Report to the U.S. Fish and Wildlife Service

For

Hawaiian Band-rumped Storm Petrel Project

Permit: TE25955C-0
Grant Agreement: F16AC00833

Reporting Period
January 1, 2019 – December 31, 2019

Submitted By:

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Executive Summary

The Hawaiian Band-rumped Storm Petrel (*Oceanodroma castro*), listed under the Endangered Species Act in 2016, is finally receiving much-needed protection, but little is known about its genetic diversity in the Hawaiian islands. Once widespread, the range of this species is now restricted to small pockets on high elevation steep surfaces that may be better protected from predator threat and light pollution. Due to their low population numbers and remote locations, only one active nesting area, on Hawai'i island, has been confirmed, despite other evidence suggesting they are indeed nesting on multiple Hawaiian islands. With only a few hundred individuals remaining, the Hawaiian populations may have problems normally associated with small numbers, including demographic stochasticity and inbreeding. The efforts carried out with this permit are aimed at conserving these remnants of a once flourishing Hawaiian species. These efforts include studying nesting behavior to determine nest-site preferences and modern DNA-genetic analyses to determine the inbreeding status, interisland connectivity, and the potential for establishment of novel colonies. These studies are labor-intensive and require expenditures of funds for supplies, equipment for molecular genetics and reagents. This report details the objectives achieved during the final year of this project.

Attachments

1. State of Hawaiʻi, Division of Land & Natural Resources, Protected Wildlife Permit.

Introduction

This report fulfills the annual reporting requirements for the permit and grant agreements listed below. The reporting period is January 1, 2019 – December 31, 2019. This is the final report for the grant agreements under F16AC0033.

Permit
Number: TE25955C-0
Effective date: July 13, 2017
Expiration Date: July 12, 2022

Grant Agreement
Number: F16AC0033
Effective date: October 1, 2016
Expiration date: December 29, 2019

Sharp declines in seabird populations in the Hawaiian Islands have occurred since the introduction of nonnative mammals such as rats, cats, and mongoose. Species are threatened due to habitat loss, invasive predators, anthropogenic impacts, and climate change. Many of these seabird populations may have experienced population bottlenecks, resulting in decreased genetic diversity. One of these seabirds, the Hawaiian Band-rumped Storm Petrel (*Oceanodroma castro*), was listed as Endangered in 2016 under the Endangered Species Act. However, little was known about its genetic diversity and nesting ecology in the Hawaiian Islands. This pelagic seabird spends most of its life at sea, and only comes to land during the summer breeding season to nest in steep heavily-vegetated cliffs and high-elevation volcanic terrain. Once widespread along the Hawaiian island chain, as evidenced by midden sites across the main Hawaiian Islands, its range is now isolated to pockets of high elevation nesting habitat. By evaluating nesting ecology and genetic patterns of this rare and cryptic species, we aim to increase the capacity for effectively managing and maintaining the diversity of the Hawaiian Band-rumped Storm Petrel across the Hawaiian Islands.

Objectives of the project include the following:

A. Genetic Research: evaluate patterns in genetic diversity among individuals across the Hawaiian islands.

B. Field studies: identify characteristics associated with nest site selection and reproductive success to aid in recolonization efforts.

A. Genetic Research

Introduction

The goals of genetic studies include: population genetics, population connectivity among islands, inbreeding & genetic diversity measures. Samples were collected from extant and historical populations of the Hawaiian Band-rumped Storm Petrel (Fig. 1). The Kauaʻi Endangered Seabird Recovery Project (KESRP), a Hawaiʻi Department of Land and Natural Resources Division of Forestry and Wildlife project, collected blood samples from the metatarsal vein from individuals on Kauaʻi island between 2014 and 2017 from birds captured using conspecific playback and mist-netting techniques. KESRP stored blood samples on filter paper from one individual in Waimea Canyon, Kauaʻi, five individuals on Honopu Ridge, Kauaʻi, and one from a downed fledgling found in Poipu, Kauaʻi. The Pōhakuloa Training Area (PTA) Natural Resources Office collected samples from individuals at the newly discovered breeding colony on the Big Island between 2015 and 2017, using dog and personnel searches (Galase, 2019). PTA collected flight feathers from nine individual carcasses found near nest sites. Sea Life Park collected two bycatch individuals on Oʻahu island between 2016 and 2017 which were subsequently stored by Dr. David Hyrenbach of Hawaiʻi Pacific University. Toe pad and preserved tissue samples collected from specimens at the Bernice Pauahi Bishop Museum included two individuals from the Big Island, two individuals from Maui, and two individuals from Kauaʻi, collected between 1893 and 2008 (Table 1).

