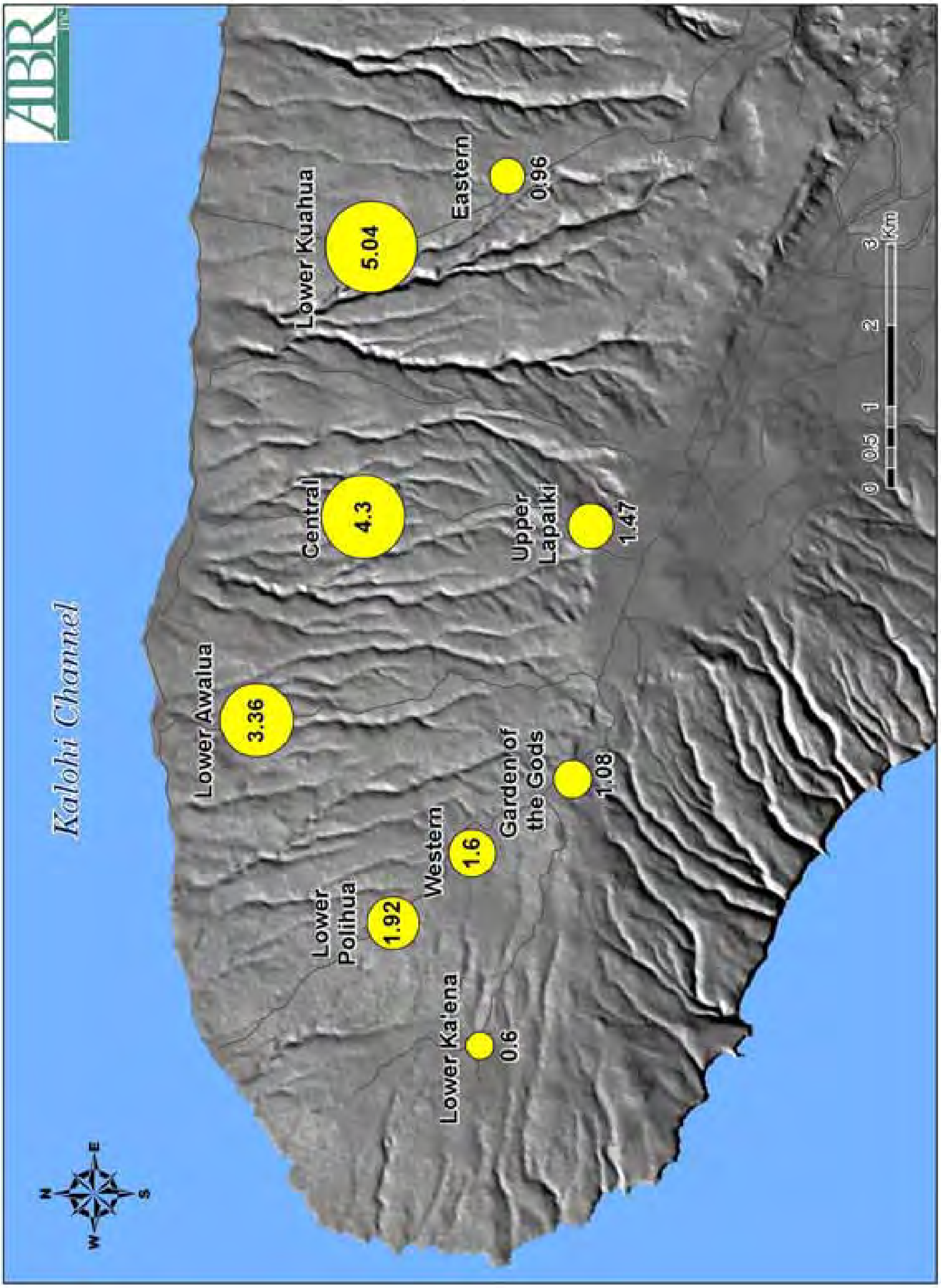

Figure 4. Geographic variation in mean movement rates (targets/h) of all probable Hawaiian Petrel targets observed during morning radar sampling at each site on Lana'i Island, Hawai'i, late spring and summer 2007. Sizes of circles are proportional to mean movement rate; numbers in/near circles are actual mean rates.

Table 6. Mean movement rates and mean counts of probable Hawaiian Petrel targets observed on surveillance radar at Lana'i Island, Hawai'i, late spring and summer 2007, by study site, time of day, and flight direction.

Sampling		Movement rate (targets/h)		Number of targets[1]	
period/site	Time of day	Landward	Seaward	Landward	Seaward
LATE SPRING					
Western	Evening	0.24	1.92	0.72	5.76
	Morning	0.00	1.60	0.00	4.80
Central	Evening	0.66	3.48	1.98	10.44
	Morning	0.00	3.68	0.00	11.04
Eastern	Evening	1.92	2.56	5.76	7.68
	Morning	0.00	0.96	0.00	2.88
SUMMER					
Lower Ka'ena	Evening	0.00	0.48	0.00	1.44
	Morning	0.00	0.60	0.00	1.80
Lower Polihua	Evening	0.48	1.60	1.44	4.80
	Morning	0.00	1.92	0.00	5.76
Garden of Gods	Evening	0.08	2.65	0.24	7.95
	Morning	0.00	1.08	0.00	3.24
Lower Awalua	Evening	0.48	2.80	1.44	8.40
	Morning	0.12	3.24	0.36	9.72
Central	Evening	0.72	2.72	2.16	8.16
	Morning	0.00	4.83	0.00	14.49
Upper Lapaiki	Evening	1.16	2.07	3.48	6.21
	Morning	0.00	1.47	0.00	4.41
Lower Kuahua	Evening	3.56	3.56	10.68	10.68
	Morning	0.12	4.92	0.36	14.76

[1]Number = movement rate * 3 to calculate the number of targets moving during the evening and morning peaks of activity.

observers (Fig. 9). That subset of visual and radar data also had a high proportion of petrels flying toward the colony, with some birds also flying away from the colony.

TIMING OF MOVEMENTS

The timing of landward movement of probable petrel targets was typical of that observed for petrels and shearwaters, with a peak in evening numbers during ~1930–2030 and very little movement in the morning during 0400–0600 (Fig. 10).The timing of the movement of seaward-flying targets however, was very different from the typical pattern, with targets moving at all hours of the night. In addition, movement rates during the final two hours of the evening and throughout the entire morning were high. In fact, seaward rates in the morning were high during even the first morning sampling session (0400–0430), which usually has little movement on other islands (Day and Cooper, unpubl. data).

BEHAVIOR

Most targets observed on radar were flying in a straight-line (directional) pattern, rather than with an erratic or circling behavior. For all sites, times, and sampling periods combined, 88.4% of flights were straight-line directional flights, 11.5% were erratic, and 0.2% were circling.

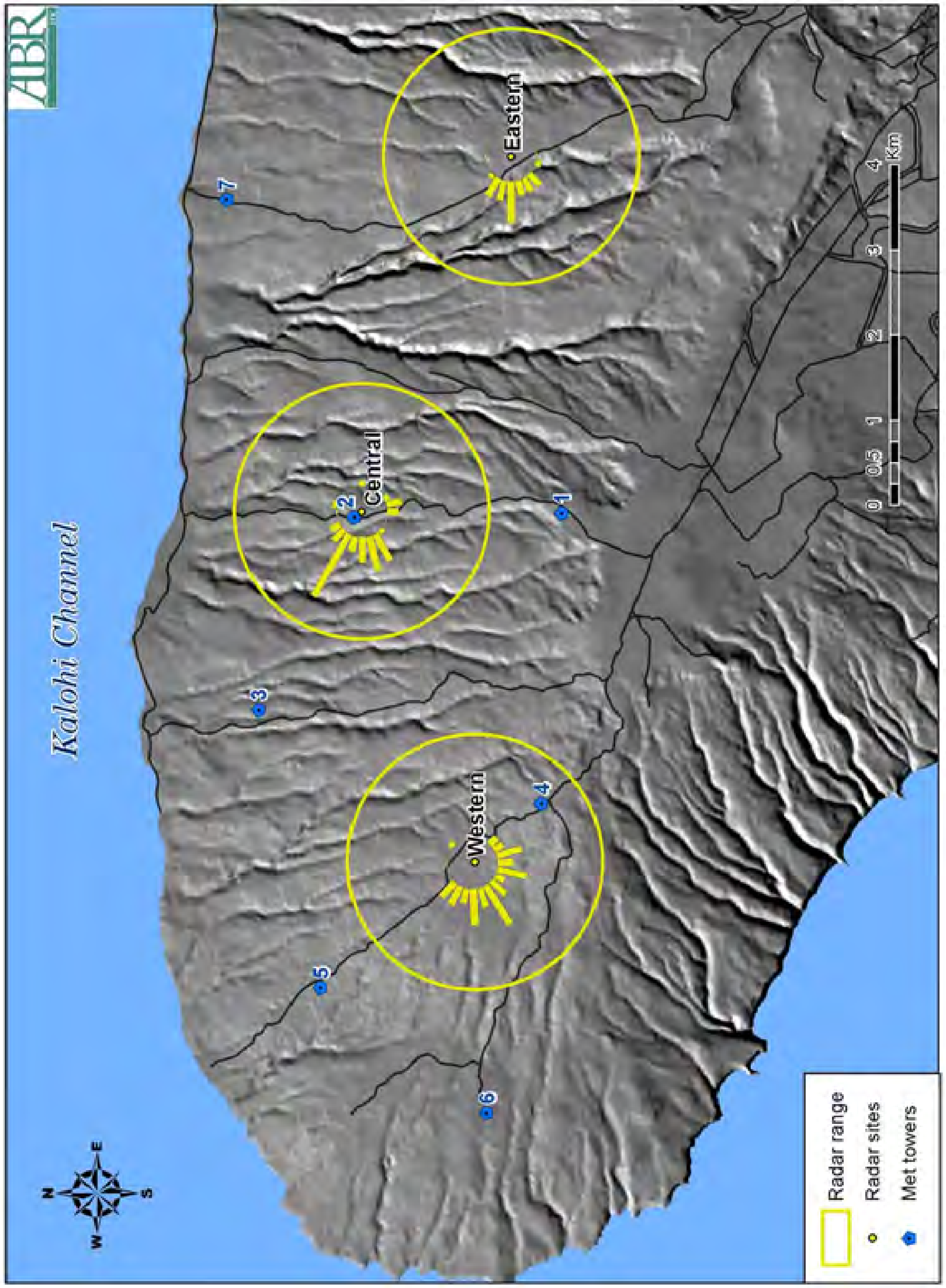

Figure 5. Flight directions of probable Hawaiian Petrel targets observed at each site during evening radar sampling on Lana'i Island, Hawai'i, late spring 2007. Length of spoke is proportional to the number of birds traveling in that direction.

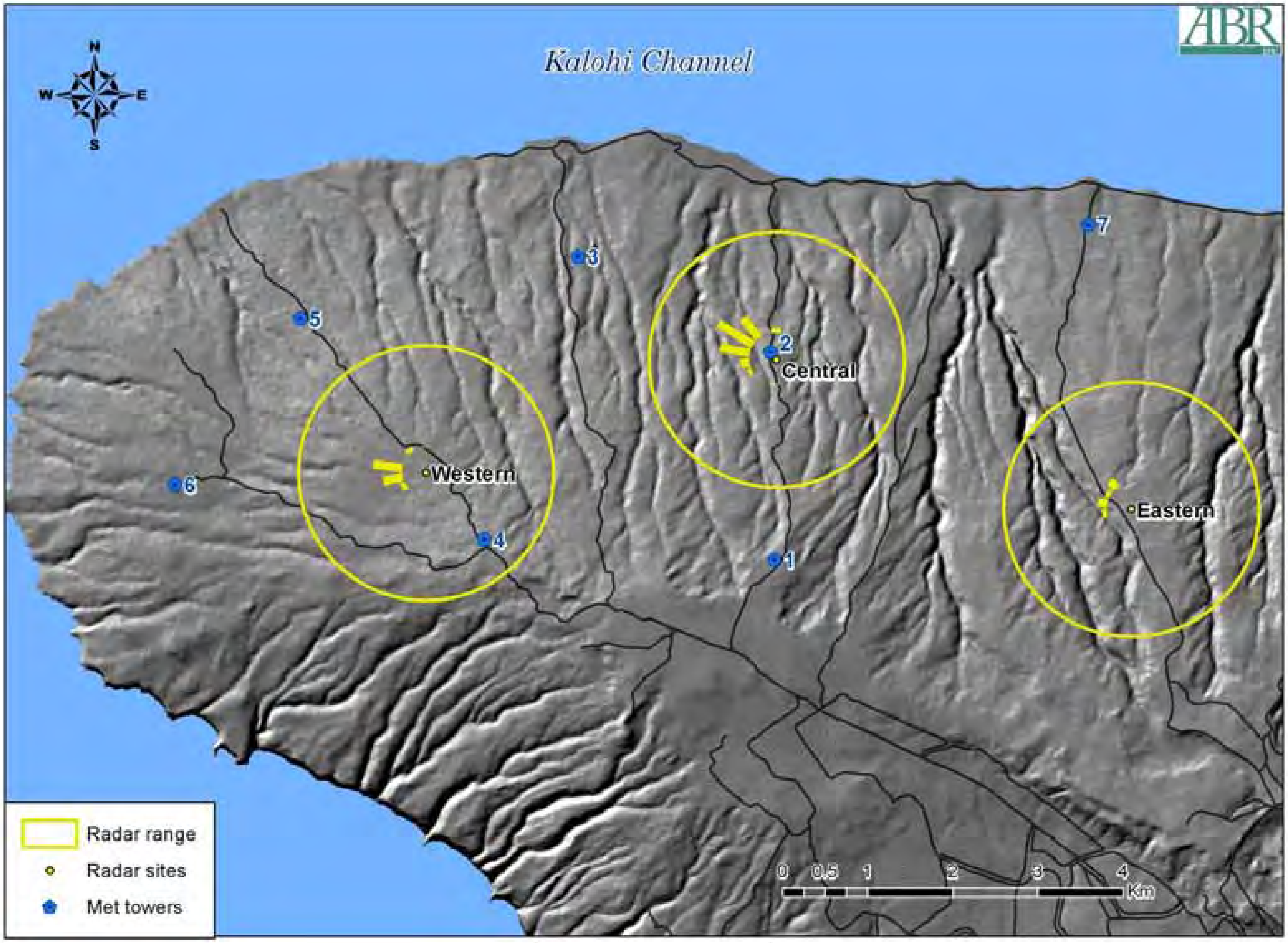

Figure 6. Flight directions of probable Hawaiian Petrel targets observed at each site during morning radar sampling on Lana'i Island, Hawai'i, late spring 2007. Length of spoke is proportional to the number of birds traveling in that direction.

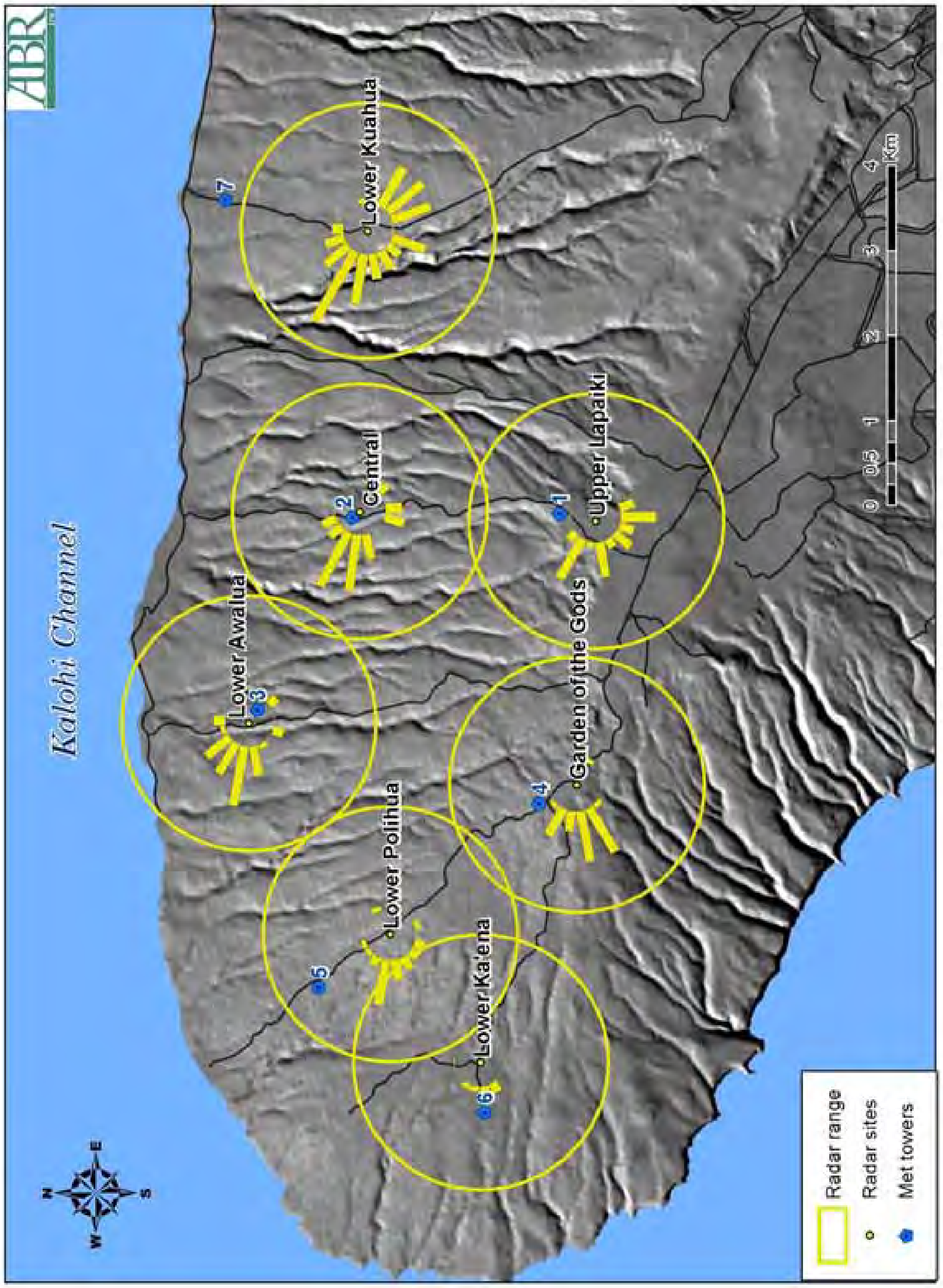

Figure 7. Flight directions of probable Hawaiian Petrel targets observed at each site during evening radar sampling on Lana'i Island, Hawai'i, summer 2007. Length of spoke is proportional to the number of birds traveling in that direction.

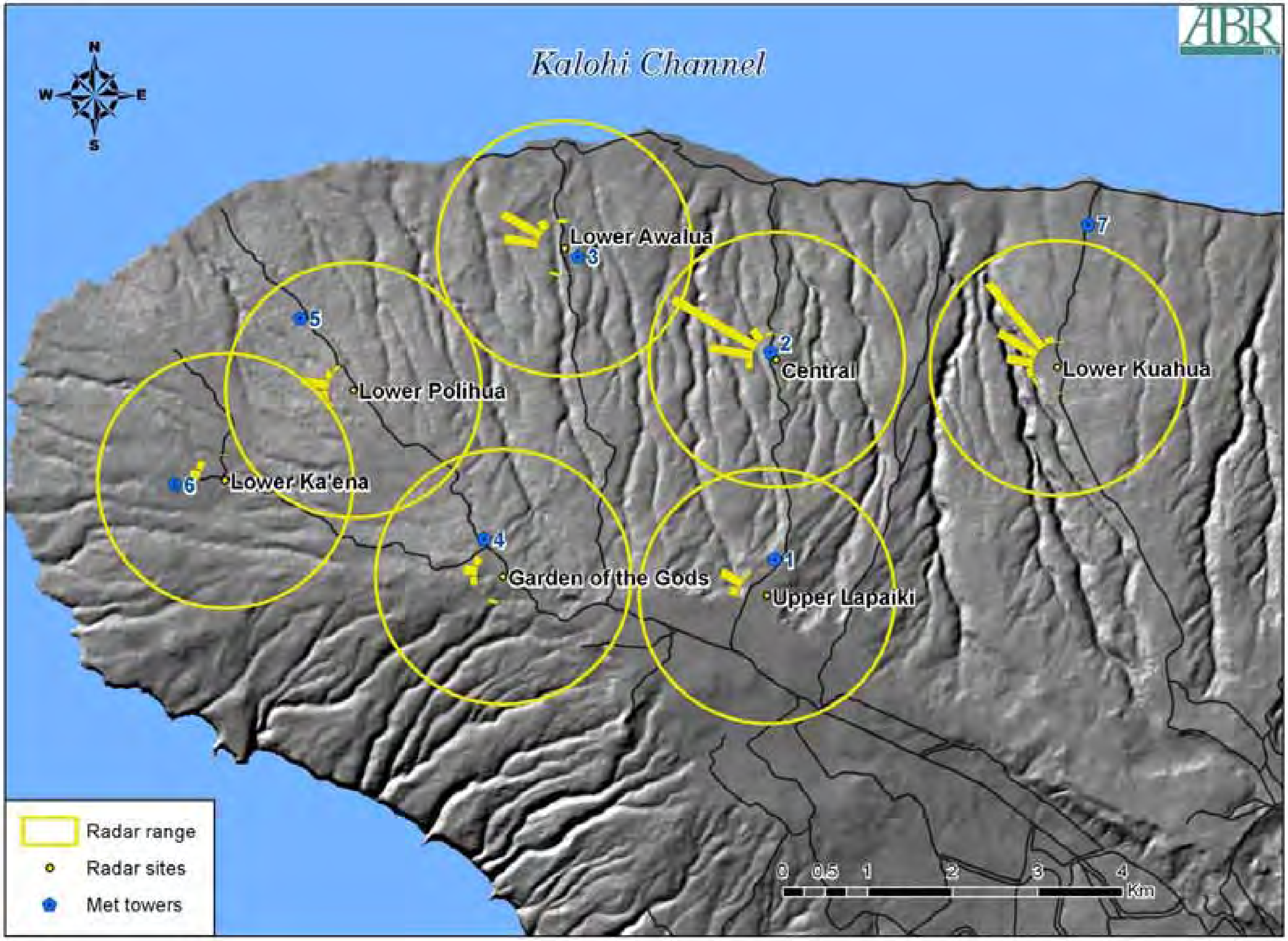

Figure 8. Flight directions of probable Hawaiian Petrel targets observed at each site during morning radar sampling on Lana'i Island, Hawai'i, summer 2007. Length of spoke is proportional to the number of birds traveling in that direction.

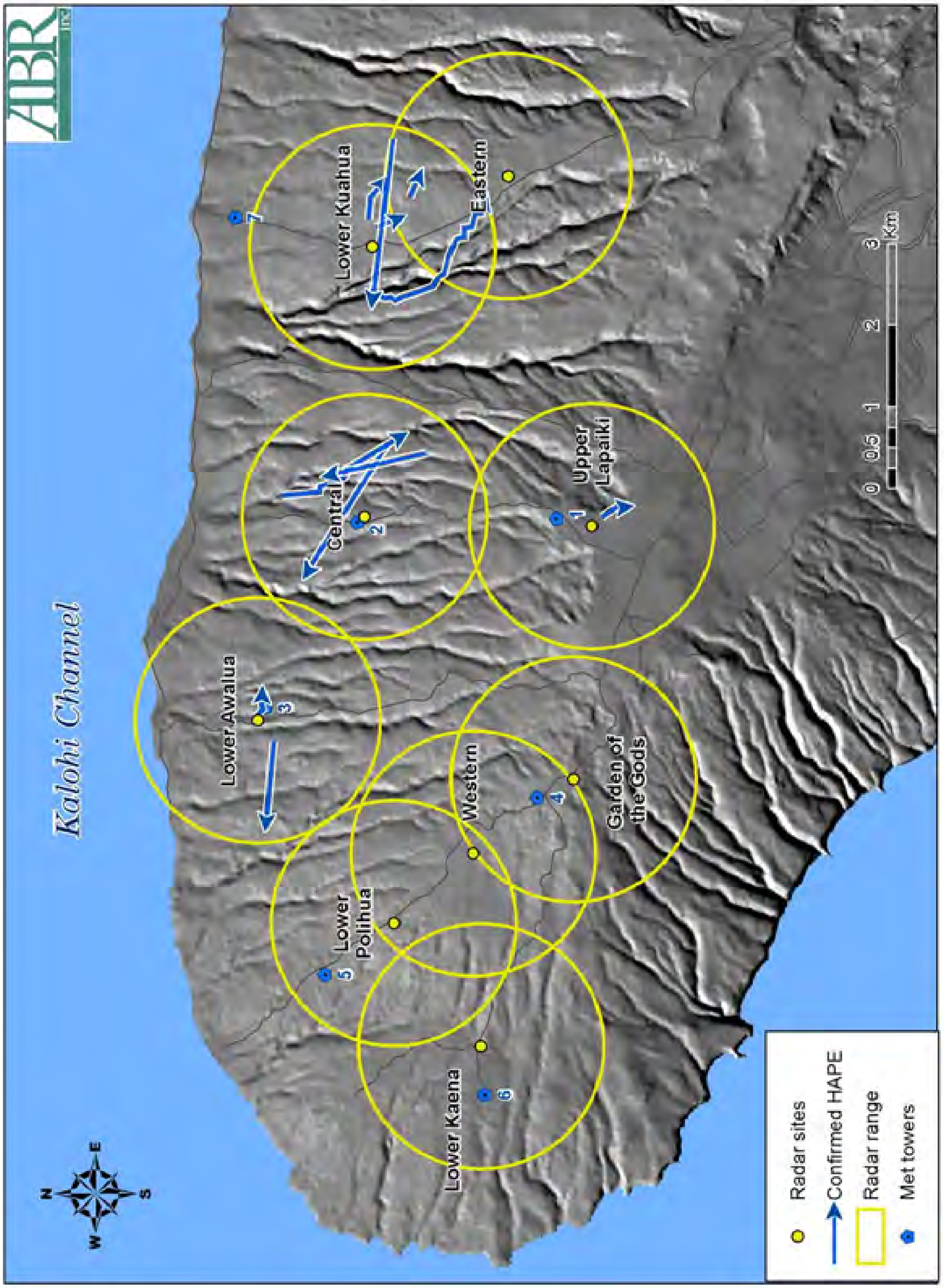

Figure 9. Flight paths (blue arrows) of 11 Hawaiian Petrels that were concurrently observed by radar and visual observers, Lana'i Island, Hawai'i, late spring and summer 2007.

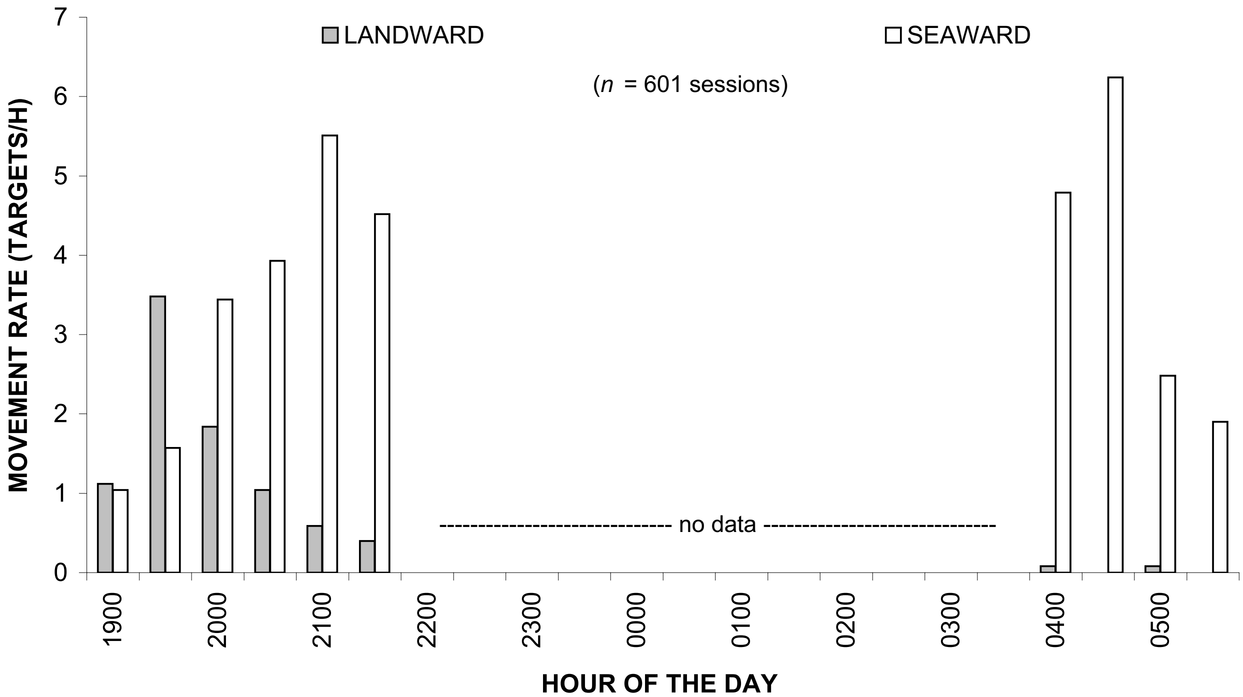

Figure 10. Hourly seaward and landward passage rates of probable Hawaiian Petrel targets observed on radar on Lana'i Island, Hawai'i, during late spring and summer 2007. Note that the number on the X-axis refers to the time that the sampling session began, not the midpoint of the session. The asterisk denotes times that were not sampled.

AUDIO-VISUAL OBSERVATIONS

NUMBERS AND SPECIES-COMPOSITION

We recorded 33 Hawaiian Petrels and 2 unidentified petrels/shearwaters during late spring and summer. Of the 5 birds recorded in late spring, we observed 0 at the Western site, 3 at the Central site, and 2 at the Eastern site (Table 7). In summer, we recorded 30 petrels, with 1 at Lower Ka'ena, 2 at Lower Polihua, 3 at Garden of the Gods, 6 at Lower Awalua, 6 at Central, 2 at Upper Lapaiki, and 10 at Lower Kuahua (Table 8).

In addition to Hawaiian Petrels, we also recorded other species of interest during our late spring and summer surveys. For instance, we saw one Hawaiian Hoary Bat at Garden of the Gods on the evening of 3 July (Tables 9 and 10). No other bats were recorded visually during the study; further, no bats were heard during the opportunistic acoustic monitoring that we did with the bat detector. Other species recorded during the audio-visual sampling included White-tailed Tropicbird (Koa'e Kea; *Phaethon rubricauda*), Greater Frigatebird ('Iwa; *Fregata minor*), Hawaiian Stilt (Ae'o; *Himatopus mexicanus knudseni*), Pacific Golden-Plover (Kolea; *Pluvialis fulva*), Short-eared Owl (Pueo; *Asio flammeus*), and Common Myna.

FLIGHT DIRECTION

We were able to assign flight directions to all Hawaiian Petrels and unidentified petrels/ shearwaters that we recorded visually during late spring and summer. Flight directions of these birds for all data combined showed a pattern of landward flights toward the colony, plus a few seaward flights, in the evening but only seaward flights away from the colony in the morning (Fig. 11). This landward–seaward pattern was similar to that seen on radar during both sampling periods (Figs. 5–8).

FLIGHT ALTITUDE

Visual observations also provided information on flight altitudes of Hawaiian Petrels and

Table 7. Number of Hawaiian Petrels and unidentified petrels/shearwater observed during visual sampling on Lana'i Island, Hawai'i, in late spring 2007, by study site, date, time of day, and flight direction. *n* = number of sampling sessions.

		Evening (1900–2200)		Morning (0400–0530)	
Site	Date	Landward (*n*)	Seaward (*n*)	Landward (*n*)	Seaward (*n*)
Western	26 May	0 (6)	0 (6)	0 (3)	0 (3)
	29 May	0 (6)	0 (6)	0 (3)	0 (3)
	1 June	0 (6)	0 (6)	0 (3)	0 (3)
	4 June	0 (6)	0 (6)	0 (3)	0 (3)
	7 June	0 (6)	0 (6)	0 (3)	0 (3)
	Total	0 (30)	0 (30)	0 (15)	0 (15)
Central	28 May	0 (6)	0 (6)	0 (3)	0 (3)
	31 May	1 (6)	0 (6)	0 (3)	0 (3)
	3 June	0 (6)	0 (6)	0 (3)	0 (3)
	6 June	1 (6)	0 (6)	0 (3)	1 (3)
	9 June	0 (6)	0 (6)	0 (3)	0 (3)
	Total	2 (30)	0 (30)	0 (15)	1 (15)
Eastern	27 May	0 (6)	0 (6)	0 (3)	0 (3)
	30 May	1 (6)	0 (6)	0 (3)	0 (3)
	2 June	0 (6)	0 (6)	0 (3)	0 (3)
	5 June	0 (6)	0 (6)	0 (3)	0 (3)
	8 June	0 (6)	1 (6)	0 (3)	0 (3)
	Total	1 (30)	1 (30)	0 (15)	0 (15)
Total	–	3 (90)	1 (90)	0 (45)	1 (45)

unidentified petrels/shearwaters. Of the 5 petrels seen during the May–June sampling period and the 30 petrels observed during the June–July sampling period, 25 (71.4%) were flying at or below met-tower height (i.e., ≤50 m agl). Flight altitudes varied by flight direction, however: 20 (87.0%) of the 23 landward-flying petrels were flying ≤50 m agl, whereas only 5 (41.7%) of the 12 seaward-bound petrels were flying ≤50 m agl. Further, 33 (94.3%) of the 35 Hawaiian Petrels and unidentified petrels/shearwaters were flying at or below proposed turbine height (i.e., ≤125 m agl). At this high a cutoff altitude, however, flight altitudes did not differ by flight direction: 22 (95.7%) of the 23 landward-bound petrels and 11 (91.7%) of the 12 seaward-bound petrels were flying ≤125 m agl.

The mean (± SE) flight altitude of Hawaiian Petrels and unidentified petrels/shearwaters observed at all sites, times of day, and sampling periods combined was 47 ± 8 m agl (range = 5–200 m agl; *n* = 35 birds). Following the directional pattern seen above, however, the mean flight altitude of Hawaiian Petrels and unidentified petrels/shearwaters flying in a landward direction was 34 ± 9 m agl (range = 5–200 m agl; *n* = 23 birds), whereas the mean altitude of seaward-flying birds was more than 100% higher, at 71 ± 15 m agl (range = 10–175 m agl; *n* = 12 birds).

We recorded only one Hawaiian Hoary Bat during 485 audio-visual sampling sessions (i.e., a rate of 0.005 bats/h). The one bat that we recorded was seen flying towards the northwest over Garden of the Gods at an altitude of ~15 m agl. This bat appeared to be associated with a swarm of insects that had become collected near the ground in the lee of the ridge crest.

Table 8. Number of Hawaiian Petrels and unknown petrel/shearwaters observed during visual sampling on Lana'i Island, Hawai'i, in summer 2007, by study site, date, time of day, and flight direction. *n* = number of sampling sessions.

		Time of day			
		Evening (1900–2200)		Morning (0400–0600)	
Site	Date	Landward (*n*)	Seaward (*n*)	Landward (*n*)	Seaward (*n*)
Lower Ka'ena	22 June	0 (6)	0 (6)	0 (4)	0 (4)
	25 June	0 (6)	0 (6)	0 (4)	0 (4)
	29 June	0 (6)	0 (6)	0 (4)	0 (4)
	2 July	1 (6)	0 (6)	0 (4)	0 (4)
	6 July	0 (6)	0 (6)	0 (4)	0 (4)
	Total	1 (30)	0 (30)	0 (20)	0 (20)
Lower Polihua	24 June	0 (6)	0 (6)	0 (4)	0 (4)
	28 June	0 (6)	0 (6)	0 (4)	1 (4)
	1 July	0 (6)	1 (6)	0 (4)	0 (4)
	5 July	0 (6)	0 (6)	0 (4)	0 (4)
	8 July	0 (6)	0 (6)	0 (4)	0 (4)
	Total	0 (30)	1 (30)	0 (20)	1 (20)
Garden of Gods	23 June	1 (6)	0 (6)	0 (4)	0 (4)
	26 June	0 (6)	0 (6)	0 (4)	0 (4)
	30 June	1 (6)	0 (6)	0 (4)	0 (4)
	3 July	0 (6)	0 (6)	0 (4)	0 (4)
	7 July	0 (6)	0 (6)	1 (4)	0 (4)
	Total	2 (30)	0 (30)	1 (20)	0 (20)
Lower Awalua	23 June	0 (6)	0 (6)	0 (4)	0 (4)
	27 June	0 (6)	0 (6)	0 (4)	0 (4)
	30 June	1 (6)	0 (6)	1 (4)	0 (4)
	4 July	0 (6)	0 (6)	0 (4)	1 (4)
	7 July	2 (6)	0 (6)	0 (4)	1 (4)
	Total	3 (30)	0 (30)	1 (20)	2 (20)
Central	24 June	0 (6)	0 (6)	0 (4)	0 (4)
	27 June	0 (6)	1 (6)	0 (4)	0 (4)
	1 July	1 (6)	0 (6)	0 (4)	0 (4)
	4 July	3 (6)	0 (6)	1 (4)	0 (4)
	8 July	0 (6)	0 (6)	0 (4)	0 (4)
	Total	4 (30)	1 (30)	1 (20)	0 (20)
Upper Lapaiki	22 June	0 (6)	0 (6)	0 (4)	0 (4)
	26 June	0 (6)	0 (6)	0 (4)	0 (4)
	29 June	1 (6)	0 (6)	0 (4)	0 (4)
	3 July	0 (5)	0 (5)	0 (0)	0 (0)
	6 July	0 (6)	0 (6)	0 (4)	1 (4)
	Total	1 (29)	0 (29)	0 (16)	1 (16)
Lower Kuahua	21 June	1 (6)	0 (6)	0 (4)	0 (4)
	25 June	1 (6)	0 (6)	0 (4)	0 (4)
	28 June	0 (6)	0 (6)	0 (4)	0 (4)
	2 July	4 (6)	0 (6)	0 (4)	1 (4)
	5 July	1 (6)	1 (6)	0 (4)	1 (4)
	Total	7 (30)	1 (30)	0 (20)	2 (20)
Total	–	18 (209)	3 (209)	3 (136)	6 (136)

Table 9. Number of Hawaiian Hoary Bats observed during visual sampling on Lana'i Island, Hawai'i, in late spring 2007, by study site, date, and time of day. *n* = number of sampling sessions.

		Time of day	
Site	Date	Evening (1900–2200)	Morning (0400–0600)
Western	26 May	0 (6)	0 (3)
	29 May	0 (6)	0 (3)
	1 June	0 (6)	0 (3)
	4 June	0 (6)	0 (3)
	7 June	0 (6)	0 (3)
	Total	0 (30)	0 (15)
Central	28 May	0 (6)	0 (3)
	31 May	0 (6)	0 (3)
	3 June	0 (6)	0 (3)
	6 June	0 (6)	0 (3)
	9 June	0 (6)	0 (3)
	Total	0 (30)	0 (15)
Eastern	27 May	0 (6)	0 (3)
	30 May	0 (6)	0 (3)
	2 June	0 (6)	0 (3)
	5 June	0 (6)	0 (3)
	8 June	0 (6)	0 (3)
	Total	0 (30)	0 (15)
Total	–	0 (90)	0 (45)

AUDITORY SURVEYS ALONG THE ROAD SYSTEM

During the summer study period, we also conducted auditory surveys along the entire road system within the WRA to investigate the possibility that some petrels were nesting away from the main colony and within the proposed project development area. This concern was raised because of the low flight altitudes of landward-flying Hawaiian Petrels seen during audio-visual surveys (see above); such low altitudes usually are seen near nesting colonies (Cooper and Day, pers. obs.). No petrels were seen or petrel-like calls were heard on any of the 15 nights of sampling that were conducted during summer 2007 (Table 11), suggesting that no petrels were nesting within the WRA.

EXPOSURE INDICES AND FATALITY MODELING

The risk-assessment technique that we have developed involves the use of both radar data and visual data in estimating the fatality of petrels and shearwaters near structures in the Hawaiian Islands (Fig. 2). This modeling technique uses the radar data on movement rates to estimate numbers of birds flying over the area of interest (sampling sites), then expands those estimates for a 270-d year that birds are present on this island (late March through late December; J. Penniman, DOFAW, pers. comm.) and, hence, will be exposed to the proposed met towers and wind turbines. The model then uses information on the physical characteristics of the towers/turbines themselves to estimate horizontal interaction rates, uses visual flight-altitude data to estimate vertical interaction rates, and combines these estimates of interaction rates with the fatality probability to estimate

Table 10. Number of Hawaiian Hoary Bats observed during visual sampling on Lana'i Island, Hawai'i, in summer 2007, by study site, date, and time of day. n = number of sampling sessions.

Site	Date	Time of day	
		Evening (1900–2200)	Morning (0400–0600)
Lower Ka'ena	22 June	0 (6)	0 (4)
	25 June	0 (6)	0 (4)
	29 June	0 (6)	0 (4)
	2 July	0 (6)	0 (4)
	6 July	0 (6)	0 (4)
	Total	0 (30)	0 (20)
Lower Polihua	24 June	0 (6)	0 (4)
	28 June	0 (6)	0 (4)
	1 July	0 (6)	0 (4)
	5 July	0 (6)	0 (4)
	8 July	0 (6)	0 (4)
	Total	0 (30)	0 (20)
Garden of Gods	23 June	0 (6)	0 (4)
	26 June	0 (6)	0 (4)
	30 June	0 (6)	0 (4)
	3 July	1 (6)	0 (4)
	7 July	0 (6)	0 (4)
	Total	1 (30)	0 (20)
Lower Awalua	23 June	0 (6)	0 (4)
	27 June	0 (6)	0 (4)
	30 June	0 (6)	0 (4)
	4 July	0 (6)	0 (4)
	7 July	0 (6)	0 (4)
	Total	0 (30)	0 (20)
Central	24 June	0 (6)	0 (4)
	27 June	0 (6)	0 (4)
	1 July	0 (6)	0 (4)
	4 July	0 (6)	0 (4)
	8 July	0 (6)	0 (4)
	Total	0 (30)	0 (20)
Upper Lapaiki	22 June	0 (6)	0 (4)
	26 June	0 (6)	0 (4)
	29 June	0 (6)	0 (4)
	3 July	0 (5)	0 (0)
	6 July	0 (6)	0 (4)
	Total	0 (29)	0 (16)
Lower Kuahua	21 June	0 (6)	0 (4)
	25 June	0 (6)	0 (4)
	28 June	0 (6)	0 (4)
	2 July	0 (6)	0 (4)
	5 July	0 (6)	0 (4)
	Total	0 (30)	0 (20)
Total	–	1 (209)	0 (136)

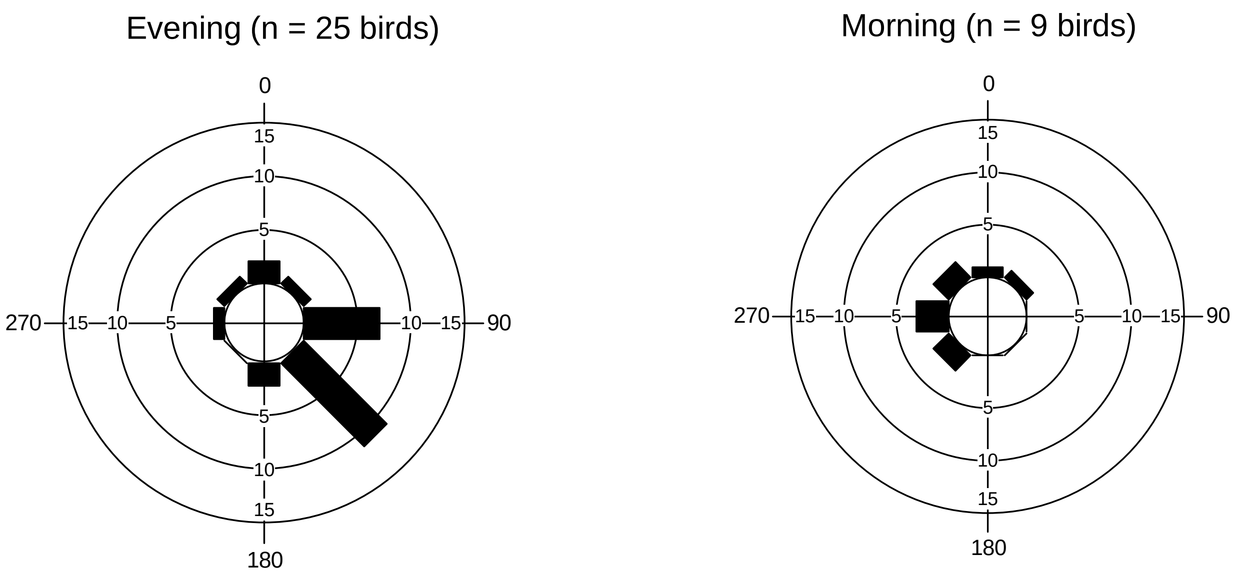

Figure 11. Flight direction of Hawaiian Petrels and unidentified shearwaters/petrels observed during visual sampling on Lana'i Island, Hawai'i, late spring and summer 2007, by time of day. Length of spoke is proportional to the number of birds traveling in that direction.

Table 11. Sampling effort and number of Hawaiian Petrels detected on acoustic surveys during late spring 2007.

Road system	No. sampling points	No. point visits	No. petrel calls
Ka'ena	7	21	0
Polihua	7 [1]	20	0
Road #7	4	8	0
Kanepu'u	6	16	0
Awalua	6	15	0
Lapaiki	8	22	0
Kahua	6	18	0
Kuahua	7	20	0

[1]One of the seven sampling points was dropped after the first visit.

fatality rates under a worst-case scenario of no collision avoidance. Finally, it presents possible levels of fatality based on possible levels of collision avoidance by these birds.

We analyzed the data separately for each of the seven radar sampling sites that we sampled in summer (late June–early July) 2007 (Fig. 1) and constructed fatality estimates for any proposed met towers or wind turbines that will be associated with each site. We tabulated all data from Lana'i on minimal flight altitudes of petrels recorded during the visual sampling and used those data for the vertical-interaction component of our fatality model. Of the 4 petrels seen during the May–June sampling period and the 31 petrels seen during the June–July sampling period, 20 (87.0%) of the 23 landward-flying petrels and 5 (41.7%) of the 12 seaward-flying petrels were flying ≤50 m agl. Further, 22 (95.7%) of the 23 landward-flying petrels and 11 (91.7%) of the 12 seaward-flying petrels were flying ≤125 m agl. We used the midpoints of the landward and seaward percentages (i.e., 64.4% and 93.7% for proposed met towers and wind turbines, respectively) in our fatality models because we assumed that there would be approximately equal numbers of landward and seaward targets passing over a location on any given night.

MOVEMENT RATE

The movement rate is an estimate of the average number of birds passing in the vicinity of the proposed towers/turbines in a day, as indicated by what is seen on the radar screen. It is generated from the radar data by: (1) multiplying the average evening landward and morning seaward movement rates by 3 h to estimate the number of targets moving over the radar site in those first and last 3 h of the night; (2) multiplying the sum of those evening landward counts and morning seaward counts by the quantity (1 + the proportion [12.6%] of targets that move during the rest of the night [= 1.126]) to account for movement during the middle of the night (Tables 6 and 12), following Day and Cooper (1995, unpubl. data); (3) adding the evening seaward counts and morning landward counts to the previous number of targets to get the total number of probable Hawaiian Petrel targets passing within 1.5 km of each site in a night; and (4) multiplying that total number of targets/night by the mean number of petrels/target to generate an estimate of the number of petrels passing in the vicinity of the proposed tower/turbine during an average night (Table 12).

Because we did not have all-night radar data available for Lanai, we used data from all-night sampling sessions on Kaua'i (Day and Cooper 1995) to determine that ~87% of the entire night's movement occurs during the evening and morning landward and seaward peaks, respectively (Day and Cooper, unpubl. data). We believe that all of the radar targets seen during this study were those of Hawaiian Petrels; certainly, all of the targets identified to species were petrels, and all birds definitely identified to species visually were petrels. The estimate of mean flock size for Hawaiian Petrel targets (1.05 ± SE 0.01 birds/target) is calculated from all visual data on this species on Kaua'i, Lana'i, Maui, and Hawai'i combined between 1992 and 2007 (n = 810 observations; Day and Cooper, unpubl. data). We then multiplied this estimate of nightly movement by 270 d (April–December) to generate an estimate of movement over each site during an entire breeding season.

Although we had to base this model of annual fatality on movement rates from the one study period, mean nightly movement rates are known to differ seasonally. For example, because movement rates tend to decrease from summer to fall (Day and Cooper 1995), the use of movement rates from only the summer will tend to overestimate annual interaction and fatality rates, whereas the use of movement rates from only the fall will tend to underestimate annual interaction and fatality rates. At this point, we are unclear exactly what movement rates in spring (April) will be, but State of Hawaii DOFAW personnel believe that that might be the season when the most birds are present at the Lana'ihale colony (J. Penniman, DOFAW, pers. comm.).

Because the resulting estimate of the number of birds/yr is not an integer, we then round it upward to the next whole number to generate an estimate of the average number of birds passing within 1.5 km of the radar site during a year. This rounding technique results in slightly-inflated fatality estimates, but we are being conservative about the fatality of an endangered species.

Table 12. Estimates of mean numbers of probable Hawaiian Petrel targets/night flying over radar-sampling sites on Lana'i Island, Hawai'i, in late spring and summer 2007, by season, radar-sampling site, time of day, and flight direction.

	Time of day				
	Evening (1900–2200)		Morning (0400–0600)		
Sampling period/study site	Mean landward movement (targets)	Mean seaward movement (targets)	Mean landward movement (targets)	Mean seaward movement (targets)	Mean nightly movement (targets)[1]
LATE SPRING					
Western	0.72	5.76	0.00	4.80	11.97552
Central	1.98	10.44	0.00	11.04	25.10052
Eastern	5.76	7.68	0.00	2.88	17.40864
Mean	2.82	7.96	0.00	6.24	18.16156
SUMMER					
Lower Ka'ena	0.00	1.44	0.00	1.80	3.46680
Lower Polihua	1.44	4.80	0.00	5.76	12.90720
Garden of Gods	0.24	7.95	0.00	3.24	11.86848
Lower Awalua	1.44	8.40	0.36	9.72	21.32616
Central	2.16	8.16	0.00	14.49	26.90790
Upper Lapaiki	3.24	6.207	0.00	4.41	15.08776
Lower Kuahua	10.68	10.68	0.36	14.76	39.68206
Mean	2.78	6.81	0.10	7.74	18.74948

[1] This value = ((mean landward evening movement + mean seaward morning movement) × 1.126) + mean seaward evening movement + mean landward morning movement.

INTERACTION PROBABILITIES

We have separated the interaction probability into horizontal and vertical components to make its estimation more tractable. The horizontal interaction probability is the probability that a bird seen on radar will pass through or over the airspace occupied by a proposed met tower or proposed turbine located somewhere on the radar screen. This probability is calculated from information on the two-dimensional area (side view) of the proposed tower/turbine and the two-dimensional area sampled by the radar screen to determine the interaction probability. The proposed met-tower system has a central tower with four sets of guy wires attached at five heights; hence, the tower/guy-wire system appears from the side to be an isosceles triangle 50 m high with a base of 67 m and a mean width of 33.5 m (Table 13). The proposed wind turbines have 80-m monopole towers and 45-m-long blades. Two calculations of area were made for turbines because of the huge differences in area of the structure that depended on the orientation when approaching it: a minimal area occupied by each proposed turbine if a bird approaches it from the side (i.e., side profile) and a maximal area occupied by each turbine if a bird approaches it from the front (i.e., front profile, including the rotor-swept area; Table 14). The ensuing ratio of cross-sectional area of the proposed tower/turbine to the cross-sectional area sampled by the radar indicates the probability of interacting with (i.e., flying over or through the airspace occupied by) the proposed tower or turbine. Because the dimensions of the proposed towers/turbines will not differ among sampling periods, estimates of horizontal interaction probabilities will be identical during all sampling periods.

The vertical interaction probability is the probability that a bird seen on radar will be flying at an altitude low enough that it might pass through the airspace occupied by a proposed tower/turbine located somewhere on the radar screen. This probability is calculated from visual data on flight altitudes and from information on the proposed towers' and turbines' heights. Because we do not have sufficient data to determine whether flight altitudes differ seasonally, we assume here that they do not vary; hence, estimates of vertical interaction probabilities will be identical during all seasons.

EXPOSURE RATE

The exposure rate is calculated as the product of the preceding three variables (annual movement rate, horizontal interaction probability, vertical interaction probability). As such, it is an estimate of the number of birds flying in the vicinity of the proposed tower/turbine (i.e., crossing the radar screen) that could fly in a horizontal location and that could fly at a low enough altitude that they could interact with the tower/turbine. Because movement rates vary among sampling periods, estimates of annual exposure rates also will vary seasonally, as described above; however, in this case, we are estimating annual rates based only based on summer (June–July) data.

FATALITY PROBABILITY

Not all birds possibly interacting with the proposed tower/turbine might be killed by it (e.g., some birds might just brush towers or guy wires with their wingtips and fly away uninjured), necessitating the estimation of the fatality probability. Factors that affect tower fatality probability include whether the tower is a solid monopole or a lattice-type tower, whether the tower is free-standing or guyed, and, if it is a lattice-type tower, the size of the lattice interstices (large free-standing lattice towers will have frameworks with openings several meters wide for birds to pass through safely, whereas towers with small lattices and multiple guy wires effectively are solid objects). Factors that affect wind-turbine fatality probability include the speed and orientation of the bird relative to the rotational speed and orientation (side view or front view) of the turbine blades.