Laboratory work was carried out at the Hawaii Institute of Marine Biology in the ToBo laboratory. The ToBo laboratory is well equipped with the apparatus for doing DNA isolation, DNA quantification, and library preparation.

Staff that worked on the genetics research of the Hawaiian Band-rumped Storm Petrel under the supervision of PI Dr. Melissa Price:

Carmen Antaky – Natural Resources and Environmental Management MS, University of Hawaiʻi at Mānoa

Equipment

No new equipment was purchased during 2019.

Methods

Laboratory analyses

We individually extracted DNA from the blood and feather samples using the DNeasy Blood and Tissue Kit (Qiagen, Valencia, CA) according to the manufacturer's protocol. We quantified the extracted DNA with the AccuClear™ Ultra High Sensitivity dsDNA Quantitation Kit (Biotium, Hayward, CA). Due to low DNA yield, we performed whole genome amplification on individual samples with the REPLI-g UltraFast Mini-kit (Qiagen, Valencia, CA) which effectively and accurately increases yields of high-fidelity DNA (Ahsanuddin et al., 2017). We prepared the replicated whole genomic DNA from all 24 individuals for reduced representation genomic sequencing using the ezRAD protocol version

3.2 (Toonen et al., 2013; Knapp et al., 2016). In brief, we digested the 24 samples with the frequent cutter restriction enzyme DpnII from New England Biolabs® (Ipswich, MA) and we prepared fragments between 150 and 350 bp in length for sequencing on the Illumina®HiSeq using the Kapa Biosystems (Wilmington, MA) Hyper Prep kit with Illumina TruSeq index adapters. We conducted laboratory work at the Hawaiʻi Institute of Marine Biology (HIMB) in Kāneʻohe Bay, Oʻahu, Hawaiʻi. We sent libraries to Vincent J. Coates Genomics Sequencing Laboratory at the University of California, Berkeley where they sequenced them on the Ilumina®HiSeq 4000 platform with paired-end 2 x 150 bp read length. The raw DNA sequences for each individual were deposited in NCBI Sequence Read Archive (BioProject accession number PRJNA559669).

Genetic data analyses

We used the dDocent pipeline (Puritz, Hollenbeck & Gold, 2014) to assemble loci and call single nucleotide polymorphisms (SNPs) within the aligned sequences. In dDocent the following settings were used: 90% similarity to cluster reads, match score of one, mismatch score of four, gap penalty of six, minimum coverage of four within individuals, and minimum coverage of three between individuals. We filtered the resulting Variant Call Format (VCF) file using vcftools (Danecek et al., 2011), retaining 13,708 SNPs found in 90% of all individuals with a minimum quality value of 30, and with 20–200x read coverage. We separated the VCF into mitochondrial SNPs (mtDNA) and nuclear SNPs (nDNA) by aligning sequences to the *O. castro* mitochondrial genome (Antaky et al., 2019) using bwa-mem (Li, 2013), samtools (Li et al., 2009), and vcftools (Danecek et al., 2011). We calculated fixation indices (F_{ST}) for both nDNA and mtDNA by using the Weir and Cockerham (1984) unbiased calculation in vcftools (Danecek et al., 2011). We analyzed the nDNA and mtDNA separately in R (R Core Team, 2013) using the package ‘PCAdapt’ to run a principal components analysis. We transformed the trimmed alignments in PGDSpider (Lischer & Excoffier, 2011) and ran them in STRUCTURE (Pritchard, Stephens & Donnelly, 2000) to identify the likely number of populations from which the samples came and infer proportion of ancestry for each individual. We ran STRUCTURE for one, two, three, and four populations (K), with 10 iterations for each K at a burn-in period of 10,000 steps and 10,000 steps after burn-in and 10 iterations at a burn-in period of 100,000 steps and 100,000 steps after burn-in. We performed multiple runs to obtain better estimates of the posterior probability of each K value. We input results from both STRUCTURE runs into the program STRUCTURE HARVESTER (Earl, 2012), to calculate the ad-hoc statistic (ΔK) suggested by Evanno (2005) that takes into account the change in the log probability of the data between increasing numbers of clusters. We used TASSEL (Bradbury et al., 2007) to determine the nucleotide diversity (π), *Watterson estimator* of diversity (θ), and Tajima’s D (D_T). For population statistics, individuals were grouped by island from which they were sourced from.