The estimate of fatality probability is derived as the product of (1) the probability of colliding with the proposed tower or its guy wires/the proposed turbine if the bird enters the airspace occupied by either of these structures and (2) the probability of dying if it hits either the tower frame/guy wires or the turbine. The former probability is needed because the above estimates of horizontal interaction probability are calculated as if the proposed tower and its guy wires/turbine are one solid structure, as described above. In the

Table 13. Estimated met tower exposure indices and fatality indices of Hawaiian Petrels (HAPE) at each site on Lana'i Island, Hawai'i, based on radar data collected in late June–early July 2007 and flight-altitude data from Lana'i Island during May–July 2007. Values of particular importance are in boxes.

Variable/parameter	Radar-sampling site (met-tower number): Lower Ka'ena (6)	Lower Polihua (5)	Garden of Gods (4)	Lower Awalua (3)	Central (2)	Upper Lapaiki (1)	Lower Kuahua (7)
MOVEMENT RATE (MVR)							
A) Movement rate (petrel targets/night)	3.46680	12.90720	11.86848	21.32616	26.90790	15.08776	39.68206
B) Mean number of HAPE/target	1.05	1.05	1.05	1.05	1.05	1.05	1.05
C) Daily movement rate (HAPE/day =B*C)	3.64	13.55	12.46	22.39	28.25	15.84	41.67
D) Fatality domain (days/year)	270	270	270	270	270	270	270
E) Annual movement rate (HAPE/year; =C*D, rounded to next whole number)	983	3,660	3,365	6,046	7,629	4,278	11,250
HORIZONTAL INTERACTION PROBABILITY (IPH)							
F) Maximal cross-sectional area of tower and guys (side view = ((33.5m * 50 m)/2)*2 = 1675 m²	1,675.0	1,675.0	1,675.0	1,675.0	1,675.0	1,675.0	1,675.0
G) Cross-sectional sampling area of radar at or below 50 m tower height (= 3000 m * 50 m = 15,000 m²)	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000
H) Horizontal interaction probability (= F/G, rounded to 8 decimal places)	0.01116667	0.01116667	0.01116667	0.01116667	0.01116667	0.01116667	0.01116667
VERTICAL INTERACTION PROBABILITY (IPV)							
I) Vertical interaction probability (proportion petrels flying ≤ tower height; rounded to 8 decimal places)	0.64350000	0.64350000	0.64350000	0.64350000	0.64350000	0.64350000	0.64350000
EXPOSURE RATE (ER; = MVR * IPH * IPV)							
J) Daily exposure rate (HAPE/day = C*H*I, rounded to 8 decimal places)	0.02615714	0.09738531	0.08954813	0.16090668	0.20302111	0.11383771	0.29940263
K) Annual exposure rate (HAPE/year = E*H*I, rounded to 8 decimal places)	7.06359225	26.29984500	24.18004875	43.44504450	54.82008675	30.74063850	80.83968750

Table 13. Continued.

Variable/parameter	Radar-sampling site (met-tower number)						
	Lower Ka'ena (6)	Lower Polihua (5)	Garden of Gods (4)	Lower Awalua (3)	Central (2)	Upper Lapaiki (1)	Lower Kuahua (7)
FATALITY PROBABILITY (MP)							
L) Probability of striking tower or guys if in airspace	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M) Probability of fatality if striking tower or guys	0.95	0.95	0.95	0.95	0.95	0.95	0.95
N) Probability of fatality if an interaction (= L*M, rounded to 5 decimal places)	0.95000	0.95000	0.95000	0.95000	0.95000	0.95000	0.95000
ANNUAL FATALITY RATE (= IR * MP)							
O) Annual fatality rate with 0% exhibiting collision avoidance (HAPE/tower/year = K*N, rounded to 5 decimal places)	6.71041	24.98485	22.97105	41.27279	52.07908	29.20361	76.79770
P) Annual fatality rate with 50% exhibiting collision avoidance (HAPE/tower/year = K*N*0.5)	3.35521	12.49243	11.48553	20.63640	26.03954	14.60181	38.39885
Q) Annual fatality rate with 95% exhibiting collision avoidance (HAPE/tower/year = K*N*0.05)	0.33552	1.24924	1.14855	2.06364	2.60395	1.46018	3.83989
R) Annual fatality rate with 99% exhibiting collision avoidance (HAPE/tower/year = K*N*0.01)	0.06710	0.24985	0.22971	0.41273	0.52079	0.29204	0.76798

Table 14. Estimated turbine exposure indices and fatality indices of Hawaiian Petrels (HAPE) at each site on Lana'i Island, Hawai'i, based on radar data collected in late June–early July 2007 and flight-altitude data from Lana'i Island during May–July 2007. Values of particular importance are in boxes.

	Radar-sampling site (met-tower number)						
Variable/parameter	Lower Ka'ena (6)	Lower Polihua (5)	Garden of Gods (4)	Lower Awalua (3)	Central (2)	Upper Lapaiki (1)	Lower Kuahua (7)
MOVEMENT RATE (MVR)							
A) Movement rate (petrel targets/night)	3.46680	12.90720	11.86848	21.32616	26.90790	15.08776	39.68206
B) Mean number of HAPE/target	1.05	1.05	1.05	1.05	1.05	1.05	1.05
C) Daily movement rate (HAPE/day =B*C)	3.64	13.55	12.46	22.39	28.25	15.84	41.67
D) Fatality domain (days/year)	270	270	270	270	270	270	270
E) Annual movement rate (HAPE/year; =C*D, rounded to next whole number)	983	3,660	3,365	6,046	7,629	4,278	11,250
HORIZONTAL INTERACTION PROBABILITY (IPH)							
F) Turbine height (m)	125	125	125	125	125	125	125
G) Blade radius (m)	45	45	45	45	45	45	45
H) Height below blade (m)	35	35	35	35	35	35	35
I) Front to back width (m)	6	6	6	6	6	6	6
J) Min side profile area (m^2) = (A x D)	750	750	750	750	750	750	750
K) Max front profile area (m^2) = (C x D) + (p x B^2)	6,572	6,572	6,572	6,572	6,572	6,572	6,572
L) Cross-sectional sampling area of radar at or below 50 m tower height (= 3000 m * 50 m = 150,000 m^2)	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000	150,000.000
M) Minimal horizontal interaction probability (= J/L)	0.00500000	0.00500000	0.00500000	0.00500000	0.00500000	0.00500000	0.00500000
N) Maximal horizontal interaction probability (= K/L)	0.04381160	0.04381160	0.04381160	0.04381160	0.04381160	0.04381160	0.04381160
VERTICAL INTERACTION PROBABILITY (IPV)							
O) Vertical interaction probability (proportion petrels flying ≤ turbine height)	0.93700000	0.93700000	0.93700000	0.93700000	0.93700000	0.93700000	0.93700000
EXPOSURE RATE (ER; = MVR * IPH * IPV)							
P) Daily minimal exposure rate (HAPE/day = C*M*O)	0.01705406	0.06349374	0.05838402	0.10490871	0.13236669	0.07422046	0.19520597
Q) Daily maximal exposure rate (HAPE/day = C*N*O)	0.14943310	0.55635250	0.51157947	0.91924371	1.15983927	0.65034345	1.71045721
R) Annual minimal exposure rate (HAPE/year = E*M*O)	4.60535500	17.14710000	15.76502500	28.32551000	35.74186500	20.04243000	52.70625000
S) Annual maximal exposure rate (HAPE/year = E*N*O)	40.35359422	150.2483772	138.1381938	248.1971827	313.1816585	175.61818524	461.8290285

Table 14. Continued.

Variable/parameter	Radar-sampling site (met-tower number) Lower Ka'ena (6)	Lower Polihua (5)	Garden of Gods (4)	Lower Awalua (3)	Central (2)	Upper Lapaiki (1)	Lpwer Kuahua (7)
FATALITY PROBABILITY (MP)							
T) Probability of striking turbine if in airspace on a side approach	1.00	1.00	1.00	1.00	1.00	1.00	1.00
U) Probability of striking turbine if in airspace on frontal approach	0.14	0.14	0.14	0.14	0.14	0.14	0.14
V) Probability of fatality if striking turbine	0.95	0.95	0.95	0.95	0.95	0.95	0.95
W) Probability of fatality if an interaction on side approach (= T*V)	0.95000	0.95000	0.95000	0.95000	0.95000	0.95000	0.95000
X) Probability of fatality if an interaction on frontal approach (= U*V)	0.13585	0.13585	0.13585	0.13585	0.13585	0.13585	0.13585
ANNUAL FATALITY RATE (= IR * MP)							
Minimal annual fatality rate with 0% exhibiting collision avoidance (HAPE/turbine/year = R*W)	1.75003	6.51590	5.99071	10.76369	13.58191	7.61612	20.02838
Maximal annual fatality rate with 0% exhibiting collision avoidance (HAPE/turbine/year = S*X)	2.19281	8.16450	7.50643	13.48703	17.01829	9.54309	25.09579
Minimal annual fatality rate with 50% exhibiting collision avoidance (HAPE/turbine/year = R*W*0.5)	0.87502	3.25795	2.99536	5.38185	6.79096	3.80806	10.01419
Meximal annual fatality rate with 50% exhibiting collision avoidance (HAPE/turbine/year = S*X*0.5)	1.09641	4.08225	3.75322	6.74352	8.50915	4.77155	12.54790
Minimal annual fatality rate with 95% exhibiting collision avoidance (HAPE/turbine/year = R*W*0.05)	0.08750	0.32580	0.29954	0.53818	0.67910	0.38081	1.00142
Maximal annual fatality rate with 95% exhibiting collision avoidance (HAPE/turbine/year = S*X*0.05)	0.10964	0.40823	0.37532	0.67435	0.85091	0.47715	1.25479
Minimal annual fatality rate with 99% exhibiting collision avoidance (HAPE/turbine/year = R*W*0.01)	0.01750	0.06516	0.05991	0.10764	0.13582	0.07616	0.20028
Maximal annual fatality rate with 99% exhibiting collision avoidance (HAPE/turbine/year = S*X*0.01)	0.02193	0.08165	0.07506	0.13487	0.17018	0.09543	0.25096

proposed met-tower design, the tower frame is a solid monopole, and the four sets of guy wires at five heights each occupy a substantial proportion of the total cone of airspace enclosed by the tower and guy wires, making it a low probability that a bird could fly though the space occupied by this tower without hitting some part of it. Hence, we estimated the probability of hitting the tower or guy wires if the bird enters the airspace at 100%. We consider this probability to be a worst-case scenario for this tower and guy-wire layout, both because of this assumption of hitting some part of the structure and because we assume that there is no behavioral avoidance of the structure by these birds (but see below).

Similarly, a bird approaching a turbine from the side has essentially a 100% probability of getting hit by a blade; in contrast, a bird approaching from the back or front has only a 14.9% probability of hitting a blade. This calculation for the "frontal" bird approach was based on the length of a petrel (43 cm; Simons and Hodges 1998); the average groundspeed of petrels on Lana'i (mean velocity = 48.5 ± 0.4 mi/h; n = 597 probable petrel targets); and the time that it would take a 43-cm-long petrel to travel completely through a 2-m-wide turbine blade spinning at its maximal rotor speed (19 revolutions/min); also see Tucker (1996). Thus, these calculations indicated that 14.9% of the disk of the rotor-swept area would be occupied by a blade sometime during the length of time (i.e., 0.0017 min) that it would take a petrel to fly completely past a rotor blade (i.e., to fly 2.43 m). Again, this probability is a worst-case scenario that assumes no avoidance behavior.

Finally, a bird hitting either the proposed met-tower frame or guy wire or the proposed wind turbine will have a high probability of actually dying unless it just brushes the structure with a wingtip; therefore, we used an estimate of 95% for that parameter. Hence, the overall fatality probability of a bird entering the airspace occupied by a proposed met tower is high and is estimated at 95% (i.e., 1.00 [= probability of colliding with the structure] × 0.95 [= probability of dying if colliding]). The overall fatality probability of a bird entering the airspace occupied by a proposed turbine is estimated at 95% (i.e., 1.00 × 0.95) for a side approach and 14.3% (i.e., 0.149 × 0.95) for a frontal approach. Because these probability estimates do not differ among sampling periods, this estimate of fatality probability will be identical among sampling periods.

FATALITY RATE

The annual fatality rate is calculated as the product of the exposure rate (i.e., the number of birds that might fly in the airspace occupied by the proposed met tower/guy wires or the proposed wind turbine) and the fatality probability (i.e., the probability of collision with a portion of the structure and dying while in the airspace). It is generated as an estimate of the number of birds killed/year as a result of the tower/turbine, based on a 270-d breeding season. Because movement rates vary seasonally (i.e., among sampling periods), fatality rates also will. Again, however, we present annual estimates here based on only on summer data.

The major variables involved in this fatality estimation are presented in Figure 2. The individual steps and estimates involved in these calculations are shown in Table 13 for proposed met towers and Table 14 for proposed wind turbines. Based on data from summer 2007, we estimate annual movement rates of ~983, ~3,660, ~3,365, ~6,046, ~7,629, ~4,278 and ~11,250 Hawaiian Petrels within 1.5 km of the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites, respectively (Tables 13 and 14). Thus, there is a gradation of increasing bird numbers from west to east in the proposed windfarm (also see Figs. 3 and 4). Based on flight-altitude data from Lana'i., we estimate that, on average, 64% of the birds flying through the WRA are flying at altitudes low enough to interact with the proposed met towers (i.e., ≤50 m agl) and that 94% fly at altitudes low enough to interact with the proposed turbines (i.e., ≤125 m agl). Based on these altitudes, the estimated annual movement rates, and the horizontal interaction probability, annual fatality rates at proposed met towers are estimated to be 6.7, 25.0, 23.0, 41.3, 52.1, 29.2, and 76.8 Hawaiian Petrels/tower near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and

Lower Kuahua radar sites, respectively, assuming that no collision-avoidance behavior occurs (Table 13). Based on these altitudes, the estimated annual movement rates, and the horizontal interaction probabilities, annual fatality rates at proposed wind turbines are estimated to be 1.8–2.2, 6.5–8.2, 6.0–7.5, 10.8–13.5, 13.6–17.0, 7.6–9.5, and 20.0–25.1 Hawaiian Petrels/turbine near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites, respectively, assuming that no collision-avoidance behavior occurs (Table 14). Fatality rates for proposed wind turbines are presented as ranges because of differential risks associated with side and frontal views of the turbines, as described above.

EFFECTS OF COLLISION AVOIDANCE ON ESTIMATES

We emphasize here that these fatality estimates assume a worst-case scenario in which there is no collision-avoidance behavior by Hawaiian Petrels. Because these birds mostly move during periods of daylight or twilight (Day and Cooper 1995, unpubl. data), however, it is likely that many will be able to see and avoid met towers/guy wires and wind turbines. Similarly, avoidance rates for nocturnally-moving Hawaiian Petrels should be high during periods when the moon is fairly full and visible. Consequently, we have recalculated estimated annual fatality rates for each site and flight-altitude scenario by assuming that 0%, 50%, 95%, or 99% of all Hawaiian Petrels flying near a met tower will see and avoid it. Based on these assumptions about possible collision-avoidance rates, annual fatality rates for proposed met towers are estimated to be 0.1–6.7, 0.3–25.0, 0.2–23.0, 0.4–41.3, 0.5–52.1, 0.3–29.2, and 0.8–76.8 Hawaiian Petrels/tower near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites, respectively (Table 13). Based on the same set of assumptions about possible avoidance rates, annual fatality rates for proposed wind turbines are estimated to be 0.02–2.2, 0.1–8.2, 0.1–7.5, 0.1–13.5, 0.1–17.0, 0.1–9.5, and 0.2–25.1 Hawaiian Petrels/turbine near the Lower Ka'ena, Lower Polihua, Garden of the Gods, Lower Awalua, Central, Upper Lapaiki, and Lower Kuahua radar sites, respectively (Table 14). We caution again, however, that these assumptions for avoidance rates are not based on empirical data.

DISCUSSION

PETRELS AND SHEARWATERS

SPECIES COMPOSITION

Our visual data suggest that all of the radar targets that we observed with the radar on Lana'i in 2007 were Hawaiian Petrels. Of the 33 tubenoses seen during visual sampling and identified to species, all were identified as Hawaiian Petrels, so we assume that the 2 unidentified petrels/shearwaters also were petrels. Thus, there was no indication from the visual data that Newell's Shearwaters also flew over the area. In addition, other researchers on Lana'i consider Newell's Shearwaters to be extremely rare and are not even convinced that the species nests there (J. Penniman, DOFAW, pers. comm.).

We have suggested previously that Hawaiian Petrels on other islands (Kaua'i, Maui, and Hawai'i) fly into nesting areas earlier in the evening than Newell's Shearwaters do (Cooper and Day 2003; Day et al. 2003a, 2003b). Consequently, we have suggested that radar targets observed after ~30 min past sunset (i.e., at about the point of complete darkness) are predominantly Newell's Shearwaters. Clearly, this is not the case on Lana'i, where there are many Hawaiian Petrels flying into colonies well after the point of complete darkness. On the other hand, our studies from the other islands emphasized coastal sampling, whereas the Lana'i work (this study) and recent research on Maui (Day et al. 2005a, Day and A. Gall, unpubl. data) have occurred inland; in the three latter studies, Hawaiian Petrels were recorded flying primarily after dark, apparently reflecting the time it takes for these birds to fly from the coast to the colonies.

MOVEMENT RATES

Our sampling dates occurred during the incubation period (i.e., the May–June observations) and late-incubation/early chick-rearing period (i.e., the June–July observations) of Hawaiian Petrels (Simons and Hodges 1998; J.

Penniman, DOFAW, pers. comm.). During the summer period, breeding adults, nonbreeding adults, and subadults are visiting the colonies (Simons 1985, Simons and Hodges 1998). The average incubation shift is 16.5 d for Hawaiian Petrels (Simons 1985), so a breeding adult visits the nesting colony every 16–17 d, on average. Further, it is doubtful that all nonbreeding adults and subadults visit the colonies every night. Hence, the mean radar movement rates that we have presented here represent far less than the actual number of birds visiting the colony.

Overall mean movement rates (landward + seaward) on radar recorded on Lana'i tended to be much lower than were rates recorded during radar studies on Kaua'i and East Maui and were slightly lower than rates on West Maui; however, movement rates recorded on Lana'i were similar to rates recorded on Hawai'i (Table 15). Our data from Lana'i also indicate that there are fewer petrels flying over the western portion of the Lana'i WRA than over the central and eastern parts of it. This finding makes sense, given that it is the portion of the WRA that is farthest from the Lana'ihale colony. In fact, mean movement rates in the western portion of the WRA were lower than rates recorded at nearly all other locations that have ever been studied in the Hawaiian Islands (Cooper and Day 2003; Day et al. 2003a, 2003b, Day and Cooper, unpubl. data). Mean overall (i.e., landward + seaward) movement rates near the recently-installed Met Tower 6 in the western end of the study area were ~0.5 targets/h, which is even lower than mean movement rates at the recently-built Kaheawa Wind Park on Maui (1.0–1.2 targets/h; Day and Cooper 1999, Cooper and Day 2004a).

The typical movement pattern for Hawaiian Petrels and Newell's Shearwaters on the way to and from nesting colonies is a pattern of substantial landward movement toward the colonies for ~2 h after sunset, followed by low levels of landward and seaward movement during the middle of the night, followed by a substantial seaward departure from the colonies for 1–2 h prior to sunrise (Day and Cooper 1995, Cooper and Day 2003, Day et al. 2003a). This pattern also fits fairly well with what is known about the timing of vocalizations near the colonies and the timing of nest exchanges (Simons and Hodges 1998). Surprisingly, it appears that the movement pattern on Lana'i may be different from what has been seen on other islands. On Lana'i, the pattern that we observed was that seaward rates always were higher than landward rates, even in the evening; however, seaward rates were as high or higher in the morning than in the evening at most sites, similar to what we have seen on other islands. Seaward rates were as high or higher in the evening than in the morning at only two of seven sites, and those shared similar geographical (farthest inland) and geomorphological (along the east–west ridge) characteristics.

Until more data are collected, we hesitate to speculate extensively on the reasons for the early

Table 15. Mean movement rates (targets/h) of probable Hawaiian Petrel targets observed during radar studies on Lana'i, Kaua'i, East Maui, West Maui, and Hawai'i islands during 2001–2007.

Island	Year	Movement rate (targets/h)[1] Mean	Range	No. sites sampled	Source
Lana'i	2007	2.9	0.5–7.1	9	this study
Kaua'i[2]	2001	118	8–569	13	Day et al. (2003b)
East Maui	2001	53	3.6–134	8	Cooper and Day (2003)
West Maui[2]	2001	8.7	0.4–21	6	Cooper and Day (2003)
Hawai'i[2]	2001–2002	2.5	0–25.8	18	Day et al. (2003a)

[1]All rates are total movement rates (i.e., landward + seaward).
[2]Definitely or probably includes Newell's Shearwaters.

seaward movements over the Lana'i study area, but these movements could be related to differences in landward and seaward flight paths into and out of the Lana'ihale colony. For instance, if most birds flew into the colony from the closest shorelines (as seems to be the case on the other islands; Cooper and Day, unpubl. data) but dispersed seaward in a variety of directions (clearly seen on Lana'i), one would expect a pattern of higher seaward movements like those we saw during both late spring and summer 2007. On the other hand, perhaps landward-flying targets flew inland at rates similar to seaward ones throughout the study area but flew at altitudes lower than seaward-flying ones did, making them less likely to be detected by radar; however, that alternative explanation does not explain the extensive seaward movements that we observed in the evening. Radar observations of birds around the perimeter of the island near the colony and, to some extent, around the rest of the island, could be used to answer these questions and to determine better the movement patterns between the inland colony and marine foraging areas. Such a study also could be used to help determine approximate colony size and to determine the proportion of landward and seaward movements that were from/toward the proposed WRA.

FLIGHT ALTITUDES

The mean flight altitude of Hawaiian Petrels and unidentified petrels/shearwaters recorded at all sites and during all times of day and sampling periods was 47 m agl. Further, the mean landward flight altitude of these birds was much lower (34 m agl) than was the mean seaward flight altitude (71 m agl). Thus, mean flight altitudes (especially landward ones) tend to be much lower than the average seen elsewhere in Hawaii: the mean flight of Hawaiian Petrels on Kaua'i, Maui, and Hawai'i combined is 200 m agl (range = 2–1,000 m agl; n = 696 birds; Day and Cooper, unpubl. data). It is possible that the lower flight altitudes on Lana'i could be related to the moderate, gently-sloping terrain between the coast and the low-elevation colony on Lana'ihale and/or to the low-elevation location of the colony itself: these birds nest at much higher elevations on all other islands, so birds there probably have to fly higher because they have a greater climb to the colonies. Another factor that may cause these lower flight altitudes for birds flying inland is the fact that those birds crossing the WRA are flying primarily into a headwind or a quartering headwind, so perhaps they are flying low because they are trying to get down into the boundary layer to reduce the effects of the headwind.

HAWAIIAN BATS

We recorded only one Hawaiian Hoary Bat during 485 sampling sessions. Thus, our data indicate that bats were present in the proposed WRA but occurred there in very low densities during the study period. Hoary Bats are known to occur on all of the Main Hawaiian Islands, including Lana'i (Baldwin 1950, van Riper and van Riper 1982, Tomich 1986, Fullard 1989, Kepler and Scott 1990, Hawaii Heritage Program 1991, David 2002), so our record is not unexpected. More extensive visual and/or acoustic work could be done to provide better information on the distribution and abundance of bats in the WRA, but our data from this study so far suggest that bat numbers will be low.

EXPOSURE INDICES AND FATALITY MODELING

We estimate that ~8–81 Hawaiian Petrels/yr (i.e., exposure rate) will fly within the space occupied by each proposed met tower in the study area and that 5–462 Hawaiian Petrels/yr will fly within the space occupied by each proposed wind turbine in the study area, based on movement-rate data collected during the late June–early July period. We used these estimated exposure rates as a starting point for developing a complete avian risk assessment; however, we emphasize that it currently is unknown whether bird use and fatality at windfarms are strongly correlated. For example, Cooper and Day (1998) found no relationship between movement rates and fatality rates of Hawaiian Petrels and Newell's Shearwaters at powerlines on Kaua'i. Other factors (e.g., weather) could be more highly correlated with fatality rates than is bird abundance. To determine which factors are most relevant, studies such as those that collect concurrent data on movement rates, weather, and fatality rates would be needed to begin to determine whether movement rates and/or weather conditions can be used to predict the likelihood of petrel fatalities at these proposed met towers and the proposed windfarm.

In addition to these questions about the unknown relationships among fatality, weather, and abundance, there also are no hard data available on the proportion of petrels and shearwaters that do not collide with towers or turbines because of collision-avoidance behavior (i.e., birds that alter their flight paths and/or flight altitudes to avoid colliding with these structures); however, see Winkelman (1995), Desholm and Kahlert (2005), and Desholm et al. (2006) for studies of avoidance of wind turbines by waterbirds in Europe. Clearly, the detection of met towers/turbines could alter movement rates, flight paths, and/or flight altitudes of these birds, which, in turn, would reduce the likelihood of collision. In addition, there could be differences among species in their ability to avoid obstacles. For example, Cooper and Day (1998) believed that Hawaiian Petrels have flight characteristics that make them more maneuverable at avoiding powerlines than do Newell’s Shearwaters, suggesting that this greater maneuverability also might increase their ability at avoiding towers or turbines.

There is evidence that many species of birds do detect and avoid wind turbines in low-light conditions (Dirksen et al. 1998, Winkelman 1995, Desholm and Kahlert 2005, Desholm et al. 2006), but no petrel-specific data on avoidance of met towers or wind turbines is available. For example, seaducks in Europe have been found to detect and avoid wind turbines >95% of the time (Desholm 2006). Further, natural anti-collision behavior (especially alteration of flight paths) is seen in migrating Common and King eiders (*Somateria mollissima* and *S. fischeri*) approaching human-made structures in the Beaufort Sea off of Alaska (Day et al. 2005b) and in diving ducks approaching offshore windfarms in Europe (Dirksen et al. 1998). Collision-avoidance rates around wind turbines are high for Common Eiders in the daytime (Desholm and Kahlert 2005), gulls (*Larus* spp.) in the daytime (>99%; Painter et al. 1999, cited in Chamberlain et al. 2006), Golden Eagles (*Aquila chrysaetos*) in the daytime (>99%; Madders 2004, cited in Chamberlain et al. 2006), American Kestrels (*Falco sparverius*) in the daytime (87%, Whitfield and Band [in prep.], cited in Chamberlain et al. 2005), and passerines during both the day and night (>99%; Winkelman 1992, cited in Chamberlain et al. 2006). Further, Erickson et al. (2002) suggested that the proportion of nocturnal migrants that detect and avoid turbines must be very high because fatality rates of nocturnal migrants appear “insignificant” relative to nocturnal passage rates of migrating birds. Although Hawaiian Petrels have flight characteristics very different from those of these other species, they are adept at flying through forests near their nests during low-light conditions; hence, it is reasonable to assume that they too have enough visual acuity and maneuverability to help avoid met towers and wind turbines if they see them. Thus, while we agree with others (Chamberlain et al. 2006, Fox et al. 2006) that species-specific and site-specific data are needed in models to estimate fatality rates accurately, we speculate that a high proportion of petrels would detect and avoid large structures under average conditions of weather and visibility. Until petrel-specific data on the relationship between exposure and fatality rates are available, however, we provide a range of assumptions for this variable in our fatality models.

To err on the conservative side, we used a wide range of assumptions about the proportion of petrels and shearwaters that would detect and avoid the proposed met towers (i.e., 0%, 50%, 95%, and 99%) and estimated an annual take of ~7–77 Hawaiian Petrels/tower if 0% of them detect and avoid the met towers; 4–39 if 50% of them detect and avoid the met towers; 1–4 if 95% of them detect and avoid the met towers; and ≤1 if 99% of them detect and avoid the met towers. Obviously, there is a wide range in fatality estimates within each location, but one will be able to refine these estimates only with further research on avoidance behavior at met towers and on the proportion of petrels and shearwaters able to fly close to the met towers without being killed or injured.

Although the actual avoidance rate of wind turbines by petrels is unknown at this time, recent data from the Kaheawa Wind Plant on Maui Island suggests that it is high. After ~1 yr of operation, the recorded (but uncorrected for sampling bias) petrel mortality rate at that 20-turbine windfarm has been 1 Hawaiian Petrel (B. Standley, USFWS, pers.

comm.). Cooper and Day (2004b) modeled seabird fatality for the KWP based on movement rates from radar studies there (Day and Cooper 1999, Cooper and Day 2004a) and estimated that the combined annual fatality of Hawaiian Petrels and Newell's Shearwaters at that site would be ~3–18 birds/yr with a 50% avoidance rate, ~1–2 birds/yr with a 95% avoidance rate, and <1 bird/yr with a 99% avoidance rate. Thus, this data set from 1 yr of operation suggests that the true avoidance rate of petrels around wind turbines is ~95%.

There are several factors that could affect our estimates of exposure and fatality, some in a positive direction and some in a negative direction. One factor that would have increased these estimates was the inclusion of targets that were not petrels or shearwaters. Our visual observations (especially during crepuscular periods, when we could use binoculars) helped to minimize the inclusion of non-target species, but it is possible that some of our radar targets after dark were of other fast-flying species that were active at that time (e.g., Pacific Golden-Plover, Greater Frigatebird).

A second factor that could increase our exposure and fatality estimates was that we collected data during the late incubation period, which is that time when some of the highest counts of the entire breeding season are expected, and then extrapolated those rates across the entire 270-d breeding season. For example, radar counts of petrels and shearwaters on Kaua'i in 1993 were significantly (~3 times) higher in summer (incubation period) than in fall (fledging period; Day and Cooper 1995). The increase in movement rates during incubation and early chick-rearing occurs because of regular visits of breeding birds after hatching and because non-breeders visit the colonies at that time, whereas the fall declines occur because attendance at colonies by non-breeders and failed breeders declines as chick-rearing progresses (Serventy et al. 1971, Warham 1990, Ainley et al. 1997b, Simons and Hodges 1998). We plan to collect data during late fall 2007 to help increase our understanding of this seasonal variation in movement rates on Lana'i Island.

A third factor that would increase our exposure and fatality estimates is that petrels may enter and leave the colony by different routes, as suggested above. Our radar data suggest that petrels are flying inland over the WRA in lower numbers than are petrels flying seaward. Because the risk-assessment modeling assumed that the number flying inland over the WRA balanced the number flying seaward, we took the midpoint between the percentage of inland-flying and seaward-flying petrels that were flying low enough to hit a proposed met tower (87.0% and 41.7%, respectively) or turbine (95.7% and 91.7%, respectively) in the modeling exercise. If, however, more birds were flying seaward than inland because most birds flew inland farther east (out of the WRA), the true vertical interaction probability would be closer to the lower value than to the midpoint. Because we suspect that petrels may be flying into and out of the colony by different routes (see above), our modeling probably overestimates the true fatality rate.

A factor that would decrease our exposure and fatality estimates is if inland-flying targets were missed because they flew low to the ground, within radar shadows. The sites generally were excellent from a radar-sampling perspective, but we know that we missed some targets on radar because of the unusually low flight altitudes of petrels on Lana'i: the mean flight altitude was only 47 ± 8 m agl, or much lower than a mean flight altitude of 200 m agl for all of the other Main Hawaiian Islands combined (Day and Cooper, unpubl. data). For example, ~63% of the 35 birds observed visually in the present study were not detected on radar, suggesting that many were flying too low for the radar to detect them. In contrast, only 9 of the 121 radar targets that passed within 250 m of the visual observer were observed by the visual observer, even though the radar operator alerted the visual observer to the approach of these targets. Thus, the radar and visual techniques are sampling only partially-overlapping subsets of birds, making it problematic to calculate a valid correction factor for the percentage of low-flying targets that the radar might have missed.

A second factor that would decrease our exposure and fatality estimates is if some of the peak morning-movement period occurred before sampling began at 0400. Although our evening and morning sampling periods correspond to the evening and morning peaks of movement for these birds at other islands (Day and Cooper 1995), we noticed on Lana'i that some birds were flying seaward, even in the half-hour before observations began at 0400, suggesting that the peak morning movement out of the colony already had begun before our sampling started. To account in the fatality model for this unexpected-early morning exodus, we expanded our peak morning movement rates to 3 h (i.e., 0300–0600), rather than just to the 2-h sampling window (i.e., 0400–0600) when sampling occurred. Clearly, some all-night radar sampling on Lana'i would help us refine our understanding of the movement patterns of petrels during the middle of the night.

A factor that could affect our exposure and fatality estimates in either direction is interannual variation in counts. For example, counts on Kaua'i were four times lower in fall 1992 than in fall 1993, with the lower counts in 1992 being attributed to the effects of Hurricane Iniki, one of the strongest hurricanes ever to hit the Hawaiian Islands (Day and Cooper 1995). In addition, oceanographic factors (e.g., El Niño–Southern Oscillation events) also vary among years and are known to affect the distribution, abundance, and reproduction of seabirds (e.g., Ainley et al. 1994, Oedekoven et al. 2001).

A final factor affecting exposure indices involves marking of the proposed met towers and guy wires with white flagging to make them more visible to flying Hawaiian Petrels. This flagging has been found to be effective in reducing collisions of Hawaiian Petrels with ungulate fences near breeding colonies on Hawai'i Island, both because Hawaiian Petrels see flagged structures more easily and because they see them at greater distances, allowing more time for collision avoidance to occur (Swift 2004). Anecdotal information from the petrel colony on Lana'i also suggests that white flagging on ungulate fences there are effective in reducing collisions of petrels with the fence (J. Penniman, DOFAW, pers. comm.). We see no reasons why Hawaiian Petrels' ability to see white-flagged met towers should differ from their ability to see white-flagged fences, so we encourage marking of the towers and guy wires to increase their visibility to these birds and, thus, to increase the birds' anti-collision behavior.

CONCLUSIONS

Although the number of Hawaiian Petrels that might be killed by collision with the proposed met towers and turbines on Lana'i is unknown, we have used our risk-assessment model to approximate their potential fatality rates. The model is affected by all of the input variables; however, the collision-avoidance rate variable has both a very large effect on modeled estimates and also is one of the most poorly understood variables at this time. It will take nocturnal behavioral sampling to understand how these birds will behave around met towers and wind turbines in this proposed windfarm. There is a body of evidence that indicates that a high percentage of birds see and avoid structures (see above), and the limited data from the Maui windfarm suggest that avoidance rates will be high. We suspect that Hawaiian Petrels also have good nocturnal eyesight, given the fact that they must be able to see well to get to and from their burrows. Consequently, we suspect that there will be natural anti-collision behavior as they approach these structures, although the true rate of avoidance is unknown at this time. The fact that many petrels move while there is still light in the sky also will enhance their anti-collision behavior. Finally, we believe that marking the met towers and guy wires to make them more visible to petrels also will increase anti-collision behavior and decrease risk. Hence, we believe that the proportion of petrels that see and avoid the proposed met towers and turbines will be high and will be enhanced by marking but emphasize that, until studies to measure avoidance behavior at marked structures are conducted, that proportion will remain unknown.

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Appendix 4

Lānaʻi Spring Avian Report

SPRING AVIAN SURVEY
LĀNA'I RESOURCE AREA
MAUI COUNTY,
HAWAII

PREPARED FOR

CASTLE & COOKE INC.

Prepared by

TETRA TECH EC, INC.

August 2007

Executive Summary

Tetra Tech, EC (TtEC) was contracted by Castle and Cooke to undertake spring avian use surveys for the proposed Lāna'i Wind Resource Area (WRA) in Maui County, Hawaii. Weekly spring surveys were performed at the Lāna'i WRA from April 20 to June 28, 2007. Fixed point count surveys (800 m radius) were conducted at 11 points distributed throughout the WRA.

A total of 15 species, consisting of 299 birds from five taxonomic groups were observed within the Lāna'i WRA. Overall mean use of the WRA was 3.5 birds/20 min. Mean raptor use at the Lāna'i WRA (0.1 birds/20 min; 0.15 birds/30 min when scaled to a 30-minute survey) was the lowest compared to the rates recorded for 14 other wind power sites throughout the continental U.S. A single species of raptor, the short-eared owl, was detected during the 20-minute surveys. The short-eared owl had a mean use of 0.1 birds/20 min and flew through the RSA 9.1% of the time, resulting in an exposure risk of 0.01 birds flying within the RSA/20 min. The short-eared owl has been listed as a bird of conservation concern by the U.S. Fish and Wildlife Services (USFW 2007) and is a state listed endangered species on the island of O'ahu (Hawaii 2007). Short-eared owls primarily flew below the RSA; however, males are known to perform higher altitude aerial displays within the RSA when mating.

Overall non-raptor avian use at Lāna'i WRA is low. Use by non-raptors collectively at the Lāna'i WRA (3.4 birds/20 min; 5.1 birds/30 min when scaled to a 30-min survey) was the lowest when compared to other previously recorded rates from existing wind facilities throughout the continental U.S. The most abundant species of non-raptor within the WRA were the common myna (0.7 birds/20 min; 0.06 exposure risk), sky larks (0.4 birds/20 min; 0.02 exposure risk), house finches (0.1 birds/20 min; 0.02 exposure risk), and white-tailed tropicbird (<0.1birds/20min; 0.01 exposure risk).

No threatened or endangered non-raptor species were observed during the survey; however, dawn-dusk and nocturnal visual and radar surveys conducted by ABR Inc. did detect the presence of the endangered Hawaiian petrel within the WRA (ABR 2007). Due to the lack of Hawaiian petrel observations during this survey, their exposure risks could not be estimated; however this does not indicate that there is no exposure risk to the Hawaiian petrel.

Although much of the WRA is already disturbed, it does provide birds and other wildlife with cover and opportunities for nesting, perching, and foraging. Short-term disturbance associated with construction activities could temporarily displace birds from construction areas and result in the abandonment of nests; long-term noise and disturbance associated with turbine operation may also reduce habitat quality.

Lāna'i Project Area Recommendations

Based on the data available from this survey, it is unlikely that construction of the Lāna'i wind facility will cause detrimental impacts to native bird populations. The following Best Management Practices and recommended studies should provide measures to minimize impacts to birds from the construction and operation of the Lāna'i wind facility. These practices are important not only to reduce the potential for an avian species to be injured or killed by turbines, transmission lines, or other wind farm components but to also protect and enhance habitat for species of concern.

Standard Best Management Practices

- The use of overhead power lines should be minimized. When they are necessary, power poles should be fitted with bird perch guards to minimize bird use. Studies have shown that birds are susceptible to electrocution by power lines (APLIC 2006).
- The use of lights on turbines should be minimized, in accordance with state, federal, and local requirements, when practicable because lights may attract migrating birds to the vicinity of turbines, particularly during certain weather conditions.
- If a raptor nest is discovered during construction it should be mapped, flagged, and designated a 'no disturbance zone' during the construction phase. Active raptor nests may require timing restrictions for construction or operation activities, or alterations to the turbine design plan.
- Habitat loss is typically the leading cause for population declines in a number of species of concern. Bird species are dependent on the native plants for food, cover, and breeding habitat. Degraded vegetative communities or the presence of invasive plant species can reduce the amount of available quality habitat for birds in these areas. In order to decrease the loss of bird habitat therefore:
    - To the greatest extent possible, minimize impacts to native vegetation and riparian areas during design and construction of turbines and associated infrastructure.
    - If native vegetation is disturbed or removed during construction of roads or turbines or during on-going maintenance activities, these areas should be reseeded or planted with native material.
    - Where practical, existing degraded habitat could also be enhanced through the removal and replacement of invasive species with plants native to the site.

Additional studies

- Fall surveys are recommended to determine the level of avian use during fall, because avian use may differ between spring and fall.
- Post-construction monitoring is recommended to quantify mortality impacts to avian species.

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Report prepared by John Crookston and peer reviewed by Laura Nagy and Lynn Sharp.

INTRODUCTION

Castle & Cooke Inc. is proposing to develop a wind energy conversion facility in Lāna'i, Hawaii. The Lāna'i Wind Resource Area (WRA) is located on the northwest corner of Lāna'i island in Maui County, Hawaii (Figure 1). Castle & Cooke Inc. is committed to environmental due diligence at all of its wind energy facilities and therefore contracted Tetra Tech EC (TtEC) to conduct spring avian surveys to quantify local avian use and to identify potential avian impacts associated with the construction and/or operation of the proposed wind facility at the Lāna'i WRA.

Lāna'i is a small volcanic island, approximately 90,000 acres in size. The Lāna'i WRA encompasses approximately 27,204 acres and is located within the Dry Tropical Forest/Tropical Low Shrublands ecoregion in Maui County, Hawaii (National Geographic 2007). Most of the islands endemic habitat has been disturbed by invasive species, widespread cattle grazing, and habitat loss in the form of pineapple plantations (TtEC 2007). The few remaining patches of undisturbed habitat can be found in the northern portion of the island, where the WRA is located. Most of the WRA consists of shrublands growing on windswept hills with steep eroded slopes.

Avian diversity in the Hawaii islands was historically high; however, a combination of habitat destruction and invasion by non-native predators has caused the decline of many endemic avian species (TtEC 2007). There are currently 37 threatened or endangered avian species in Hawaii (Bishop Museum Hawaiian Bird Checklist 2007).

METHODS

Diurnal Fixed-point and Incidental Avian Use Surveys

Avian point count surveys were conducted to evaluate avian use, behavior and species composition at the WRA. Fixed-point surveys, described below, were conducted for 20 minutes at 11 circular plots in the Lāna'i WRA, with incidental observations of other birds made either before or after the official 20 minute point count period or while traveling between survey points. Surveys were conducted during daylight hours under variable weather conditions.

Fixed-point Surveys

Survey dates and locations of survey points were selected to cover a diversity of habitats, and to ensure the best possible viewshed. Surveys were conducted weekly between April 20 and June 28, 2007 (Table 1) at 11 points distributed throughout the WRA (Figure 2). Due to incidental weather and other extenuating circumstances, early setup was delayed at a few of the 11 points, resulting in a total of 85 fixed-point surveys completed during this study.

Data were collected on all birds observed within an 800-meter radius circle centered on the point station. Birds outside the 800-meter radius circle were recorded as incidentals. Surveys at each point lasted for 20 minutes, during which the observer continuously scanned for birds and recorded both visual and auditory observations. Data that were recorded and used in the analysis included species, time, height above ground, distance from observer (horizontal), behavior and flight direction. The order in which stations were surveyed was randomized to account for species variation during the day. Flight heights and distances from the observer were estimated by experienced field ornithologists, who used existing features and topographic maps for reference.

Incidental Observations

Incidental observations were those recorded outside of the official 20-minute survey period. Incidental observations included observations that occurred 1) during travel between points, 2) before or after the official 20-minute survey period, and 3) outside the 800-meter radius circle. These observations were recorded on separate data sheets to provide additional information on avian use of the WRA.

Data Quality Assurance/Quality Control

QA/QC measures were implemented during all stages of data collection, analysis, and report preparation. To ensure legibility and completeness of data sheets, each observer reviewed, and clarified if needed, all data sheets before data entry into a Filemaker™ relational database for data storage and analysis. Prior to analysis, an independent reviewer conducted a 100% quality review of the data entries. Any questions that arose at this time were directed toward and answered by field personnel.

Analysis

Avian Use of the WRA

Avian use of the WRA was derived by calculating the average number of birds observed per 20-minute point count survey. To evaluate the diversity and composition of avian species using the WRA, the number of individuals of each species was summarized. In addition, the number of observations is also presented, where an observation can be either an individual bird or a discrete flock of birds. This information helps evaluate if a high use number is driven by a single event (e.g., flock of birds moving through the rotor swept area).

Flight Behavior

Flight behavior was evaluated by calculating the proportion of flying birds that were observed below, within, or above the turbine rotor swept area (RSA). Turbine type had yet to be established at the time of this survey. As a consequence, a RSA between 35 and 125 meters above the ground was used, representing the largest turbines being considered by Castle & Cooke at the time of the analysis. Birds that were observed flying, but for which there were no flight height data (< 1% of our observations), were excluded from this analysis. A bird was considered to have flown within the RSA if any of its recorded heights overlapped the RSA. That is, if a bird flew at heights that correspond to the RSA at any time during the survey, it was considered to have occurred within the RSA.

Risk Index

To estimate the exposure risk of collision for each species, the following equation was applied:

$$R = A*P_f*P_t$$

where R is the exposure risk, A is the mean number of birds/20 min, P_f is the proportion of all activity observations of species i that were observed flying, and P_t is the proportion of species i that were observed flying within the turbine RSA. R can be interpreted as the average number of birds flying through the RSA during a 20 minute period.

RESULTS

Lāna'i WRA

A total of 5464 acres of the Lāna'i WRA were surveyed during spring point count surveys, covering approximately 20% of the total area of the WRA.

Species Composition

A total of 299 birds, of 15 identified species, were recorded during 85 fixed-point count surveys (Table 2). Because individual birds were not marked, the terms 'abundant' or 'abundance' represent use estimates, and do not indicate absolute density or number of individuals. The most abundant birds were common mynas (20.4% of total birds detected), northern mockingbirds (14.7% of birds detected), sky larks (12.4% of birds detected), and Japanese white-eyes (11.0% of birds detected). Each remaining species comprised 7.4% or less of the total number of birds detected (Table 2).

Avian Use

Overall mean bird use within the Lana' WRA was 3.5 birds/20 min, ranging from 1 to 14 birds per 20-minute point count. Among taxonomic groups, mean use was highest for passerines (3.0 birds/20 min; Table 3) and included common mynas (0.7 birds/20 min), northern mockingbirds (0.5 birds/20 min), sky larks (0.4 birds/20 min), Japanese white-eyes (0.4 birds/20 min), and northern cardinals (0.3 birds/20 min). Mean use for each additional passerine species was ≤ 0.2 birds/20 min.

Game birds had the second highest mean use (0.3 birds/20 min) and included gray francolins (0.2 birds/20 min), wild turkeys (< 0.1 birds/20 min), and ring-necked pheasants (< 0.1 birds/20 min). The only raptor species that was observed during the 20 minute surveys was the short-eared owl, which had a mean use of 0.1 birds/20 min. The remaining taxonomic groups each had an overall mean use of ≤ 0.1 birds/20 min.

Frequency of Occurrence

Passerines were the most commonly detected group. The most common passerines observed were northern mockingbirds (observed in 30.6% of surveys), common mynas (29.4% of surveys), sky larks (23.5 of surveys), northern cardinals (22.4% of surveys), and Japanese bush-warblers (17.6% of surveys). All other species from the varying taxonomic groups were detected in ≤ 12.9% of surveys.

Flight Height and Exposure Risk

During spring avian use surveys, behavioral data were collected for 99.3% of all birds observed during point count surveys. Of these birds, 67.2% were observed flying (data on flight height and direction were available for 99.5% of birds in flight). For raptors with flight height data, 90.9% flew below the RSA and 9.1% flew within the RSA. For non-raptors with flight height data, 94.7% flew below and 5.3% flew within the RSA (Table 4).

Exposure risk was determined by multiplying mean use, by the proportion of birds observed flying, and the proportion of birds that occurred within the anticipated RSA. Common mynas had the greatest exposure risk (0.06 birds flying within the RSA/20 min), followed by sky larks (0.02), house finches (0.02), white-tailed tropicbirds (0.01), and short-eared owls (0.01). All remaining species had exposure risk of < 0.01 (Table 5). Although the exposure index provides a relative ranking as to what species may be most at risk, an index value of zero indicates low, rather than no risk associated with the construction and operation of wind turbines at the Lānaʼi WRA.

Flight Direction

No trend in flight direction was seen. These flight patterns primarily represent Lānaʼi residents; therefore, this survey captured local movements in the form of short flights within the WRA.

Species Distribution

Most bird observations occurred at survey points one, four, nine, ten, and eleven (Table 7). The majority of common mynas (20 out of 51 birds) were seen at point 9. Northern cardinals were seen throughout the WRA.

Incidental Surveys

Three species were documented as incidentals during the spring surveys that were not seen during the point count surveys (Table 8). These additional species include chukars, house sparrows, and a single barn owl.

DISCUSSION AND RECOMMENDATIONS:

Raptor Use and Exposure Risk

Raptor use at the Lānaʼi WRA is low (0.1 birds/20 min; 0.15 birds/30 min when scaled to a 30 minute survey), ranking the lowest out of 14 WRAs when compared to rates observed at existing wind facilities within the continental U.S. (Table 9). Because studies of avian use do not share identical methodologies (e.g., length of survey period or location) comparisons should only be used to provide useful generalities.

A single species of raptor, the short-eared owl, was detected during the 20 minute surveys. The short-eared owl had a mean use of 0.1 birds/20 min and flew through the RSA 9.1% of the time, resulting in an exposure risk of 0.01 birds flying within the

RSA/20 min. The short-eared owl has been listed as a bird of conservation concern by the U.S. Fish and Wildlife Services (USFW 2007) and is a state listed endangered species on the island of O'ahu (Hawaii 2007). Its current population size on the island of Lana'i is unknown. Populations of this ground-nesting species have been declining throughout the U.S. due to a loss of suitable nesting habitat (Melvin et al. 1989). Short-eared owls primarily flew below the RSA during the 20-minute survey (90.9% of the time); however, males are known to perform higher altitude aerial displays during the mating season. These displays occur at an altitude range of 30 to 150 meters (Carson 1962), which is within the RSA. Their mating season extends from mid-February to June with its peak in April (Holt 1992).

Non-raptor Use and Exposure Risk

Overall non-raptor avian use at Lāna'i WRA is low. Use by non-raptors collectively at the Lāna'i WRA (3.4 birds/20 min; 5.1 birds/30 min when scaled to a 30 min survey) was the lowest when compared to other previously recorded rates from existing wind facilities throughout the continental U.S. (Table 9). Exposure risks were low at the WRA due to low mean use and the majority of individuals flying below the RSA. The most abundant species of non-raptor within the WRA was the common myna, which had a mean use of 0.7 birds/20 min and an exposure risk of 0.06. The common myna is not a native Hawaiian species, and was first introduced to the islands as a bio-control method for cutworms (Caum 1933). It has since become one of the most common species within the pacific islands. Due to its low exposure risk and large population size, potential impacts are unlikely to negatively impact the common myna's population.

Other non-raptor species detected during the survey include sky larks (0.4 birds/20 min; 0.02 exposure risk), and house finches (0.1 birds/20 min; 0.02 exposure risk), neither of which are endemic to Hawaii (Grinnell 1911; Scott et al. 1986) and both of which have low exposure risks. Only two native Hawaiian non-raptor species were detected during this survey: the white-tailed tropicbird (< 0.1 birds/20 min), and the great frigatebird (< 0.1 birds/20 min), both of which had an exposure risk of < 0.01, indicating that they are not likely to be at risk for colliding with turbines. All additional non-raptor species had an exposure risk of < 0.01.

No threatened or endangered non-raptor species were observed during this survey; however, a nocturnal visual and radar survey conducted by ABR Inc. did detect the presence of the endangered Hawaiian petrel within the WRA (ABR 2007). The reason for the lack of Hawaiian petrel observations within this current survey may be due to this species' propensity to travel at dawn, dusk, and night, while this point count survey was conducted during daylight hours. Due to the lack of Hawaiian petrel observations, their exposure risks could not be estimated at this time; however this does not indicate that there is no exposure risk to the Hawaiian petrel. In fact, although the 2007 sonar survey was unable to determine a fixed exposure risk for the Hawaiian petrel, it did indicate that they may be at risk of turbine collisions within the Lāna'i WRA (ABR 2007).

Potential Impacts to Avian Species

The impacts to avian species that could result from the construction and operation of the Lāna'i WRA are direct morality and injury from collisions with turbines or guy wires, permanent or temporary habitat loss, and displacement of birds from habitats near turbines. Although much of the WRA is already disturbed, it does provide birds and other wildlife with cover and opportunities for nesting, perching, and foraging. Short-term disturbance associated with construction activities could temporarily displace birds from areas; long-term noise and disturbance associated with turbine operation may also reduce habitat quality in the WRA. Much of the WRA is highly disturbed and mitigation of impacts through native habitat restoration and enhancement may offset impacts.

Songbird displacement associated with wind power development has been documented at other wind plants. This displacement has been attributed to the direct loss of habitat or reduced habitat quality within 50 meters of a turbine pad (WEST and NWC 2004). For example, at the Buffalo Ridge WRA, densities of male songbirds were significantly lower in Conservation Reserve Program (CRP) grasslands containing turbines than in CRP grasslands without turbines, which has been attributed to avoidance of turbine noise and maintenance activities, and reduced habitat quality due to the presence of access roads and large gravel pads surrounding the turbines (Leddy et al. 1999). Likewise, at the Buffalo Ridge site in Wyoming, the abundance of shorebirds, waterbirds, upland game birds, woodpeckers, and several groups of passerines was found to be lower in areas with turbines than without (Johnson et al. 2000a). However, data from Johnson et al. (2000a) suggest that the extent of reduced use is primarily limited to those areas within 100 meters of turbines.

Lāna'i Project Area Recommendations

Based on the data available from this survey, it is unlikely that construction of the Lāna'i wind facility will cause detrimental impacts to native bird populations within the WRA. The following Best Management Practices and recommended studies will provide measures to minimize impacts to birds from the construction and operation of the Lāna'i wind facility.