Results

Table 1 Location information and year of collected tissue and blood samples of *Oceanodroma castro* across the Main Hawaiian Islands (N = 24).

Island	Collector	Permit #	Year	No. of Samples
Kauaʻi	Bernice Pauahi Bishop Museum (CAT#: 156975)	MB675506-0, WL19-21	1893	1
	Bernice Pauahi Bishop Museum (CAT#: 185162)	MB675506-0, WL19-21	2006	1
	Kauaʻi Endangered Seabird Recovery Project	MB673451-0, BBL08487	2014	1
	Kauaʻi Endangered Seabird Recovery Project	MB673451-0, BBL08487	2016	4
	Kauaʻi Endangered Seabird Recovery Project	MB673451-0, BBL08487	2017	2
Kauaʻi subtotal				9
Oʻahu	Dr. David Hyrenbach, Hawaiʻi Pacific University	MB180283-0, WL19-01	2016	1
	Dr. David Hyrenbach, Hawaiʻi Pacific University	MB180283-0, WL19-01	2017	1
Oʻahu subtotal				2
Maui	Bernice Pauahi Bishop Museum (CAT#: 185001)	MB675506-0, WL19-21	2005	1
	Bernice Pauahi Bishop Museum (CAT#: 185313)	MB675506-0, WL19-21	2008	1
Maui subtotal				2
Big Island	Bernice Pauahi Bishop Museum (CAT#: 183608)	MB675506-0, WL19-21	1994	1
	Bernice Pauahi Bishop Museum (CAT#: 184416)	MB675506-0, WL19-21	2001	1
	Pōhakuloa Training Area Natural Resources Office	MB95880B-0, WL17-10	2015	3
	Pōhakuloa Training Area Natural Resources Office	MB95880B-0, WL17-10	2016	1
	Pōhakuloa Training Area Natural Resources Office	MB95880B-0, WL17-10	2017	5
Big Island subtotal				11
Total				24

Table 2 Summary statistics by island for *Oceanodroma castro* genetic variation across the Main Hawaiian Islands based on 13,708 gDNA Single Nucleotide Polymorphisms (SNPs).

Island	n	θ	D_T	F_{IS}	π
Kauaʻi	9	0.193	-0.937	-0.057	0.159
Oʻahu	2	0.376	-5.807	-0.341	0.197
Maui	2	0.333	-5.829	-0.354	0.172
Big Island	11	0.225	-1.128	0.097	0.176

*Due to small sample size, results should be interpreted with caution.

Figure 1 Map of the Main Hawaiian Islands with yellow shading on islands with known or suspected breeding colonies of *Oceanodroma castro* (Big Island, Maui Nui, and Kaua'i). Approximate locations of sampled individuals are marked with a blue circle. Note that the breeding range on each island is not island-wide but represents a lack of knowledge at an island level.