Best Management Practices

Several best management practices can be implemented at wind farm facilities in order to avoid and minimize potential impacts to avian species and habitat (Kerlinger 2004). These practices are important not only to reduce the potential for an avian species to be injured or killed but to also protect and enhance habitat for species of concern.

Standard Best Management Practices

- The use of overhead power lines should be minimized. When they are necessary, power poles should be fitted with bird perch guards to minimize bird use. Studies have shown that birds are susceptible to electrocution by power lines (APLIC 2006).
- The use of lights on turbines should be minimized, in accordance with state, federal, and local requirements, when practicable because lights may attract

migrating birds to the vicinity of turbines, particularly during certain weather conditions.

- If a raptor nest is discovered during construction it should be mapped, flagged, and designated a 'no disturbance zone' during the construction phase. Active raptor nests may require timing restrictions for construction or operation activities, or alterations to the turbine design plan.
- Habitat loss is typically the leading cause for population declines in a number of species of concern. Bird species are dependent on the native plants for food, cover, and breeding habitat. Degraded vegetative communities or the presence of invasive plant species can reduce the amount of available quality habitat for birds in these areas. In order to decrease the loss of bird habitat therefore:
  - To the greatest extent possible, minimize impacts to native vegetation and riparian areas during design and construction of turbines and associated infrastructure.
  - If native vegetation is disturbed or removed during construction of roads or turbines or during on-going maintenance activities, these areas should be reseeded or planted with native material.
  - Where practical, existing degraded habitat could also be enhanced through the removal and replacement of invasive species with plants native to the site.

Additional studies

- Pre-construction fall surveys are recommended to determine the level of avian use during fall, because avian use differs between spring and fall.
- Post-construction monitoring is recommended to quantify mortality impacts to avian species.

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TABLES

Table 1. Lanai 2007 spring point count survey dates.

Date
April 20
April 27
May 3
May 4
May 8
May 17
May 23
May 24
May 30
May 31
June 21
June 22
June 28

Table 2. Avian species observed during spring point count surveys at the Lanai Wind Resource Area, 2007.

Species	Number of Birds	Number of Observations	Mean Use # birds/ 20 min.	Frequency % of surveys detected	Percent Composition
common myna	61	44	0.7	29.4	20.4%
northern mockingbird	44	42	0.5	30.6	14.7%
sky lark	37	33	0.4	23.5	12.4%
Japanese white-eye	33	25	0.4	17.6	11.0%
northern cardinal	22	21	0.3	22.4	7.4%
unidentified passerine	17	11	0.2	12.9	5.7%
Japanese bush-warbler	17	17	0.2	9.4	5.7%
gray francolin	15	14	0.2	10.6	5.0%
house finch	12	9	0.1	9.4	4.0%
short-eared owl	11	11	0.1	10.6	3.7%
zebra dove	8	7	0.1	7.1	2.7%
Indian silverbill	8	4	0.1	4.7	2.7%
wild turkey	4	1	0.0	1.2	1.3%
ring-necked pheasant	4	4	0.0	4.7	1.3%
white-tailed tropicbird	2	2	0.0	2.4	0.7%
unknown bird	2	2	0.0	2.4	0.7%
unidentified sparrow	1	1	0.0	1.2	0.3%
great frigatebird	1	1	0.0	1.2	0.3%
Grand Total	**299**	**249**	**3.5**		

Table 3. Avian species, by taxonomic group, observed during spring point count surveys at the Lanai Wind Resource Area, 2007.

Taxonomic Group Species	Number of Birds	Number of Observations	Mean Use # birds/ 20 min.	Frequency % of surveys detected	Percent Composition
Passerine					
common myna	61	44	0.7	29.4	20.4%
northern mockingbird	44	42	0.5	30.6	14.7%
sky lark	37	33	0.4	23.5	12.4%
Japanese white-eye	33	25	0.4	17.6	11.0%
northern cardinal	22	21	0.3	22.4	7.4%
unidentified passerine	17	11	0.2	12.9	5.7%
Japanese bush-warbler	17	17	0.2	9.4	5.7%
house finch	12	9	0.1	9.4	4.0%
Indian silverbill	8	4	0.1	4.7	2.7%
unknown bird	2	2	0.0	2.4	0.7%
unidentified sparrow	1	1	0.0	1.2	0.3%
Group Total	**254**	**209**	**3.0**		**84.9%**
Raptor					
short-eared owl	11	11	0.1	10.6	3.7%
Group Total	**11**	**11**	**0.1**		**3.7%**
Gamebird					
gray francolin	15	14	0.2	10.6	5.0%
wild turkey	4	1	0.0	1.2	1.3%
ring-necked pheasant	4	4	0.0	4.7	1.3%
Group Total	**23**	**19**	**0.3**		**7.7%**
Pigeons/Doves					
zebra dove	8	7	0.1	7.1	2.7%
Group Total	**8**	**7**	**0.1**		**2.7%**
Waterbird					
white-tailed tropicbird	2	2	0.0	2.4	0.7%
great frigatebird	1	1	0.0	1.2	0.3%
Group Total	**3**	**3**	**0.0**		**1.0%**
Grand Total	**299**	**249**			

Table 4. Summary of avian flight heights (includes flying birds only) in relation to the turbine rotor swept area (RSA) during spring point count surveys at the Lanai Wind Resource Area, 2007.

	Observations		Individuals	
	Number	Percentage	Number	Percentage
Non-raptors				
Below RSA (<35m)	136	94.4%	179	94.7%
Within RSA (between 35m and 125m)	8	5.6%	10	5.3%
Raptors				
Below RSA (<35m)	10	90.9%	10	90.9%
Within RSA (between 35m and 125m)	1	9.1%	1	9.1%

Table 5. Avian flight height characteristics in relation to the turbine rotor swept area (RSA) for species at risk of collision at the Lanai Wind Resource Area, during spring 2007. Exposure risk=proportion of birds flying × proportion flying within the RSA × mean use.

Species	Exposure Risk*	Mean Use # birds/ 20 min.	Percent Flying	Percent Below RSA	Percent Within RSA	Percent Above RSA
common myna	0.06	0.7	100.0	91.8	8.2	0.0
sky lark	0.02	0.4	64.9	91.7	8.3	0.0
house finch	0.02	0.1	91.7	81.8	18.2	0.0
white-tailed tropicbird	0.01	0.0	100.0	50.0	50.0	0.0
short-eared owl	0.01	0.1	100.0	90.9	9.1	0.0
zebra dove	0.00	0.1	100.0	100.0	0.0	0.0
wild turkey	0.00	0.0	0.0	0.0	0.0	0.0
unidentified sparrow	0.00	0.0	0.0	0.0	0.0	0.0
unidentified passerine	0.00	0.2	94.1	100.0	0.0	0.0
unknown bird	0.00	0.0	100.0	100.0	0.0	0.0
ring-necked pheasant	0.00	0.0	25.0	100.0	0.0	0.0
northern mockingbird	0.00	0.5	61.4	100.0	0.0	0.0
northern cardinal	0.00	0.3	18.2	100.0	0.0	0.0
Japanese white-eye	0.00	0.4	72.7	100.0	0.0	0.0
Japanese bush-warbler	0.00	0.2	0.0	0.0	0.0	0.0
Indian silverbill	0.00	0.1	87.5	100.0	0.0	0.0
gray francolin	0.00	0.2	20.0	100.0	0.0	0.0
great frigatebird	0.00	0.0	0.0	0.0	0.0	0.0

Table 6. Flight directions of birds observed during spring point count surveys at the Lanai Wind Resource Area, 2007.

Species	Number Flying	Number of Observations	Percentage of Flights in Various Flight Directions								
			N	NE	E	SE	S	SW	W	NW	Variable
common myna	61	44	24.6	14.8	23.0	0.0	21.3	4.9	11.5	0.0	0.0
northern mockingbird	27	25	18.5	11.1	11.1	14.8	25.9	3.7	3.7	11.1	0.0
sky lark	24	21	13.6	18.2	31.8	9.1	13.6	0.0	9.1	4.5	0.0
Japanese white-eye	24	17	29.2	8.3	20.8	0.0	29.2	0.0	12.5	0.0	0.0
unidentified passerine	16	10	6.3	0.0	6.3	0.0	25.0	0.0	62.5	0.0	0.0
short-eared owl	11	11	36.4	9.1	27.3	0.0	9.1	9.1	0.0	0.0	0.0
house finch	11	8	18.2	9.1	18.2	0.0	27.3	0.0	18.2	9.1	0.0
zebra dove	8	7	12.5	25.0	25.0	0.0	0.0	0.0	12.5	25.0	0.0
Indian silverbill	7	3	28.6	0.0	0.0	0.0	0.0	28.6	42.9	0.0	0.0
northern cardinal	4	3	25.0	0.0	25.0	0.0	0.0	0.0	50.0	0.0	0.0
gray francolin	3	2	0.0	0.0	0.0	0.0	0.0	0.0	66.7	33.3	0.0
white-tailed tropicbird	2	2	50.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0
unknown bird	2	2	0.0	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0
ring-necked pheasant	1	1	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Grand Total	**201**	**156**	**20.9**	**10.9**	**19.4**	**4.0**	**19.4**	**3.5**	**16.4**	**4.0**	**0.0**

Table 7. Avian species observed by point during spring 2007 point count surveys at Lanai Wind Resource Area.

Species	Number of Indiv.	Number of Obs.	Points										
			1	2	3	4	5	6	7	8	9	10	11
common myna	61	44	7	0	2	0	1	0	7	5	20	6	13
northern mockingbird	44	42	2	4	1	1	1	3	2	13	2	14	1
sky lark	37	33	0	11	4	6	0	0	2	6	3	3	2
Japanese white-eye	33	25	0	0	1	1	0	0	2	0	8	3	18
northern cardinal	22	21	5	2	1	1	0	2	3	0	3	3	2
unidentified passerine	17	11	1	0	1	3	0	0	1	0	2	2	7
Japanese bush-warbler	17	17	0	0	0	6	0	0	4	0	0	0	7
gray francolin	15	14	7	0	0	1	2	1	1	0	2	1	0
house finch	12	9	0	0	2	8	0	0	1	0	0	0	1
short-eared owl	11	11	0	0	0	0	1	2	3	0	2	0	3
zebra dove	8	7	3	0	0	0	1	0	0	2	1	1	0
Indian silverbill	8	4	7	1	0	0	0	0	0	0	0	0	0
wild turkey	4	1	0	0	0	4	0	0	0	0	0	0	0
ring-necked pheasant	4	4	0	0	0	1	0	0	1	0	1	0	1
white-tailed tropicbird	2	2	1	0	0	0	0	1	0	0	0	0	0
unknown bird	2	2	1	1	0	0	0	0	0	0	0	0	0
unidentified sparrow	1	1	0	0	0	1	0	0	0	0	0	0	0
great frigatebird	1	1	0	0	0	1	0	0	0	0	0	0	0
Grand Total	**299**	**249**	**34**	**19**	**12**	**34**	**6**	**9**	**27**	**26**	**44**	**33**	**55**

Table 8. Incidental observations of birds during spring point counts at the Lanai Wind Resource Area, 2007.

Species	Number of individuals
barn owl	1
chukar	7
common myna	10
gray francolin	35
house sparrow	5
Indian silverbill	6
Japanese white-eye	2
northern cardinal	2
northern mockingbird	4
ring-necked pheasant	6
short-eared owl	11
sky lark	7
wild turkey	20
white-tailed tropicbird	4
zebra dove	21
Grand Total	**141**

Table 9. Comparison of mean use at the Lana'i Wind Resource Area to existing WRA (estimates standardized to birds/30-min survey).

Project site	Mean Use (fall surveys unless otherwise indicated)		Estimate Basis	Reference
	Raptors	Other Birds		
Montezuma Hills, CA	6.72 (annual average)	474 (mostly unidentified blackbirds)	1.5* use/20 min	Kerlinger et al. (2005)
Altamont Pass WEC, CA	3.20 (annual average)	N/A	1.5*use/20 min	Orloff and Flannery (1992)
Cotterel Mountain, ID	2.54	14.29	1.5*use/20 min	BLM (2005)
Klickitat County PEIS study area, WA	1.43	23.01	1.5*Use/20 min	Johnson et al. (2006)
Windy Point, WA	1.19	25.75	1.5*Use/20 min	Johnson et al. (2006)
Buffalo Ridge WEC, MN	0.96-1.26 (various areas)	N/A	1.5*use/20 min	Erickson et al. (2002)
Stateline Wind Project, OR-WA	0.88	10.64	1.5*use/20 min	West, Inc. (2004)
Foote Creek WEC, WY	0.73	N/A	0.75*use/40 min	Johnson et al. (2000b)
Klondike, OR	0.70	N/A	1.5*use/20 min	Erickson et al. (2002)
Wild Horse, WA	0.68(fall-summer)	8.63	Use/30 min	Erickson et al. (2003)
Condon, OR	0.52	7.14	1.5*use/20 min	URS Corporation et al. (2001)
Biglow Canyon, OR project site and reference area	0.47 0.54	15.18 10.09	Use/30 min	WEST, Inc. (2005)
Maiden, WA	0.44	6.83	Use/30 min	Young et al. (2002)
Lānaʻi, HI	**0.15**	**5.1**	**1.5*use/20 min**	**This Study**

FIGURES


Kailua
Honolulu
Lanai City
Kahului
Kailua
Pacific Ocean
Figure 1. Vicinity Map
Castle and Cooke Lana'i Wind Project
Maui County, Hawaii
Project Boundary
Cities
Rivers/Streams
Interstate
Highway
Major Road
Miles
August 8, 2007

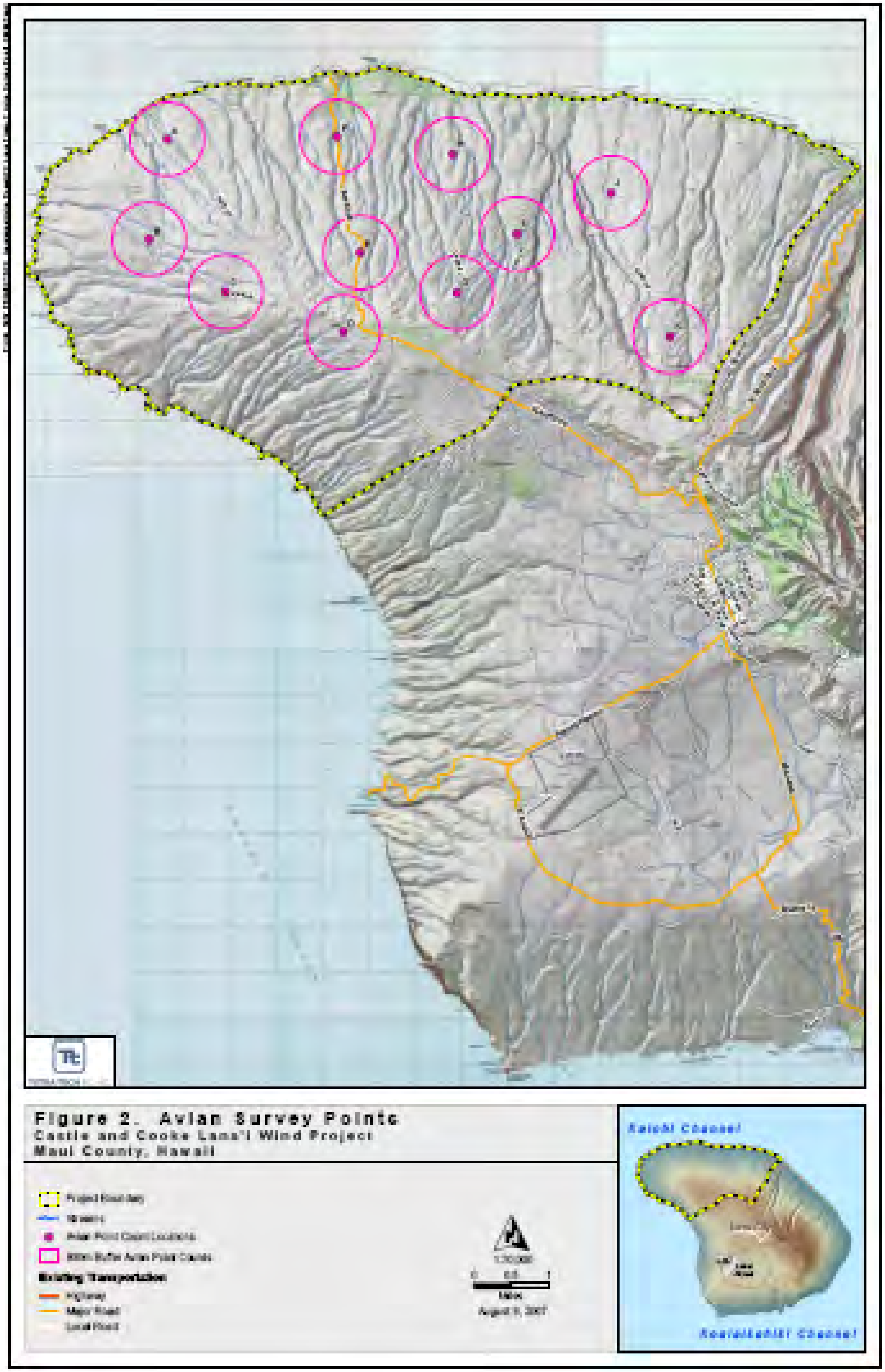

Figure 2. Avian Survey Points
Castle and Cooke Lana'i Wind Project
Maui County, Hawaii

Appendix 5

Met Tower Botanical Survey

Botanical surveys at seven meteorological tower sites on northern Lānaʻi, Hawaiʻi[1]

December 13, 2007 *AECOS* No. 1162

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Summary

The results of two days of surveys at seven meteorological sites (one developed, six proposed) from November 26 through 28, 2007 revealed a mix of introduced and native plant species in essentially grassland to low-growing shrubland communities on the northern part of the Island of Lānaʻi. A list of the species present with an estimate of the relative abundance of species at each site was developed. The surveys extended outward to or slightly beyond a radius of 100 meters from a pre-established center-point for each site in order to provide flexibility in the erection of the meteorological towers. No plant species listed as federally threatened or endangered was observed in any of the survey areas.

Introduction

This report presents the results of botanical surveys at seven specific sites located on the northern part of the Island of Lānaʻi, Maui County, Hawai`i (Figure 1). The sites are to be used for erection of meteorological (met) towers to provide information on wind conditions across the undeveloped part of the Island for the proposed Lānaʻi Wind Energy Project (Project). The purpose of these initial botanical surveys is to assure the planning and engineering teams of the project proponent, Castle & Cooke Resorts, Hawaii, that tower erection can proceed without concern for the presence of federally listed plant species.

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[1] Report prepared for TetraTech EC Inc., Honolulu to become part of the public record for the Lanai Wind Energy Facility.
[2] Botany Department, B. P. Bishop Museum.

Figure 1. Northern Lānaʻi showing locations of the seven met tower sites. Project area boundary shown as blue line; orange lines are roads (most paved).

All of the seven sites surveyed are accessible over the network of 4-wheel drive roads that extend from just west of Lanai City to Garden of the Gods (a badland rock formation) and downslope on many of the interfluves (land between gulches or fluves). In all but one case, the sites are located directly adjacent to a 4-wheel drive road. At Site 3, a shallow gulch separates the center of the site from the roadway.

Survey Methods

The primary purpose of this set of surveys is to establish that no federally listed endangered, threatened, or proposed-for-listing plants are growing at or near seven proposed met tower sites. Federal and State of Hawaiʻi listed species status follows species identified in the following documents: DLNR (1998); Federal Register (2005), USFWS (2005, 2006)[3].

Survey boundaries were established to be a minimum of 100 meters (330 feet) out from a center point previously selected as the best position in each specific area for the erection of a tower to hold the meteorological instrumentation. Generally, the boundary was slightly exceeded in any direction where the terrain suggested the met tower could be moved (that is, where the ground remained level or had low slope). Surveys were terminated at steep slopes or at gulch bottoms within the 100 meter radius. Met tower center points provided to the survey team are given in Table 1.

Table 1. UTM and longitude/latitude coordinates for the seven met tower sites surveyed November 26-28, 2007.

Tower Site	Elevation (ft)	NAD83 UTM Zone 4Q X	NAD83 UTM Zone 4Q Y	NAD83 º LAT	NAD83 º LONG
1	1563	710784	2310552	20.883216	-156.973733
2	682	710737	2312995	20.905283	-156.973883
3	370	708471	2314115	20.915650	-156.995533
4	1459	707369	2310790	20.885750	-157.006516
5	492	705205	2313386	20.909433	-157.027000
6	565	703734	2311433	20.891966	-157.041366
7	928	714255	2311957	20.895502	-156.940208

The two botanists started at the center point of a site and moved outward slowly together to develop a species list of the dominant and common species present. Each botanist then separately covered on foot approximately two-thirds of a met tower survey area in wandering transects, using hand-held GPS units to establish that coverage was complete and roughly within bounds. This approach provided an

3 State statutes link the threatened and endangered plant species for the State of Hawaiʻi to the federal list of threatened and endangered species.

efficient use of each botanists' time while insuring some overlap in area actually surveyed by each.

A typical record of the survey track from one of the botanist's GPS unit is shown as Figure 2. Coverage during a wandering transect varied with the terrain and the vegetation type. In areas of low topography with sparse or low-growing grass, this distance might be 20 meters; in areas of greater topography or taller shrub growth, this distance would be reduced to 5 or 10 meters. In badland areas it was possible to inspect the few plants standing out on the barren ground and concentrate on the margins supporting plant growth.

Figure 2. Example of GPS recorded track produced by one of the botanists surveying Site 5 on November 27. Track in yellow represents a November 26 reconnaissance visit. The track of the vehicle along roads was also recorded.

Upon completion of the surveys, the positional information gathered from each site was plotted on a topographic map. This included the central point and a series of waypoints recorded by one GPS unit, and a comparison of the track recorded by the other unit. This approach insured that the resulting smoothed polygon connecting the waypoints incorporated all the area shown by the second GPS unit (which had the capability of recording the actual track as a series of time interval set waypoints). The mapped individual survey areas are presented herein as Figures 3 through 9. Elevation contours on these maps are in meters.

Most plants were easily identified in the field. In a few cases, photographs were taken and specimens collected for closer examination in the laboratory. In one case a mounted voucher specimen of *Mollugo cerviana,* representing a new record for the Island of Lānaʻi was created for deposit in the herbarium of the B. P. Bishop Museum.

With respect to conditions at the time of the survey, rainy weather was experienced throughout the morning of November 27, which slowed the work on that date. However, the wet season on Lānaʻi was well underway and the vegetation was green and flushed with growth. Some annuals were observed only as seedlings, and thus their abundance could not be estimated in any meaningful way. Seedlings of some shrubs, such as ʻilima (*Sida fallax*) and ʻuhaloa (*Waltheria indica*), were very abundant and the abundance estimates for these plants are for adults only.

Results

Lānaʻi has a number of areas where rare native plants are found, and these are scattered widely over the island, although most federally listed species occur in the uplands east of Lānaʻi City and in the dry forest preserve to the north of town. Because of the large population of Axis deer or chital (*Axis axis*) on the island, several areas supporting native plants are fenced to exclude herbivory on the rare native plants.

Some 37 federally listed plants are known from the island, including 7 that are endemic to (known only from) Lānaʻi. The remaining 30 species are also found on other islands in the Hawaiian archipelago (Federal Register, 2002). Critical Habitat has been proposed totaling 4,800 acres (1942 hectares) for some 18 endangered plant species on Lānaʻi. However, presently, a total of 789 acres (320 hectares) has been designated. With one exception, units are all located on the southern half of the Island. The exception is Unit 1 (373 acres or 151 hectares) located between elevations of 590 and 950 feet (180 and 290 meters) upslope of Pōhakuloa Point on the north side of Lānaʻi (Federal Register, 2003). Unit 1 is designated Critical Habitat for *Tetramolopium remyi*, a short-lived perennial in the Family Asteraceae. This species once occupied the designated Unit 1 area but was considered extirpated at the time of the final ruling, with the possibility that there remained a seed bank of *T. remyi* in the area.

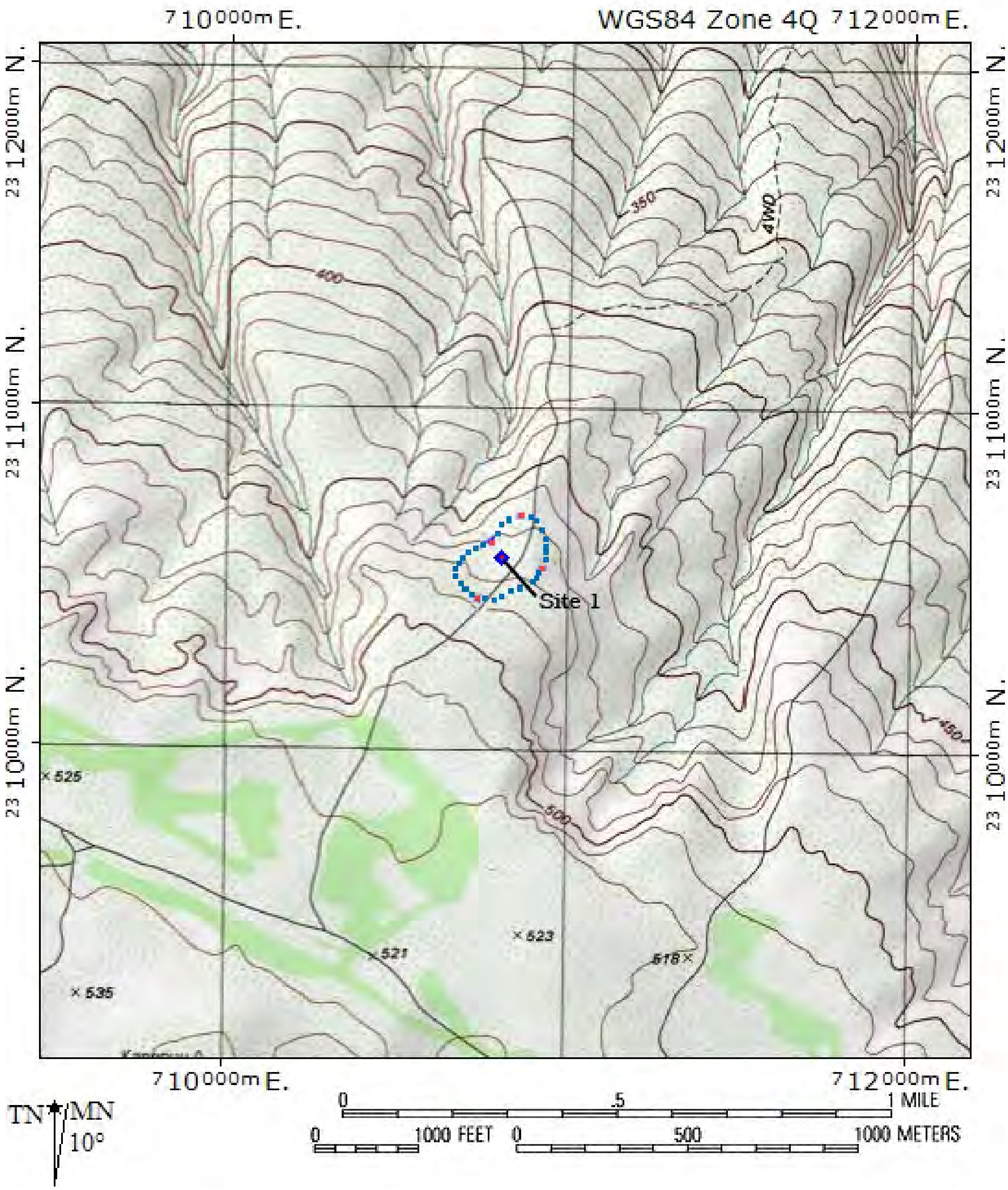

Figure 3. Location and survey area boundary for Site 1, surveyed on November 27, 2007 (GPS recorded waypoints shown in red).

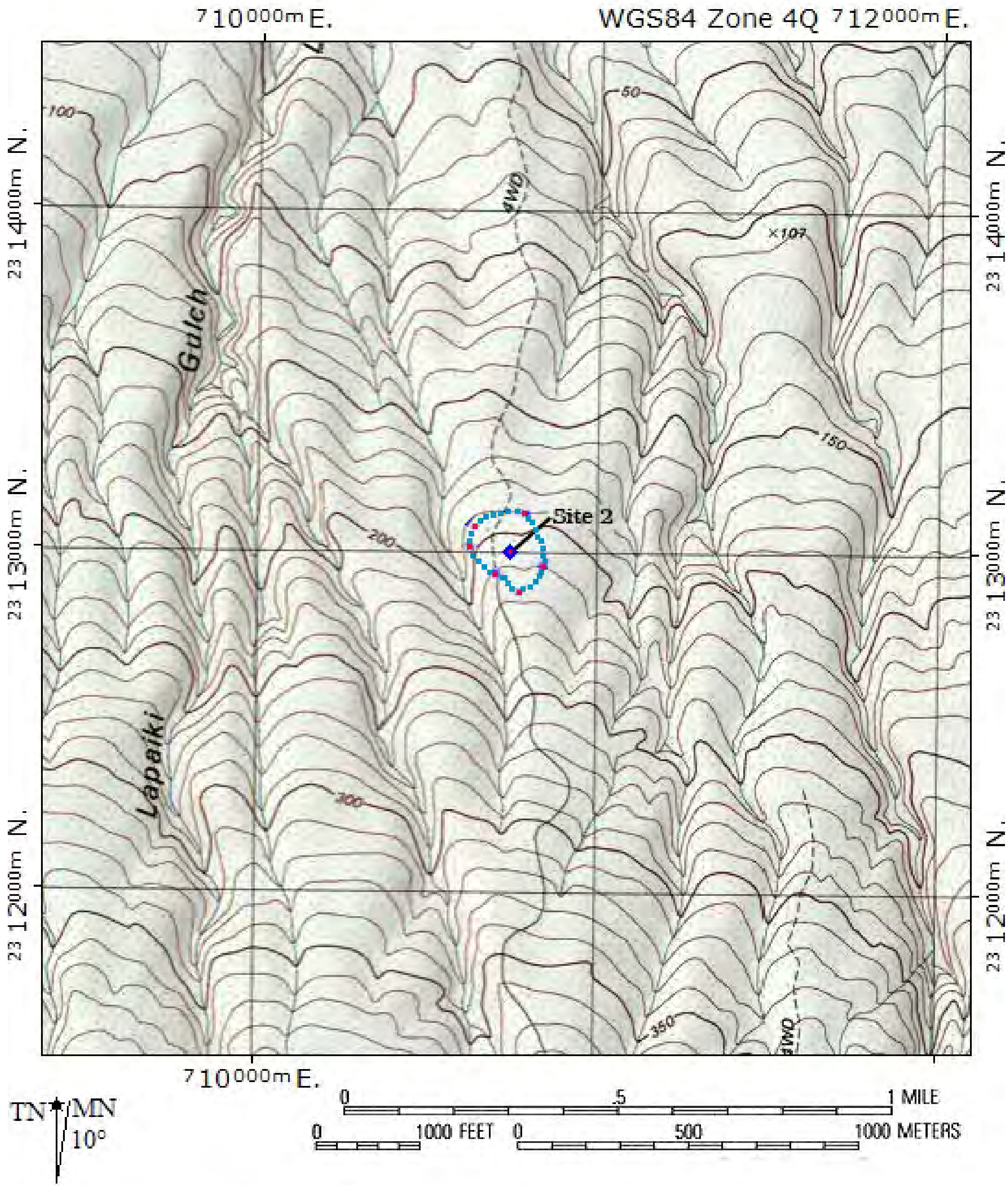

Figure 4. Location and survey area boundary for Site 2, surveyed on November 27, 2007 (GPS recorded waypoints shown in red).

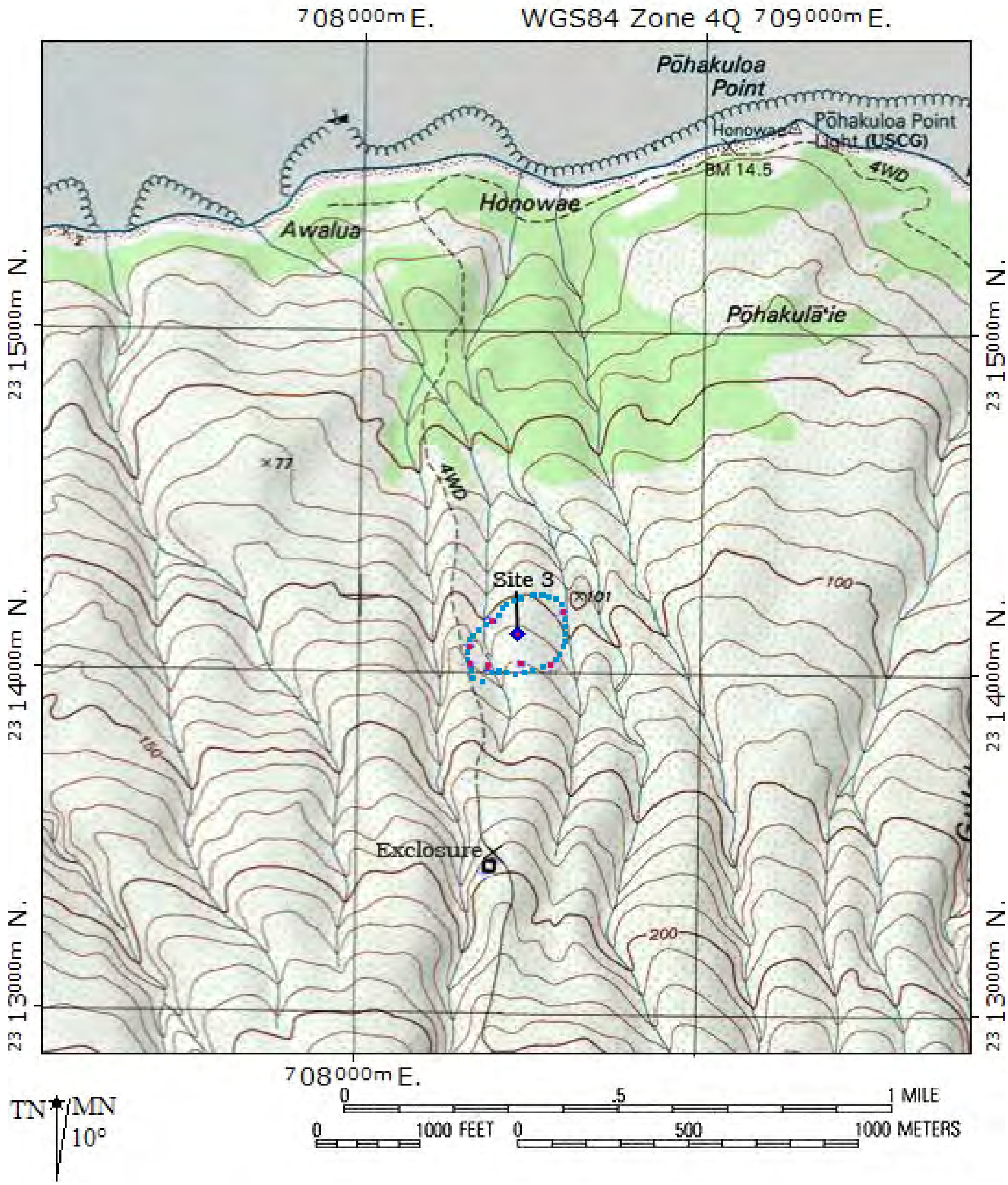

Figure 5. Location and survey area boundary for Site 3, surveyed on November 28, 2007 (GPS recorded waypoints shown in red).

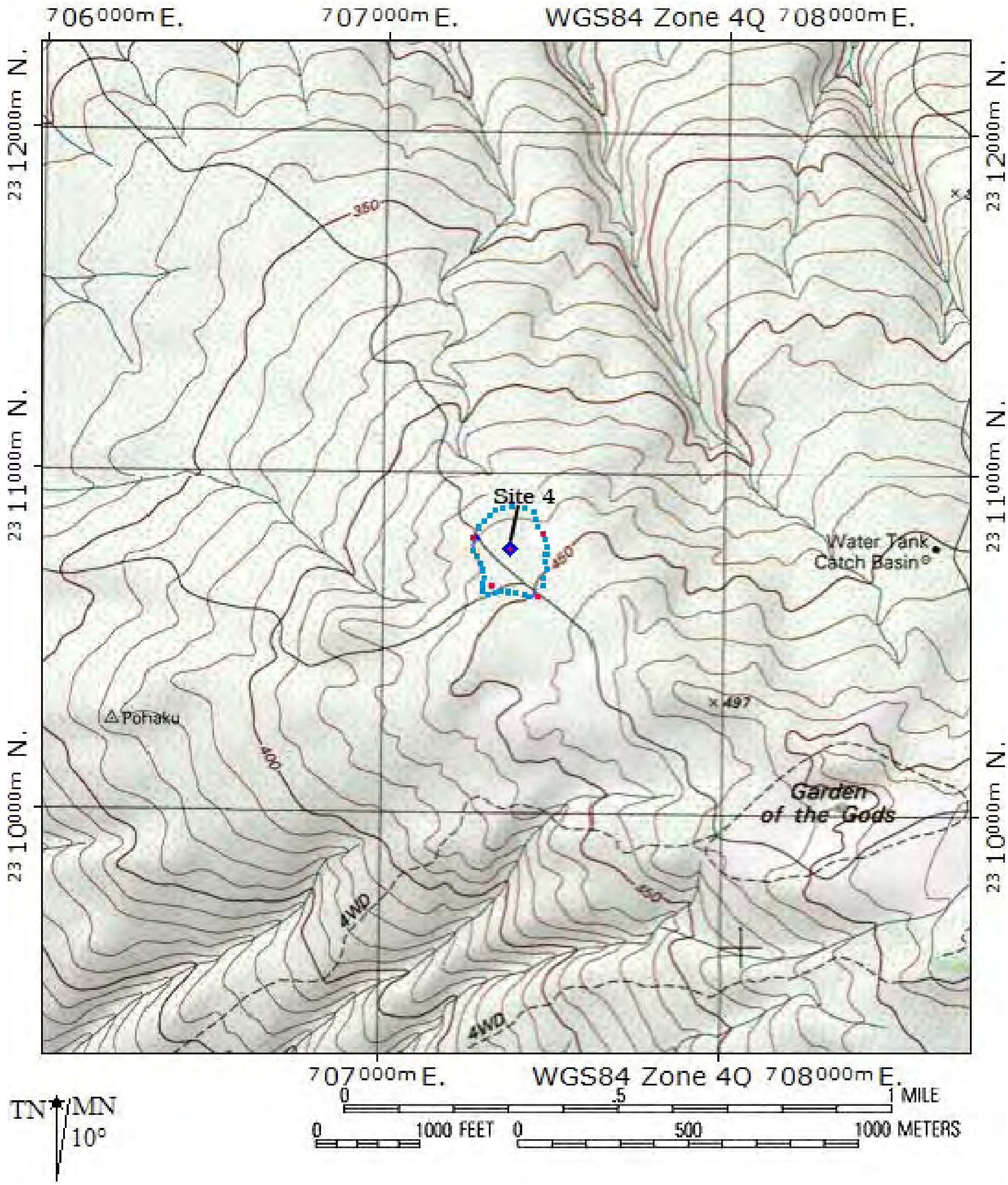

Figure 6. Location and survey area boundary for Site 4, surveyed on November 27, 2007 (GPS recorded waypoints shown in red).

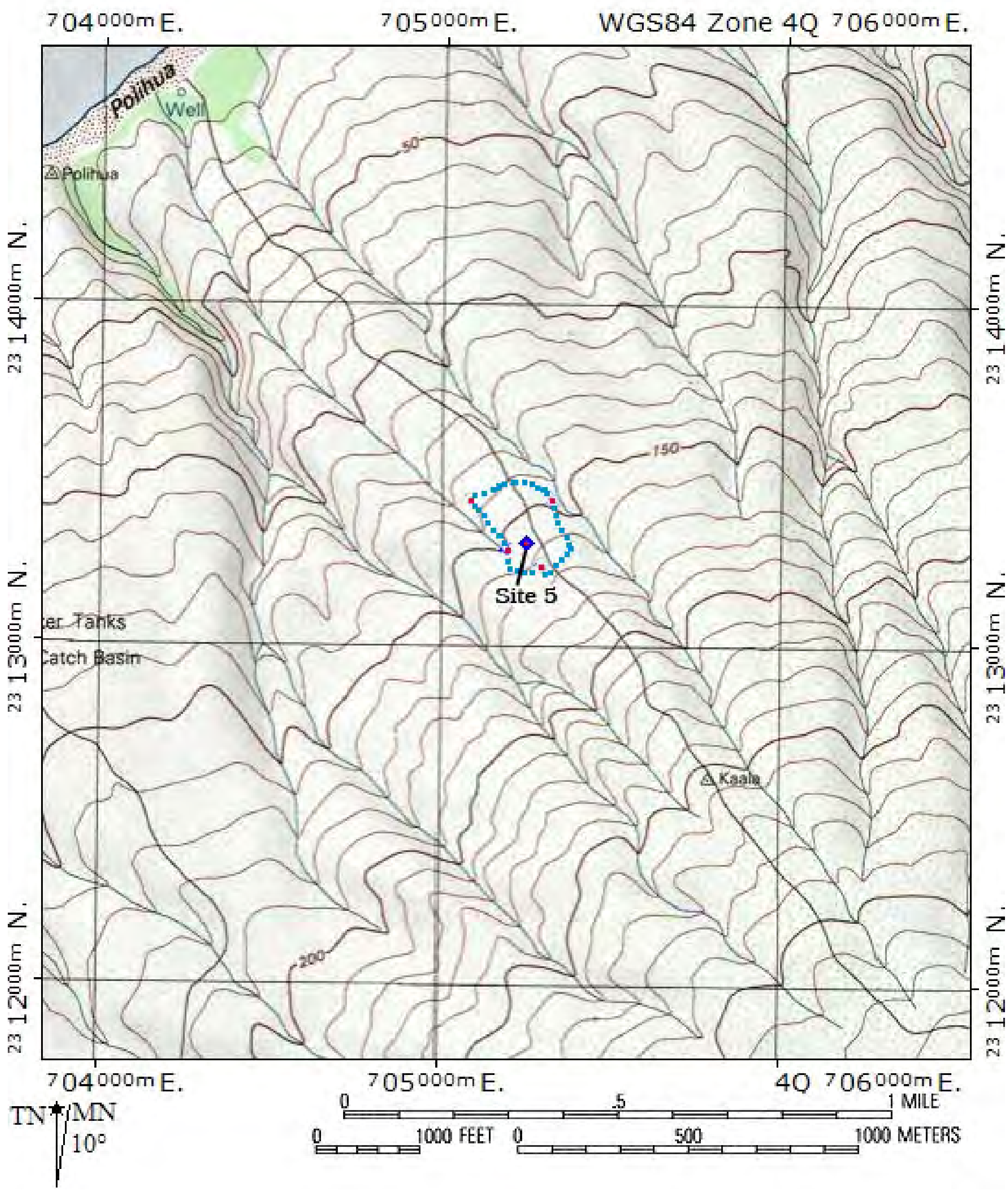

Figure 7. Location and survey area boundary for Site 5, surveyed on November 27, 2007 (GPS recorded waypoints shown in red).

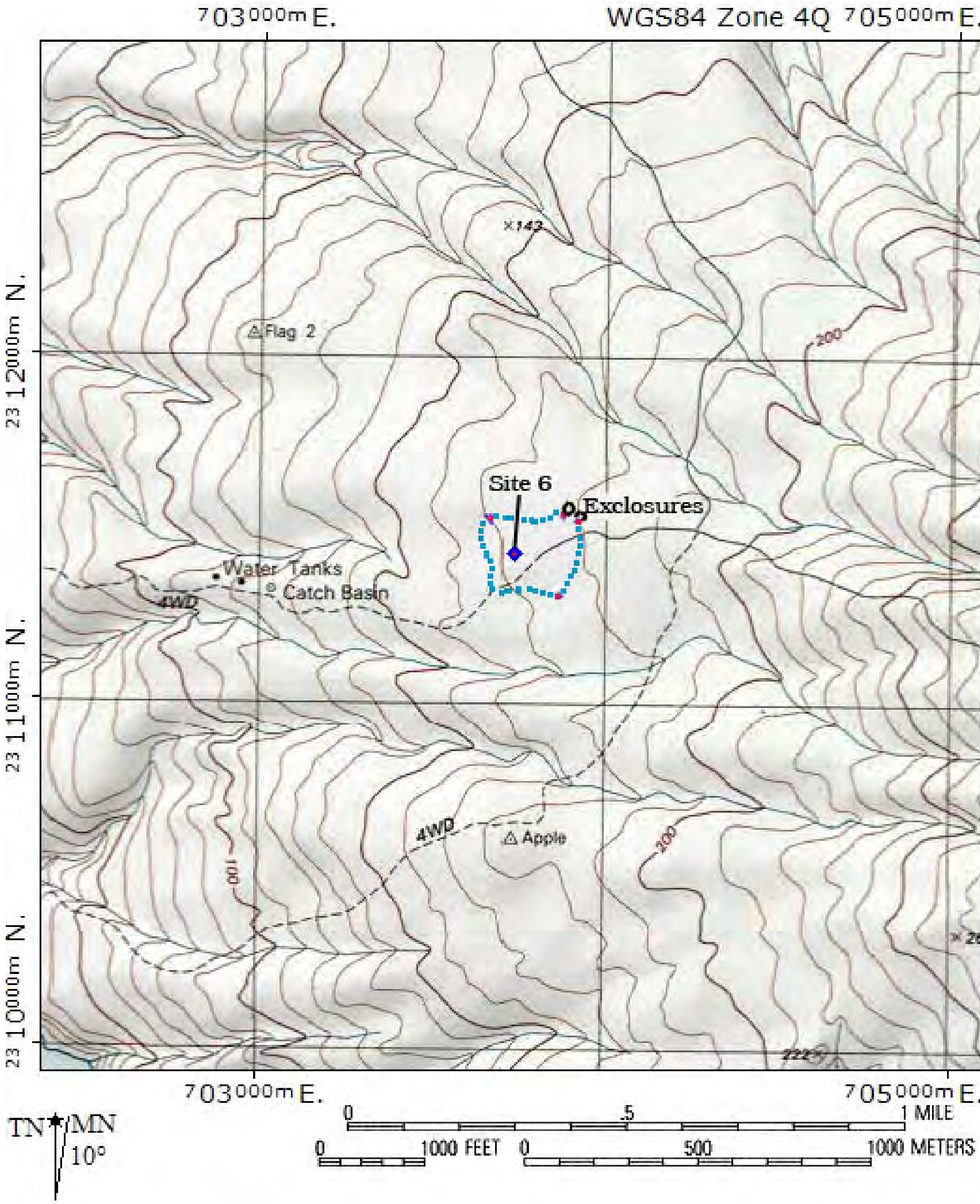

Figure 8. Location and survey area boundary for Site 6, surveyed on November 27, 2007 (GPS recorded waypoints shown in red).

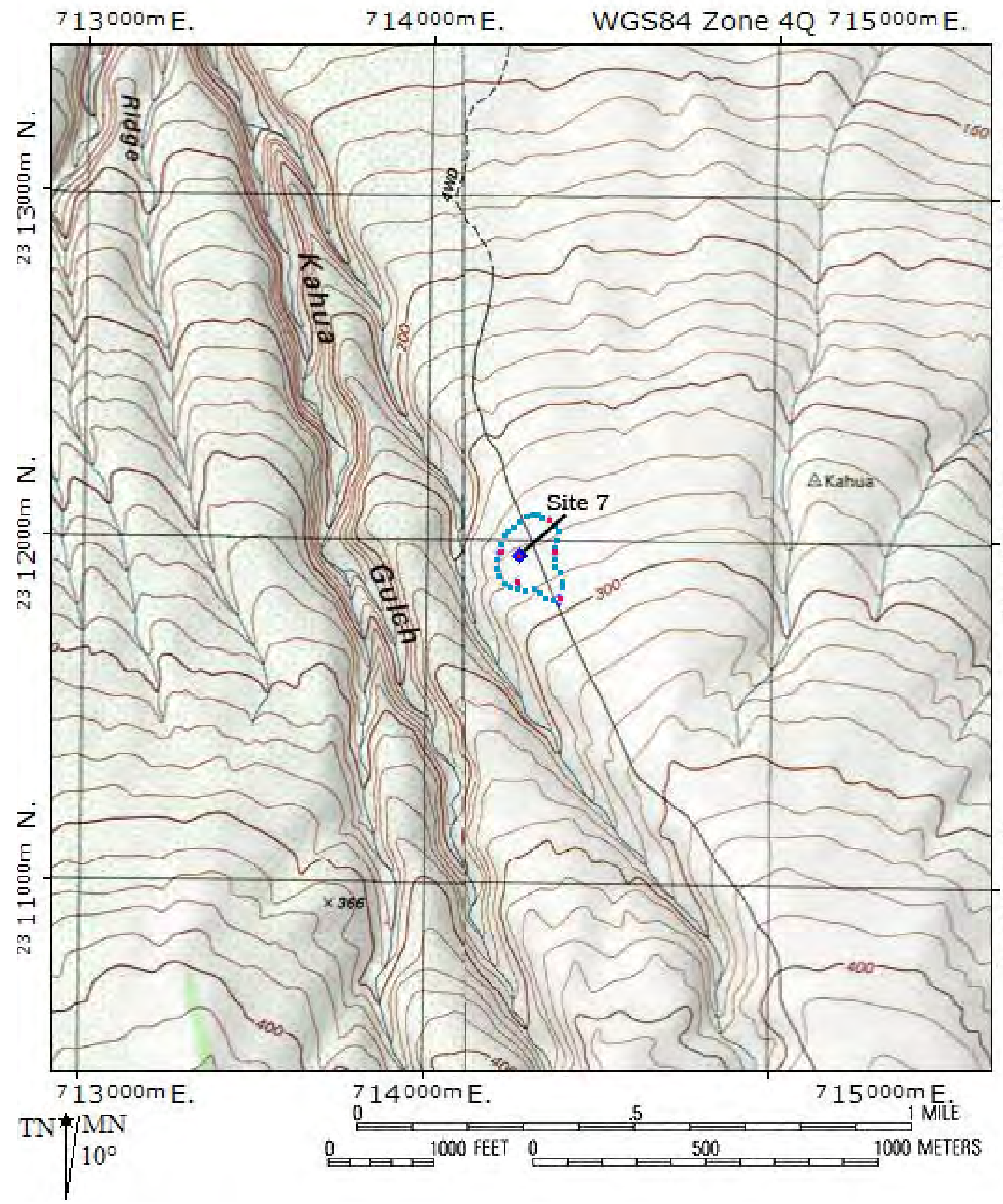

Figure 9. Location and survey area boundary for Site 7, surveyed on November 28, 2007 (GPS recorded waypoints shown in red).

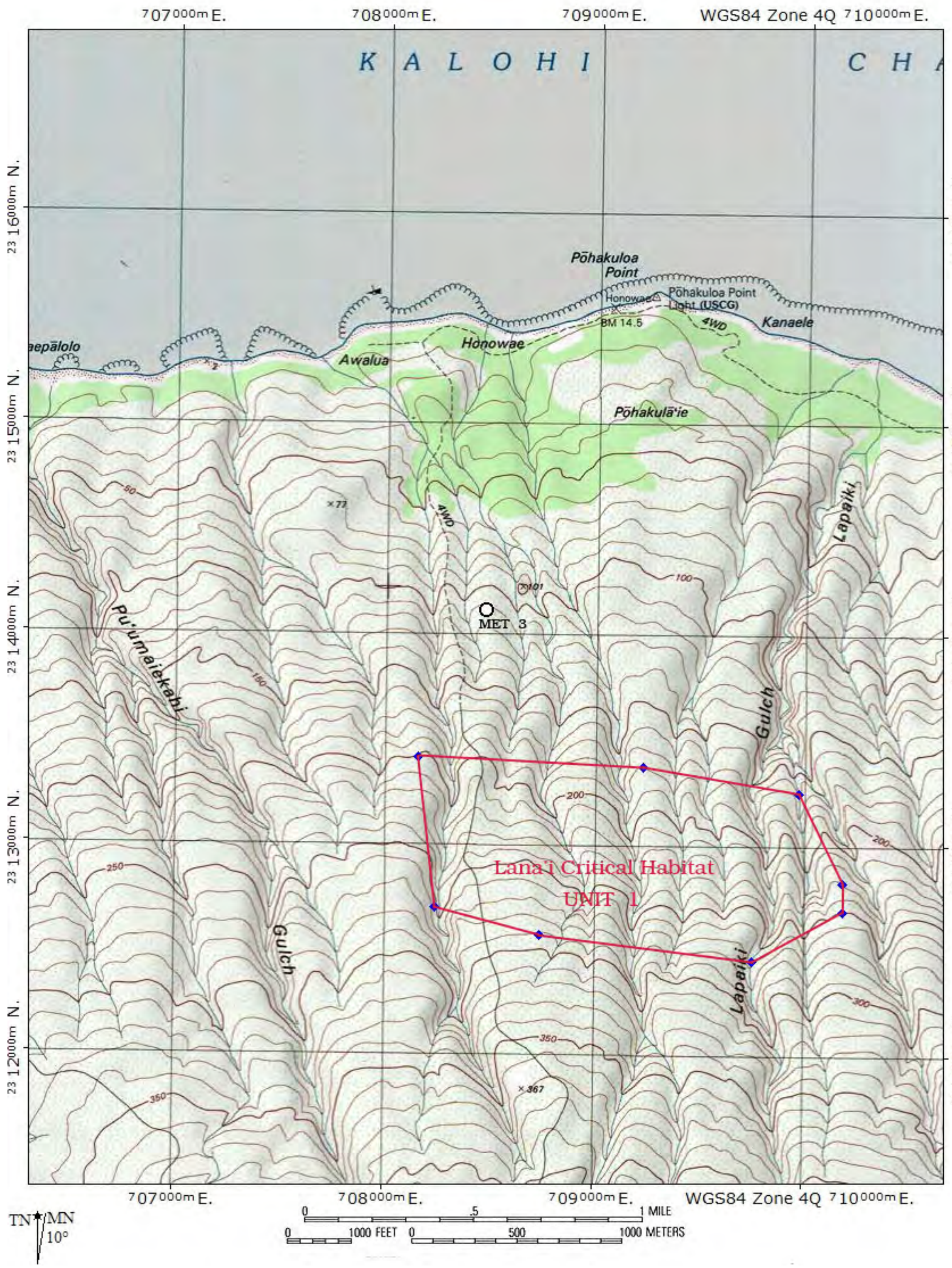

Figure 10. USFWS designated Critical Habitat Unit 1 on Lānaʻi shown in relation to met tower Site 3 (MET 3), the nearest met tower site of the seven proposed.

None of the met tower survey areas is located within a designated Critical Habitat. Met tower Site 3, at 370 feet (113 meters) elevation is located approximately 4000 feet (1200 meters) down slope of Unit 1 (Figure 10). Note that the roadway passing through Unit 1 is specifically exempted from the critical habitat (Federal Register, 2003, §17.96).

General Vegetation Descriptions

A future phase of the botanical efforts to be undertaken on Lānaʻi for the proposed Project will involve mapping of vegetation types within the Project boundary. However, it is valuable to point out here the general vegetation at each of the met tower sites. This vegetation varies from badlands (that is, areas of severe erosion lacking or with extremely sparse plant growth; Figure 11) to grasslands to scrub lands (areas dominated by low or scrubby bushes; Figure 12).

Figure 11. Margin of a badlands area showing invasion by *ʼilima*.

Met tower Site 1 (Figure 3) is in a badlands area. Vegetated land beyond the severely eroded ground covering most of the area is grassland where Angleton grass (*Dichanthium aristatum*) predominates. Very scattered shrub growth consists of ʻaʻaliʻi (*Dodonaea viscosa*), lantana (*Lantana camara*), and ʻuhaloa.

Met tower Site 2 is located further down the interfluve from Site 1 (Figure 4). In this area, the grassland is dominated by Angleton grass and pili grass (*Heteropogon contortus*), with ʻaʻaliʻi common as a low shrub. Another grass, Natal redtop (*Melinus repens*) is prominent. Other plants regularly encountered are ʻilima (*Sida fallax*), ʻuhaloa, lantana, and partridge pea (*Chamaecrista nictitans*). A native shrub, *Lipochaeta heterophylla*, is present in this area, as is an endemic vine, *Ipomoea tuboides*.

Figure 12. Heavily grazed grassland and low-growing shrubs (ʻaàliʻi) at Site 7.

Met tower Site 3 is located well downslope near the coast (at 370 feet or 113 meters) on the road to Awalua (Figure 5). Areas of dense Guinea grass (*Urochloa maxima*) and Christmas berry (*Schinus terebinthefolius*) growth occur along the road further upslope, but the grassland at Site 3 is very open and dominated by a mix of pitted beardgrass (*Bothriochloa pertusa*) and native pili grass. A gulch between the site and the road contains kiawe (*Prosopis pallida*) and indigenous *Abutilon incanum*. A distance of some 0,75 mile (1.2 kilometers) up the road from Site 3 is a small fenced exclosure. This exclosure is located along the northern edge of Critical Habitat Unit 1 (Federal Register, 2003; see Figure 10). The only native plant species seen within the exclosure was a *Bidens* (possibly a hybrid). This plant was, however, more abundant immediately outside the exclosure than inside it. The fence may have been erected to prevent herbivory on germinating of *Tetromolopium remyi* seeds potentially in the soil.

Met tower Site 4 (Figure 6) is located on the central ridge beyond (west of) the Garden of the Gods. A part of the site is badlands. This site is mostly grassland of Angleton grass, but includes significant areas of Guinea grass and shrubland. The shrubland is exclusively low growing ʻaʻaliʻi mixed with Angleton grass in the center of the site, but other areas are a mix of lantana, Guinea grass, and koa haole (*Leucaena leucocephala*). The plants here display greater stature than the grasses and shrubs seen at other sites.

Met tower Site 5 is located off the road to Polihua Beach, at about 490 ft (150 m) in elevation (Figure 7). This area is very open grassland of mostly pili grass and pitted beardgrass. A shallow gulch with kiawe trees lies off to the west. The most common shrubs in this area are klu (*Acacia farnesiana*) and ʻuhaloa.

Met tower Site 6 (Figure 8) already has a met tower erected and is being used to survey interactions between the tower, guy wires, and birds. Although much of the site is fairly open, this site is best described as a koa haole shrubland. Klu is common. The dominant grass is pitted beardgrass, with a few areas dominated by pili grass. Two fenced exclosures are located just outside the survey area, approximately 650 feet (200 meters) from the erected tower. Only one of the exclosures appeared to contain an unusual plant, a single specimen of the endangered *Hibiscus brackenridgei.* The fenced exclosures will not be disturbed by Project activities to ensure no impacts on this specimen.

Met tower Site 7 is located on the interfluves east of Kahua Gulch, furthest east of the proposed met tower sites, and is reached by a 4-wheel drive road off State Route 44 (Figure 9). The grass here appeared either severely cropped or lagging behind the grasses observed at the other sites in reaching maturity (Fig. 11). Both pili and pitted beardgrass are present, and the latter is presumed to be the dominant species over much of the site. However, this site included upslope of the central point, a dense scrub growth of native ʻaʻaliʻi, unusual among all the locations surveyed in the density and monotypic nature of the growth. Another native shrub, *Lipochaeta heterophylla*, and the native vine, *Ipomoea tuboides*, are present in this area, although less abundant than at Site 2.

Flora

A plant checklist (Table 2) was compiled from the observations made on the wandering transects conducted over each of the seven sites. Entries in Table 2 are arranged alphabetically under family names. Included are the scientific name, the common name, and status (whether native or introduced) of each species. The nomenclature of the flowering plants follows that of Wagner, Herbst, and Sohmer

(1999) for both the native and naturalized plants. Names for ferns (only one species was recorded) follow Palmer (2003).

A total of 54 species of flowering plants (and one fern) are listed for all seven met tower sites combined. Of the 55 plant species identified, 13 are regarded as native to the Hawaiian Islands (either indigenous or endemic), or 23.6% of the species. This proportion of natives (nearly one-quarter of the species present) is high compared with most disturbed areas in the Hawaiian Islands. On Oʻahu, lowland and middle elevation sites seldom exceed 12% native species (and are typically under 3%) and the number of natives is typically low. On northern Lānaʻi, the natives at most of the met tower sites remain significant in their abundance.

The native endemics include the fern (*Doryopteris decipiens*), a fairly widespread species in the islands. Less common are the shrub, *Lipochaeta heterophylla,* and the vine, *Ipomoea tuboides.*

Discussion

None of the plants observed at or surrounding (within 100 meters) the seven met tower sites are federally listed, are particularly rare on Lānaʻi, or would require special care to be taken in planning or erecting the met towers. While the native endemics found at a few of the sites are not afforded special protection, minimal anticipated disturbance erecting the met towers should provide ample protection for these somewhat rare representatives of a once more flourishing native community.

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Table 2. Listing of plant species observed at seven meteorological sites on Lānaʻi on November 26-28, 2007.

FAMILY / *Species Name*	COMMON NAME	STATUS	TOWER SITE No. 1	2	3	4	5	6	7	Notes
FERNS & FERN ALLIES										
PTERIDACEAE										
Doryopteris decipiens (Hook.) J. Sm.		**end**	--	--	U	--	U	--	--	
FLOWERING PLANTS DICOTYLEDONES										
ANACARDIACEAE										
Schinus terebinthifolius Raddi	Christmas berry	nat	O	--	--	R	--	--	--	
ASTERACEAE										
Acanthospermum australe (Loefl.) Kuntze	Paraguay burr	nat	--	--	--	R	--	--	--	
Ageratum cf. *conyzoides* L.	---	nat	--	--	--	--	--	R	--	(4)
Bidens sp.		nat	--	--	R	--	--	--	--	(4)
Conyza bonariensis (L.) Cronquist	hairy horseweed	nat	R	--	--	--	--	--	--	
Cirsium vulgare (Savi) Ten.	bull thistle	nat	R	--	--	--	--	--	--	(4)
Emilia fosbergii Nicolson	Flora's paintbrush	nat	(1)	(1)	(1)	U	(1)	(1)	(1)	(2)
Heterotheca grandiflora Nutt.	telegraph weed	nat	R	--	--	--	--	--	--	(4)
Hypochoeris radicata L.	hairy cat's ear	nat	--	--	R	--	--	--	--	(4)
Lipochaeta heterophylla A.Gray	---	**end**	--	O1	--	--	--	--	U1	
Pluchea carolinensis (Jacq.) G.Don	sourbush	nat	--	--	--	--	R	--	--	(4)
Sonchus oleraceus L.	sow thistle	nat	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(4)
CONVOLVULACEAE										
Convolvulus arvensis L.	field bindweed	nat	--	--	--	--	R	--	--	(3)
Ipomoea cairica (L.) Sweet	*koali ʻai*	**ind?**	--	--	--	R	--	--	--	(4)
Ipomoea tuboides Degener & Ooststr.	*hunakai*	**end**	--	U	--	--	--	--	R	(4)
CUSCUTACEAE										
Cuscuta cf. *sandwichiana* Choisy	*kaunaʻoa*	**end**	--	--	--	--	--	--	R	
FABACEAE										
Acacia farnesiana (L.) Willd.	*klu*	nat	--	O	O	--	C	C	--	
Chamaecrista nictitans (L.) Moench	partridge pea	nat	O2	(1)	U	O	O	R	U	(1)
Desmodium incanum DC	Spanish clover	nat	--	--	--	R	--	--	--	

Table 2 (continued).

FAMILY Species Name	COMMON NAME	STATUS	TOWER SITE No. 1	2	3	4	5	6	7	Notes
FABACEAE (continued)										
Desmodium sandwicense E. Mey.	Spanish clover	nat	--	--	--	R	--	--	--	
Desmodium triflorum (L.) DC	---	nat	--	--	--	R	--	--	--	
Indigofera suffruticosa Mill.	indigo	nat	R	--	--	--	--	--	--	
Leucaena leucocephala (Lam.) de Wit	*koa haole*	nat	U	U	--	O	--	AA	R	
Macroptilium lathyroides (L.) Urb.	cow pea	nat	--	--	(1)	R	(1)	R	--	
Prosopis pallida (Humb. & Bonpl. ex Willd.) Kunth	*kiawe*	nat	--	O	O2	--	O2	O	--	
MALVACEAE										
Abutilon incanum (Link) Sweet	hoary abutilon	**ind?**	--	--	U	--	R	U	--	
Malva parviflora L.	cheeseweed	nat	--	--	--	--	--	R1	--	
Malvastrum coromandelianum (L.) Garcke	false mallow	nat	--	--	R	--	--	--	--	
Sida fallax Walp.	*ʻilima*	**ind**	O	C	O	U	C	O	A	
MENISPERMACEAE										
Cocculus orbiculatus (L.) DC.	*huehue*	**ind**	R	--	--	R	--	--	--	
MOLLUGINACEAE										
Mollugo cerviana (L.) Ser.	threadstem carpetweed	nat.	--	--	--	--	--	R	--	(3)
MYOPORACEAE										
Myoporum sandwicense A.Gray	*naio*	**ind**	R	--	--	--	--	--	R	
OXALIDACEAE										
Oxalis corniculata L.	*ʻihiʻai*, yellow wood sorrel	**ind?**	R	--	--	R	--	--	--	
PASSIFLORACEAE										
Passiflora suberosa L.	*huehue haole*	nat	R	--	--	--	--	--	--	(4)
PLANTAGINACEAE										
Plantago lanceolata L.	narrow-leaved plantain	nat	O2	--	--	O	--	--	(1)	
PORTULACACEAE										
Portulaca oleracea L.	pig weed	nat	--	--	--	--	--	R	--	(4)
SAPINDACEAE										
Dodonaea viscosa Jacq.	*ʻaʻaliʻi*	**ind**	AA	A	--	A	--	--	AA	
SOLANACEAE										
Solanum linnaeanum Hepper & P. Jaeger	apple of Sodom	nat	R	--	--	R	--	--	--	

Table 2 (continued).

FAMILY / *Species Name*	COMMON NAME	STATUS	TOWER SITE No. 1	2	3	4	5	6	7	Notes
STERCULIACEAE										
Waltheria indica L.	*'uhaloa*	**ind?**	A	C	O	U	C	O	C	(2)
VERBENACEAE										
Lantana camara L.	lantana	nat	C	O	O	O	O2	O	O	(2)
Stachytarpheta jamaicensis (L.) Vahl	Jamaican vervain	nat	U2	--	--	U	R	R1	O	
	FLOWERING PLANTS									
	MONOCOTYLEDONES									
POACEAE										
Bothriochloa pertusa (L.) A.Camus	pitted beardgrass	nat	--	A	AA	--	A	AA	(3)	
Cenchrus ciliaris L.	buffelgrass	nat.	--	--	O	--	U3	R1	--	
Cynodon dactylon (L.) Pers.	Bermuda grass	nat	O3	--	--	U2				
Dichanthium aristatum (Poir.) C.E.Hubb.	Angleton grass	nat	AA	AA	--	AA	--	--	U2	
Digitaria insularis (L.) Mez ex Ekman	sourgrass	nat	U3	--	R	R1	--	--	--	
Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.	*pili*	**ind?**	--	AA	A	--	AA	O	O2	
Melinis minutiflora P.Beauv.	molasses grass	nat	U1	--	--	R	--	--	--	
Melinis repens (Willd.) Zizka	Natal redtop	nat	R	C	U	U	R1	--	R	
Paspalum dilatatum Poir.	Dallis grass	nat	R2	--	--	R	--	--	--	
Sporobolis cf. *africans*	African dropseed	nat	R	--	--	--	--	--	--	
Setaria gracilis Kunth	yellow foxtail	nat	R	--	--	--	--	--	--	
Urochloa maxima (Jacq.) R. Webster	Guinea grass	nat	R	--	--	O3	R	--	U	
Indet no. 1 "vernal"	---	nat	--	O	U	--	U	--	--	

Status = distributional status

- **End**. = endemic; native to Hawaii and found naturally nowhere else.
- **Ind**. = indigenous; native to Hawaii, but not unique to the Hawaiian Islands.
- **Ind?** = Possibly indigenous or an early Polynesian introduction.
- Nat. = naturalized, exotic, plant introduced to the Hawaiian Islands since the arrival of Cook Expedition in 1778, and well-established outside of cultivation.

Abundance = occurrence ratings for plants:

- R – Rare - only one or two plants seen.
- U - Uncommon - several to a dozen plants observed.

Table 2 (continued).

O - Occasional - More than a dozen plants seen, but encountered infrequently.
C - Common - considered an important part of the vegetation and encountered regularly.
A - Abundant - found in large numbers; may be locally dominant.
AA - Abundant - abundant and dominant; a vegetation defining species for the survey site.
Numbers (1-3) after an abundance rating for a species indicate modifications for localized abundance increases as per the following examples:

R1 – species encountered perhaps once, but several plants seen together.
O2 – a species encountered only occasionally, but seen in clusters of several to many specimens.
U3 – plant uncommon in its distribution, but very numerous where encountered.

Notes:

(1) Present only as numerous seedlings.
(2) Also present as numerous seedlings.
(3) Not previously recorded from the island of Lānaʻi.
(4) Observed, but without flower or fruit and ID therefore tentative.

Appendix 6

Post-Construction Monitoring Protocol

POST-CONSTRUCTION MONITORING PROTOCOL FOR THE LĀNA‘I METEOROLOGICAL TOWERS PROJECT, LĀNA‘I, HAWAII

PREPARED FOR

Castle & Cooke Resorts, LLC

PREPARED BY

TETRA TECH EC, INC.

August 2008

POST-CONSTRUCTION FATALITY MONITORING PROTOCOL FOR THE LĀNAʻI METEOROLOGICAL TOWER PROJECT, LĀNAʻI, HAWAII

On August 8, 2007, the State of Hawaii's Department of Land and Natural Resources (DLNR) issued Castle & Cooke Resorts, LLC (Castle &Cooke) Conservation District Use Permit (CDUP) LA-3419 to conditionally approve the installation of one temporary meteorological (met) tower at site number 6 and preliminarily approve installation of the remaining six met towers on the Island of Lānaʻi, Maui County, Hawai'i. Met tower 6 was erected on August 28, 2007. The six additional towers were approved for installation by DLNR on December 10, 2007. Six of the seven towers were installed by February 8, 2008 and the seventh tower has not yet been installed. The towers will remain in operation through March 1, 2010. These towers will collect data on wind speeds and patterns throughout the northern portion of the island. This data, in turn, will be used to determine the feasibility of a commercially viable wind energy facility. Castle & Cooke is committed to developing renewable energy on the Island of Lānaʻi while preserving the unique environmental, cultural, and historic resources found on the island.

Four federally and state endangered or threatened species have the potential to occur or are known to occur on Lānaʻi within the vicinity of the wind resource area (WRA). Castle & Cooke is in the process of conducting a comprehensive radar study to determine the presence of endangered Hawaiian Petrels, Hawaiian hoary bats, Hawaiian stilts, and threatened Newell's shearwaters near proposed met tower locations and throughout the larger WRA. The Hawaiian petrel is known to nest on the island and has been observed within the WRA. The presence of the Hawaiian hoary bat and Newell's shearwater has been documented on Lānaʻi but their breeding status on the island is not known. Hawaiian stilts occur at the wastewater treatment plant, and one stilt was observed flying over the WRA during the summer 2007 radar surveys.

A post-construction monitoring protocol was developed to assess potential impacts to these species as a result of met tower operation. The primary objective of the monitoring protocol is to determine whether any of the four federally and state listed species are impacted as a result of collision with one or more of the met towers and to ensure compliance with the provisions and limitations of the Habitat Conservation Plan (HCP) for the Construction and Operation of the Lānaʻi Meteorological Towers and the Incidental Take Permit/Incidental Take License (ITP/ITL) to be issued by the U.S. Fish and Wildlife Service (USFWS) and DLNR, respectively. Monitoring will also document impacts to other non-listed species. The monitoring program will identify bird and/or bat fatalities within the study area by using systematically conducted, standardized carcass searches, carcass removal (scavenging) trials, and searcher efficiency trials. Although direct take of bats by met towers will be assessed through carcass searches, this monitoring protocol is designed primarily to detect seabird take.

The protocol described below outlines a minimum number of surveys and trials and provides an adaptive management approach to monitoring the met towers. The methods and timing of measures can be modified over time to increase the effectiveness and efficiency of the program, as needed. However, any recommended changes to the minimum number of surveys and/or trials from the baseline provided in this protocol would require review and approval by USFWS and DLNR/Division of Forestry and Wildlife (DOFAW). The protocol includes 1) standardized carcass searches to monitor potential injuries or fatalities, 2) carcass scavenging trials to assess seasonal, site-specific carcass removal rates by scavengers, and 3) searcher efficiency trials to assess observer efficiency in finding carcasses. If any of these listed species are documented to be killed as a result of collision with a met tower, the observed direct take will be evaluated and adjusted accordingly based on searcher efficiency trials to ensure compliance with the authorized HCP and ITP.

1.0 STANDARDIZED CARCASS SEARCHES

Carcass searches will be conducted to estimate the number of avian and bat fatalities attributable to the met towers. An estimate of the total number of carcasses will be made by adjusting for removal bias (affected by scavenging) and searcher efficiency bias (affected by detection) (see Sections 2.0 and 3.0). The methods, timing, and duration of the carcass searches are described below.

1.1 Methods

Personnel trained in proper search techniques ("the searchers") will conduct carcass searches at each of the met tower locations. Boundaries of square plots will be delineated along each met tower to be searched. A strip transect design is appropriate for this study, providing almost 100 percent coverage of the search area. Each search plot will be split into four quadrants, with each searched sequentially. This facilitates the searchers ability to stay on transect lines and maximize searching efficiency (Gritski pers. comm. 2006).

When conducted for wind turbines, typically, plot size extends outward from the base of a wind turbine a minimum distance equal to the turbine height. However, other research in the 1990s through the early 2000s has shown that most birds and bats killed in collisions with wind turbines remain within 63 meters (207 feet) of the turbine (Orloff and Flannery 1992, Higgins et al. 1996 (as cited in Young et al. 2003), Johnson et al. 2002). Young et al. 2003 conducted carcass searches for met towers approximately 38 meters (125 feet) in height at the Foote Creek Rim Wind Plant within 63 m (207 feet) of each tower. Casualties were documented at this project between 3 meters to 50 meters from the met towers with an average distance of 23 meters.

Met towers to be erected on Lāna'i are 50 meters (165 ft) tall with a guy wire radius of 30.5 to 33.5 meters (100 to 110 feet). Based on the results from previous wind power research, all areas within 63 meters from each met tower at Lāna'i will be searched. If the results from the initial carcass surveys show that the plot size is too large or small, the area will be adjusted accordingly pending approval by USFWS and DLNR/DOFAW. Geographic Positioning System (GPS) locations of the search plot corners will be included in initial data collection. Transects will be set at approximately 6 meters (19.7 feet) apart, depending on the habitat type, and the searcher will walk along each transect searching both sides out to 3 meters (10 feet) for fatalities. Search area and speed may be adjusted by habitat type, after evaluation of the first searcher efficiency trial, if needed. In addition, monitoring plots will be marked in such a way that searchers can easily walk the transects so they can concentrate on searching for carcasses. Materials used to identify the search area may include but are not limited to flagging, stakes or other visible item.

If carcasses of a listed species are found, searchers will follow the Downed Wildlife Protocol (**Attachment 1**), and carcasses will be left in place and moved only if directed by DOFAW or USFWS. If directed to move the carcasses, searchers will deliver carcasses to Service Law Enforcement who will send them to a forensics lab for future reference and necropsy. The original USFWS Special Purpose Permit was issued on September 21, 2007, and the Protected Wildlife Permit on DOFAW February 2008.

All carcasses (avian and bat) found during the standardized carcass searches will be recorded and identified by a unique number. A copy of the data sheet for each carcass will be kept with the carcass at all times. For each carcass found, searchers will record species, sex and age when possible, date and time collected, location, condition and any comments that may indicate cause of death (**Attachment 2**). Searchers will record the condition of each carcass found, using the following condition categories:

- Intact – a carcass that is completely intact, is not badly decomposed and shows no sign of being fed upon by a predator or scavenger
- Scavenged – an entire carcass that shows signs of being fed upon by a predator or scavenger, or portions of a carcass in one location (e.g., wings, skeletal remains, legs, pieces of skin, etc.)
- Feather Spot – 10 or more feathers at one location indicating predation or scavenging or 2 or more primary feathers

Searchers will photograph each carcass as found and establish GPS points. A detailed map of the search area can then be created showing the location of the met towers and associated facilities, the study area, and any carcasses located.

The searchers may discover carcasses incidental to formal carcass searches (e.g., predation or while driving within the project area). For each incidentally discovered carcass, the searcher will identify, photograph, and record data for the carcass as would be done for carcasses found during formal scheduled searches.

Any injured native birds found on the facility site will be carefully captured by a trained project biologist or technician and transported to a local wildlife rehabilitator. All project staff and consultants will be trained on how to handle any downed wildlife or carcasses found anywhere within the project area. Furthermore, a Downed Wildlife Incident Report (**Attachment 3**) will be completed for any injured animal or fatality.

1.2 Important Considerations

Important factors to consider in developing the monitoring plan include target species size and the type of vegetative cover being surveyed. The Hawaiian petrel and Newell shearwater are relatively large birds with wingspans over 30 inches. Hawaiian stilts are slender birds approximately 16 inches in length. Downed individuals should be detectable compared to smaller bird species and most bats. The Hawaiian hoary bat is much smaller (10.5 – 13.5 inches), with darker coloring, so it will make individuals much more difficult to detect using visual searches (USFWS, 1998). Some of the met tower sites are densely vegetated with shrub/scrub habitat while other areas are open grasslands or are barren of vegetation. However, vegetation maintenance should provide a more consistent vegetation type between towers.

2.0 CARCASS SCAVENGING TRIALS

"Carcass scavenging or removal" is the disappearance of a carcass from the search area due to scavenging. This may serve as a potential source of bias associated with fatality rate estimation. Scavengers may preclude detection of carcasses or make it problematic to identify remains and determine cause of death. Thus, seasonal differences in scavenging rates (i.e., changes in scavenger population density) and possible differences in the size of animal being scavenged are typically taken into account when estimating fatality. Additionally, the timing of fatality searches must be conducted at a frequency that minimizes loss due to scavenging.

The objective of the carcass scavenging trials is to document the length of time avian carcasses remain in the search area and subsequently determine the frequency of carcass searches within the search plots. Carcass scavenging trials will be conducted during each season in the vicinity of the search plots. Carcass scavenging rates will be used to adjust carcass surveys for removal bias. Removal rates will be determined for each season.

Carcasses used in the trials may include representatives of the seabirds if legally available and permitted by USFWS and DOFAW; bat carcasses will not be available for scavenging trials. Castle & Cooke will coordinate with DOFAW and USFWS to follow appropriate protocols in using carcasses during carcass scavenging trials. Carcasses of non-native passerines, commercially available game bird chicks or legally obtained native birds may be used to simulate bats if another appropriate alternative is not designated. Carcasses of legally obtained wedge-tailed shearwaters, commercially available adult game birds, or cryptically colored chickens will be used to simulate seabirds.

To avoid confusion with met tower-related fatalities, planted carcasses will not be placed in fatality monitoring search plots. Planted carcasses will be placed in the vicinity of met towers but not so near as to attract scavengers to the search plots. The planted carcasses will be located randomly within the carcass scavenging trial plots.

Carcasses will be placed in a variety of postures to simulate a range of natural conditions. For example, birds will be: 1) placed in an exposed posture (e.g., thrown over the shoulder), 2) hidden to simulate a crippled bird (e.g., placed beneath a shrub or tuft of grass) and, 3) partially hidden. Trial carcasses will be marked discreetly for recognition by searchers and other personnel. Trial carcasses will be left at the location until the end of the carcass scavenging trial.

Carcasses will be checked as follows, although actual intervals may vary. Carcasses will be checked for a period of 28 days to determine removal rates; however, total number of searcher days will be adjusted according to observed scavenging rates. Carcasses will be checked approximately every day for the first seven days, and then on day 10, day 14, day 21, and day 28. This schedule may vary depending on the initial removal rate observed, weather, and coordination with the other survey work. At the end of the 28-day period, any remaining trial carcasses and scattered feathers will be removed.

Each trial will use as many bird carcasses as are available; the target is 10-20 carcasses. The number and distribution of carcasses will be determined on a per site/habitat basis; carcasses will be placed near each operating met tower to account for potential local differences in scavenger populations.

3.0 SEARCHER EFFICIENCY TRIALS

The objective of searcher efficiency trials is to estimate the percentage of bird fatalities that searchers are able to find. Searcher efficiency will be estimated by habitat type and season. Estimates of searcher efficiency will be used to adjust carcass counts for detection bias. Searcher efficiency trials will be conducted on the fatality monitoring search plots in all habitat types.

Searcher efficiency trials will be conducted in each season as defined above, during the period in which the fatality monitoring occurs. Trials will be spread throughout the year to incorporate the effects of environmental variables such as weather and scavenger populations. Key elements of these trials include:

- At least three trials will be conducted in each season.
- Each trial will use a variable number of carcasses so that the searcher will not know the total number of trial carcasses being used in any trial.
- For each trial, birds will be used according to their availability. A suitable substitute will be used for bats but SEEF will not be applied to adjusted take because it is highly unlikely that an incidental take of a bat would occur.
- Wedge-tailed shearwater will be the primary species used for searcher efficiency trials if available. It is anticipated that 2 to 5 carcasses will be used per trial.
- Personnel conducting searches will not know in advance when trials are conducted; nor will they know the location of the trial carcasses.
- Carcasses will be placed in a variety of postures to simulate a range of conditions. For example, birds will be: 1) placed in an exposed posture (thrown over the shoulder), 2) hidden to simulate a crippled bird and 3) partially hidden.
- Each non-domestic carcass will be discreetly marked and located with GPS at the planted site so that it can be identified as an efficiency trial carcass after it is found.
- The number and location of the efficiency trial carcasses found during the carcass search will be recorded.

If new searchers are brought into the search team, additional detection trials will be conducted to ensure that detection rates incorporate searcher differences.

4.0 SAMPLING INTENSITY AND DURATION

The first carcass scavenging trial will be conducted in March 2008 prior to the start of met tower carcass surveys (beginning March 1, 2008) to establish an appropriate survey schedule for the spring 2008 season. This will be very useful in increasing the efficiency of the study since scavenging rate detections will determine the appropriate search frequency. If scavenging is high, search frequency needs to be high (see Arnett 2005).

Carcass searches will begin approximately on March 15, the approximate date that the seabirds return to the colony. Our initial assumption is that scavenging will be low based on the low bird use in the WRA and the low diversity of potential scavengers. However, based on DOFAW and USFWS recommendations, carcass searches will be conducted approximately two times per week or no longer than 3 days apart during the initial scavenging trial. Once data from the initial scavenging trial has been evaluated, the frequency of carcass searches will adjusted accordingly for effectiveness and efficiency for the remainder of the spring 2008 survey season, as approved by DOFAW and USFWS. Similarly, carcass search frequency in subsequent seasons will be determined by scavenging trials conducted at the beginning of each season. Carcass searches will be conducted from March 15 to approximately December 15 (or earlier in December if the petrels have been verified by DOFAW to have left the island), during the two year period in which the temporary met towers are operational. DOFAW and USFWS stated carcass searches are not required between approximately December 15 and March 15, when the seabirds are not on the island. Additional surveys may be conducted after climatic conditions/events, such as storm events, fog, or moonless nights, as these events could increase the likelihood of collisions with met towers. Seasons will be defined as: Spring (March 15 – June 15), Summer (June 16-September 15), and Fall (September 16-December 15 or when DOFAW has verified seabirds have left the colony). The exact day a new trial or surveys may begin or end may vary a few days depending on when the seabirds arrive or leave the colony, site conditions, carcass availability, etc. DOFAW and USFWS will provide Castle & Cooke and/or its consultants sufficient notice prior to conducting a site visit to enable appropriate project staff to participate. Agency staff may also conduct compliance monitoring without prior notice.

Personnel will conduct carcass scavenging trials within each of the seasons defined above during the years in which fatality monitoring occurs. The winter season beginning and ending dates may vary based on when DOFAW biologists confirm seabirds have left or returned to the colony. Trials will be spread throughout the year to incorporate the effects of environmental variables such as weather and scavenger densities.

Changed circumstances such as hurricanes, major storms, fire, and other such events may affect the timing of the surveys. If the met towers are not accessible as a result of storm events or road conditions, and/or staff safety is questionable, the surveys will continue as soon as is safely possible. Castle & Cooke will coordinate with DOFAW and USFWS on such changed circumstances as soon as possible.

5.0 ANALYTICAL METHODS FOR FATALITY ESTIMATES

Estimates of avian fatalities during the life of the met towers are based on the following:

(1) The number of carcasses located during standardized searches for which the cause of death is attributed to the met towers; carcasses found within survey plots are assumed to be the result of the met tower unless other obvious indicators exist.

(2) Carcass scavenging rates expressed as the estimated average time a carcass is expected to remain in the study area and be available for detection by the searchers during the entire survey period.

(3) Searcher efficiency expressed as the proportion of planted carcasses found by searchers.

The following sections describe how the avian fatalities will be quantified.

5.1 Fatality calculations

The estimate of total fatalities is based on the number of fatalities found within the met tower survey plots, confirmed to be attributed to the met tower, and adjusted for the probability that the observer found the carcass and the time that the caresses remained to be found (i.e., was not scavenged). Calculations are based on Young et al. (2003) and are presented below.

5.1.1 Number of carcasses

The average number of carcasses per search period is calculated using:

$$\bar{c} = \frac{\sum_{i=1}^{k} c_i}{k}$$

where c_i is the number of carcasses found at met tower i, and k is the number of met towers searched.

Total number of carcasses found is calculated by:

$$C = k * \bar{c}$$

5.1.2 Searcher Efficiency

Searcher efficiency (p) is calculated as the proportion of the carcasses found by observers divided by the total number of carcasses available to find.

5.1.3 Scavenging rate

The average number of days that a carcass remained on site is calculated using:

$$\bar{t} = \frac{\sum_{i=1}^{k} t_i}{k}$$

where t_i is the number of days each carcass remained on the study area and k is the number of carcasses evaluated.

5.1.4 Mortality estimate

The estimated total number of fatalities is calculated by

$$m = \frac{N * I * C}{k * \bar{t} * p}$$

where N is the total number of met towers, I is the time between searches (days), C is that total number of carcasses during the study period, k is the number of met towers searched, $\bar{t}$ is the mean length of time a carcass remained on the plot, and p is the searcher efficiency.

6.0 RESULTS

Fatality rates will be calculated on a per met tower basis and for the project as a whole. Each season's percent searcher efficiency will be applied to the observed direct take (carcasses found, if any, during searches) to quantify adjusted take (direct and unobserved direct take combined). Variance will not be calculated pursuant to USFWS recommendation. Adjusted take will be compared to the tiered take limits authorized in the HCP. If a Hawaiian petrel, Newell's shearwater, hoary bat, or Hawaiian stilt is documented to be killed as a result of collision with a met tower, the take will be evaluated to ensure compliance with the provisions of the authorized HCP and ITP/ITL.

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Attachment 1
Lānaʻi Downed Wildlife Protocol

LANA'I DOWNED WILDLIFE PROTOCOL *

Downed birds (any seabirds, and or Hawaiian short-eared owl) considered here may be dead or injured at discovery. Hawaiian Bats may also be found and need attention. All need immediate attention by the discoverer.

A ***prioritized*** Contact List of Division of Forestry & Wildlife (DOFAW) Staff follows, prioritized from first to last to contact. It is essential for you to actually speak with a person and not to rely on voicemail as "a contact"; however you may leave a message and then contact the next person in the listing.

DEAD BIRD OR HAWAIIAN BAT:

- Leave in place, DOFAW will do site and circumstantial assessment, make photographs, and measurements before securing and removing bird or bat.

- Contact DOFAW staff about find; Call list, for DOFAW staff, in order for calling:
  1. Fern Duvall 808-264-0922
  2. Jay Penniman 808-280-4114
  3. Christine Costales 808-559-0436
  4. Derwin Kwon 808-357-5090
  5. Mike Coelho (DOCARE) 808-565-7916

FAILSAFE if no one is contacted – call Maui Police Dispatch 808-244-6400 and request that they contact **"Wildlife"**

INJURED BIRD OR HAWAIIAN BAT:

Equipment necessary to have available for response:
- Pet carriers (medium) – 2 available at minimum
- Cardboard small animal (rat/rabbit/hamster) carriers – 2 minimum
- Pieces of artificial turf/outdoor carpeting to place on floors of pet carriers
- Non-tippable shallow dog water-bowls for water; water
- Gloves
- Tent stakes (6)

Procedure
1. Gently pick up and place bird into carrier equipped with turf/carpet (place bat first into cardboard small animal carrier, and this into the pet carrier) Place only 1 bird or bat in a carrier.
2. Mark exact spot of find(s) with tent stake(s)
3. Call DOFAW Contact List - as above
4. Move or transport bird/bat from site subsequent to notification of DOFAW staff and after DOFAW instructions
5. DO NOT feed birds, provide water in bowl. No food or water for Hawaiian bats.

*Protocol provided by DOFAW August 24, 2007

Attachment 2
Lāna'i Avian Fatality Survey Form

Page ____ of ____

Lana'i Downed Wildlife Survey

Location: ____________________	**Observer:** ______________________________	**Date:** ________________
	Start Time: ______________________________	**End Time:** ________________

Environmental Conditions:

Cloud Cover:____ (**0**=about 25%, **1**=26-50%, **2**=51-75%, **3**=76-100%) **Temperature:**_______

Precipitation:____Rain____ Fog____Other____ (**0**=None, **L**=light, **M**=Moderate, **H**=Heavy, Other= Hail, Snow)

Wind:_____ **0**=<1 mph, **1**=1-3 mph (leaves barely move), **2**=3-7 mph (leaves rustle, small twigs move),
3=8-12 mph (sm. Twigs move), **4**=13-18 mph (sm. Branches move) **5**=12-24 mph (lg. Branches move trees sway)

Vegetation: Ave. ht. ______**(cm); Ave. vigor** _____ (**G**= Green, **M** = Mixed, **B** = Brown);
Cover ______% (% ground obscured by plant cover), record details in comments

Tower No.	Species	Sex	Age	Remains	Dir. From Tower	Dist. From Tower	UTM N	UTM E	Approx. Carcass Age	Photo nmbrs	Vegetation Type	Comments

Species: 4-letter code
Sex: sex of animal if known (**M** = Male, **F** = Female); **Age: A** = Adult, **S** = Subadult, **J** = Juvenile
Remains: E=Entire body, **W**=Wing, **F**=Feathers/Fur, S=feather spot (10 or more, or 3 primaries),**B**=Bones, **O**=Other (add to Comments)
Dir. From Tower: Compass direction of carcass from Tower base
Dist. From Tower: Distance (meters) of carcass from Tower
Carcass age: Approximate age in days of carcass remains
Comments: Print notes as needed

Attachment 3

Lana'i Downed Wildlife Incident Report

Downed Wildlife Incident Report

Location	
Date and Time Identified	
Species	
Probably Cause of Injury/Death	
Action Taken	
Other Comments	
Name of Observer	

Appendix 7
Mitigation Program
Scope of Work

MITIGATION PLAN SCOPE OF WORK TO BE COMPLETED BY DIVISION OF FORESTRY AND WILDLIFE

Lānaʻi Meteorological Towers Project

1.0 INTRODUCTION

Castle & Cooke Resorts, LLC (Castle & Cooke) is conducting meteorological data collection throughout the northern portion of Lānaʻi to determine whether the existing wind resource would support the development of a commercial-scale wind energy facility. Biological surveys conducted to date have determined the presence of Hawaiian petrel (*Pterodroma sandwichensis*), Hawaiian hoary bat (*Lasiurus cinereus semotu*), and Hawaiian stilt (*Himantopus mexicanus knudseni*); Newell's shearwaters (*Puffinus newelli*) have not been detected within the proposed project area. As a result, the Division of Forestry and Wildlife (DOFAW) and the United States Fish and Wildlife Service (USFWS) have requested that Castle & Cooke prepare a Habitat Conservation Plan (HCP) and acquire an incidental take license/permit (ITL/ITP) to allow for the potential incidental take of these four federally listed threatened and/or endangered species.

Coordination with DOFAW and USFWS during HCP development determined that a combination of habitat restoration and predator control would likely result in a net benefit for these species. In 2006, DOFAW rediscovered a colony of Hawaiian petrels at the Lānaʻihale. As mitigation for the potential incidental take of the Hawaiian petrel, the Newell's shearwater, and the Hawaiian hoary bat, DOFAW and USFWS recommended restoring disturbed habitat within the petrel colony as well as augmenting DOFAW's existing cat trapping program within the Lānaʻihale. A second tier of mitigation was developed for petrels if Tier 1 take limits are reached, and would include restoration of a larger area. As mitigation for the potential take of Hawaiian stilts, DOFAW and USFWS recommended initiating a cat trapping program in the vicinity of the Lānaʻi wastewater treatment facility, the area where Hawaiian stilts are known to be breeding residents. Castle & Cooke is providing the funds to DOFAW to implement the habitat restoration and predator control program. DOFAW is responsible for the design, implementation, and monitoring of this scope of work.

This scope of work outlines the steps that will be taken to restore three acres (additional three acres for Tier 2) of habitat on Lānaʻihale and augment DOFAW's current predator control program on Lānaʻi.

2.0 LĀNAʻIHALE HABITAT RESTORATION

At Lāna'ihale, much of the potential nesting habitat for Hawaiian petrels and Newell's shearwaters has been degraded by the introduction of ungulates and subsequent establishment of invasive species such as strawberry guava (*Psidium cattleianum*). DOFAW has identified two, three-acre parcels within the Lāna'ihale that offer the opportunity for habitat restoration (see Figure 1). DOFAW selected the two, three-acre parcels based on the following:

- Reliable records of former petrel nesting behavior (Jeffrey, pers. comm.)
- Accessibility
- Uluhe present in isolated patches
- Provide a migration corridor between two gulches with known petrel nesting

As part of the Tier 1 mitigation, DOFAW will restore, at a minimum, one of the three-acre parcels. At its discretion, DOFAW has the option to reallocate the authorized Tier 1 funding to restore the second three-acre parcel.

2.1 Phase I – Site Assessment

Maui Invasive Species Committee (MISC) and DOFAW staff conducted a detailed site assessment of the habitat restoration area to identify any known native and listed plant and animal species as well as cultural resources. Project staff and cooperators on the site will also be trained to recognize and protect native snails and ʻuaʻu burrows and sign (feathers, odor, droppings) which indicate the possible presence of burrows on Lana'ihale. Any native plants, snails or petrel burrows will be mapped and protected throughout restoration and maintenance activities. In the event that burrows are located, they will be mapped and included with existing project burrows which are followed for reproductive success and other ongoing studies. Treatment of the site will require very thorough observation of the entire restoration area to give a high confidence level that all existing burrows will be known. Quantifying recruitment into the site will then be possible with regular searches for new burrows.

DOFAW will map and flag the areas in which vegetation removal will occur. The site will be divided into 12, approximate one-quarter acre management units. Random plots will be established to describe the site. Species composition, size class, canopy closure, slope and aspect will all be recorded. Plots will be permanently marked for evaluation at future dates.

2.2 Phase II – Site Clearing

DOFAW staff recognized strawberry guava (*Psidium cattleianum*) as a serious threat to the Lānaʻihale watershed and the petrel in early 2006. Strawberry guava is widely distributed in the Lānaʻi forest. In areas, it forms mono-typic stands, eliminating, among other species, uluhe fern (*Dicranopteris linearis* and *Diplopterygium pinnatum*) habitat. Uluhe fern is the dominant component of Hawaiian petrel habitat on Lānaʻi. DOFAW has consulted with the MISC, Haleakala National Park, National Tropical Botanical Gardens and others with experience in guava control.

DOFAW has contracted MISC to conduct the initial phase of vegetation removal within the restoration parcel(s). MISC will conduct much of the vegetation removal during the winter and early spring prior to the petrels return to the colony. However, clearing activities will continue throughout the summer and fall according to specific guidelines. Restoration activities will be conducted so as to minimize any disturbance to the petrel colony during the breeding season and potentially to Hawaiian hoary bats if indeed bats breed on Lānaʻi. Clearing activities will not occur in the vicinity of active petrel burrows during the breeding season. The sensitive period for bats is July 1 through September 30. During that time period, five consecutive days of negative bat detections must occur for DOFAW to be able to cut trees greater than 3 meters in height.

Vegetation removal will focus on stems greater than 1 cm. Trees will be cut with chain saws, and cut stumps will be immediately treated with herbicide. All cut material will be chipped, and chips will be distributed on and adjacent to the site in a manner which will minimize the area impacted. Stems larger than 6 inches will be offered to Castle & Cooke for their use or used on site for erosion control if such need is identified. Material of this size having no other use will be placed in such a way that it is naturally recycled into the forest soil.

DOFAW will implement erosion control measures during this initial phase of vegetation removal and on-going maintenance if needed. Erosion control would include the use of appropriate Best Management Practices so as to prevent erosion during storm events on the steep slopes.

The one non-native tree species which will not be removed is the Cook pine (*Araucaria columnaris*). Cook pine has been identified as a significant collector of moisture from clouds and fog. Therefore, it is being utilized to attempt to increase the recharge of the Lānaʻihale aquifer. One of the reasons that Cook pine is a desirable species for this use is the assumption that it will not form a closed canopy forest, pushing the wind blown cloud and fog above ground level. If this assumption holds it should mean that Cook pine can be a component in an otherwise native Lānaʻi forest. The native forest is and was a low stature forest with dense understory (uluhe, etc.). Cook pines would be scattered throughout, at distances which still allow the aerial mating behavior of the petrel to occur without presenting collision hazard.

2.3 Phase III – Site Management

DOFAW staff will monitor and maintain the restoration parcel(s) for the 2-year duration of the meteorological towers project. All stems remaining after the initial clearing will be cut and treated with herbicide. Site specific techniques i.e.: percent triclopyr, triclopyr amine or triclopyr ester, for control will be finalized before control work commences. Staff understands that control techniques will be adaptable, dependant upon conditions and situations found on site.

The majority of stems will be less than 1 cm diameter. Cutting will involve chain saws and hand cutters. Attention and care will be paid to all native plants on the site. Rats (*Rattus* sp.) eat seeds of many native plant species. Project staff will collect ripe seed from native plants, both on the site and across Lānaʻihale as they carry out their other duties. These seeds will be given to the Castle & Cooke plant nursery for propagation. When plants have reached planting age, they will be planted within the restoration parcel(s). If, during the course of the two-year period, seed or appropriate plants become available from other sources, they will be utilized to aid in the re-vegetation of the restoration parcel(s) if needed.

Re-vegetation will utilize Lānaʻi seed and plant stock. Work will be carried out and recorded by management unit. Cutting and treating all the small diameter stems will be an extremely long and demanding task. However, it is a crucial element of the attempt to eradicate strawberry guava in particular. Seed collection needs to happen from the start of the work and continue throughout. This and attention to enhancing the area for existing plants will be accelerated when the small diameter stems are removed. Project staff will have to be constantly vigilant to control re-sprouting of remaining root stock. The seed bank in the area is unknown but certainly exists and new growth must also be identified and controlled. There has been little success in propagating uluhe fern in Hawaiʻi (Romanchak et al. 2005). However, there have been some techniques learned and with these and input from botanists familiar with the plant, staff will attempt to increase the rate of uluhe re-colonization with in the site.

2.4 Phase IV – Monitoring

DOFAW will conduct regular (semi-annual) monitoring surveys within the restoration area throughout the 2-year period and for a period of up to 8 years thereafter or until nesting and/or fledging success of petrels has been documented, whichever comes first (if take of petrels occurs as a result of collision with one or more of the met towers). Plots established during the site assessment will be surveyed throughout the monitoring period. Data collected at each plot will include at a minimum percent cover and dominance of plant species within each plot and wildlife species observations including sign of petrels or burrows. Each plant or animal species will be identified as native, federally or state-protected, or invasive. Management recommendations will be identified after each monitoring event and described in the annual summary reports provided to Castle & Cooke.

3.0 PREDATOR CONTROL

Predation of young and adults is considered one of the primary threats to all four species. Feral cats, barn owls, and rats represent the predators known to occur on Lāna'i that may kill adult or young Hawaiian petrels, Newell's shearwaters, and Hawaiian stilts. An active feral cat population has been documented in the vicinity of the petrel colony and the wastewater treatment plant. DOFAW has established traps in some locations around the colony and does not currently have the staff to conduct regular trapping at the treatment plant. Twenty percent of cats trapped at the petrel colony to date contained seabird remains in their stomachs which suggests cats are a source of mortality. Increasing the trapping efforts for cats at the Lāna'ihale, as well as establishing a regular program at the wastewater treatment plant, would logically have the potential to decrease the number of adult and juvenile birds killed and have a net positive effect on these populations.

3.1 Lāna'ihale Predator Control

As part of the Tier 1 mitigation plan for the met towers, DOFAW will augment their existing predator-control within the petrel colony by adding 20 additional cat traps throughout the Lāna'ihale for a two-year period beginning March 1, 2008; locations will be determined by DOFAW. Traps will be placed in previously disturbed areas; creating new trails through the colony would only provide increased access for the cats to the birds and burrows. The stomach content of cats trapped will be examined to verify the presence of remains of the covered species. Cat tissue will also be analyzed for stable isotopes of carbon and nitrogen to identify prey consumed.

If Tier 2 mitigation is required, an additional 15 traps will be set within the Lāna'ihale for the duration of the meteorological towers project, or March 1, 2010.

3.2 Wastewater Treatment Plan Predator Control

DOFAW will conduct cat trapping within the vicinity of the wastewater treatment facility to mitigate for potential take of Hawaiian stilts. Twelve cat traps will be placed at locations surrounding the wastewater treatment plant; locations will be determined by DOFAW. Cat trapping at the wastewater treatment facility will begin sometime after March 1, 2008 and continue through March 1, 2010.

4.0 MONITORING

DOFAW will provide Castle & Cooke with status reports after each semi-annual monitoring event that will be expanded upon for annual reports to be completed throughout the 2-year project period. DOFAW's annual report for the mitigation program must be submitted to Castle & Cooke by August 15 of each year. Castle & Cooke will then provide DLNR with annual reports for the HCP and mitigation program on August 31, 2008 and August 31, 2009 and will provide a final report 30 days after completion of the project (March 1, 2010). DOFAW will continue monitoring and maintaining the restoration area after the 2-year project period pursuant to the conditions outlined in the Memorandum of Agreement between DOFAW and Castle & Cooke.

5.0 REFERENCES

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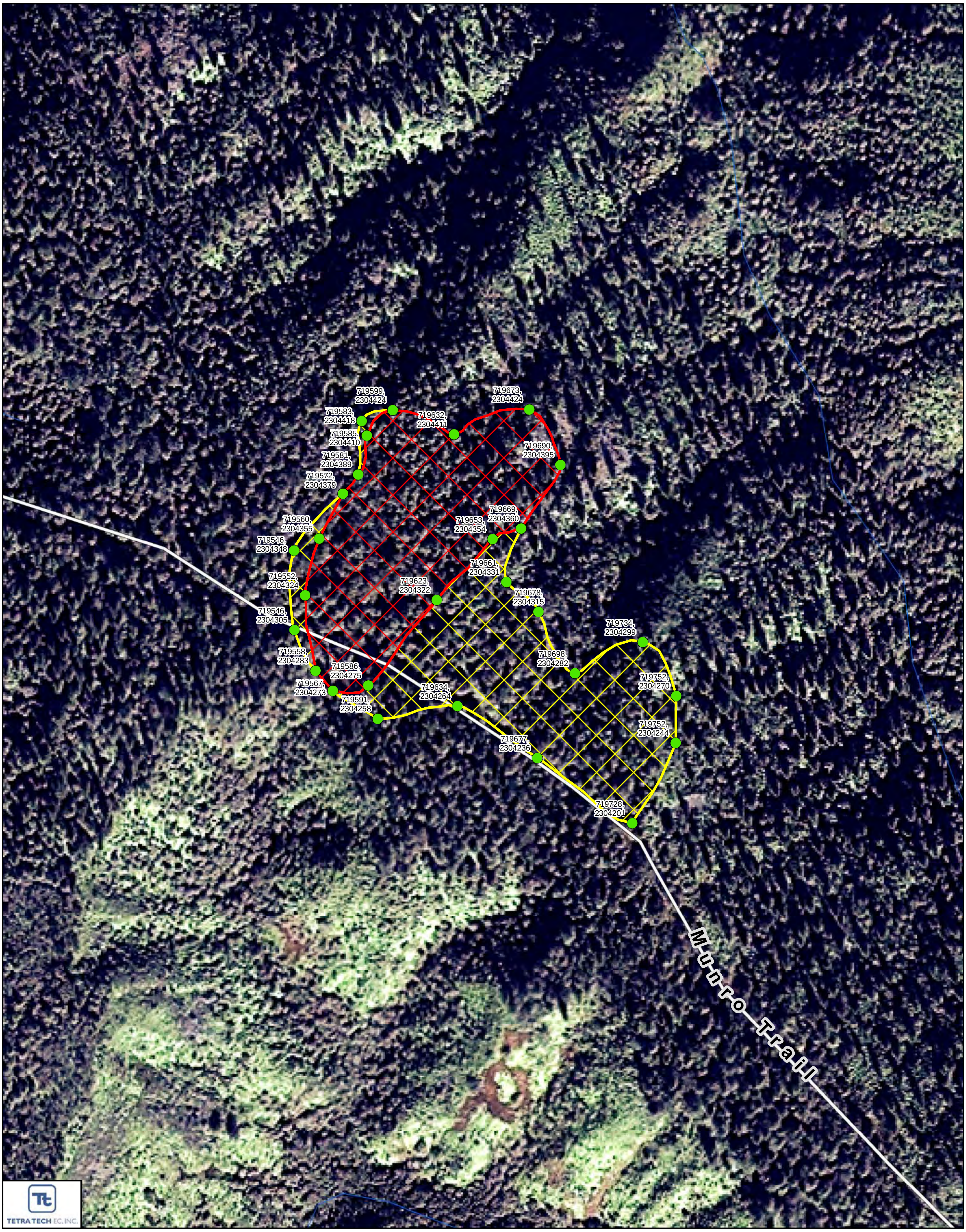

Figure 1. Lāna'i Hale Restoration Area
Castle and Cooke Lāna'i Meteorological Towers Project
Maui County, Hawaii

Restoration Areas

- Tier 1: 3 acres
- Tier 2: 3 acres
- Restoration Area Turning Points
- Local Road

Note: Restoration area turning points are presented as X,Y coordinate pairs in NAD83, UTM Zone 4 North

N

1:2,000

0 25 50 100

Meters

February 13, 2008