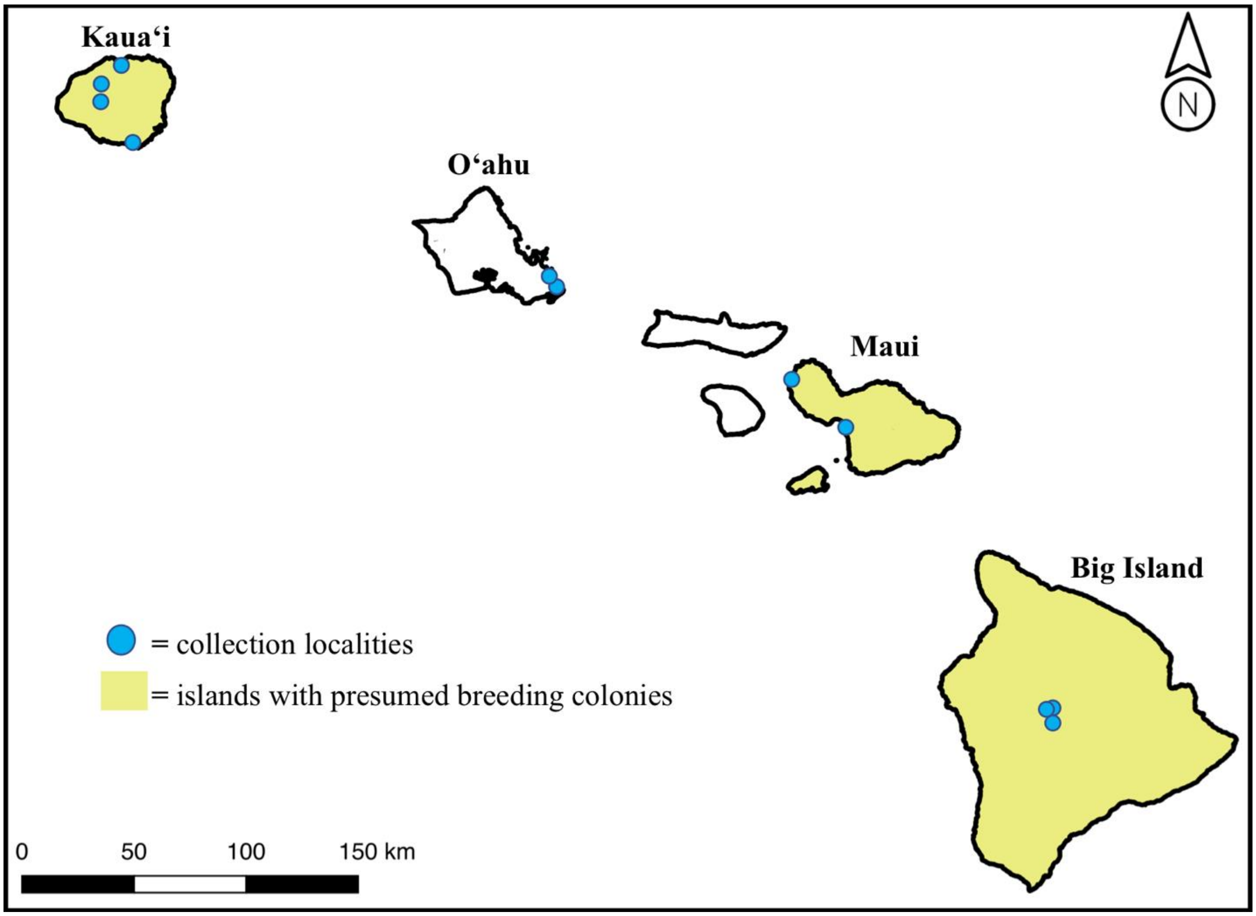


Figure 2 Genetic structure plots indicating inferred proportion of ancestry of *Oceanodroma castro*. Plots are based on analysis of 13,641 nuclear SNPs for K = 2 (A) and K = 3 (B), and 67 mitochondrial SNPs for K = 2 (C) and K = 3 (D) using STRUCTURE. Each bar represents an individual bird and the color represents the assignment probability to a particular genetic group. The most likely clustering for K, denoted with an asterisk, was determined by STRUCTURE HARVESTER.

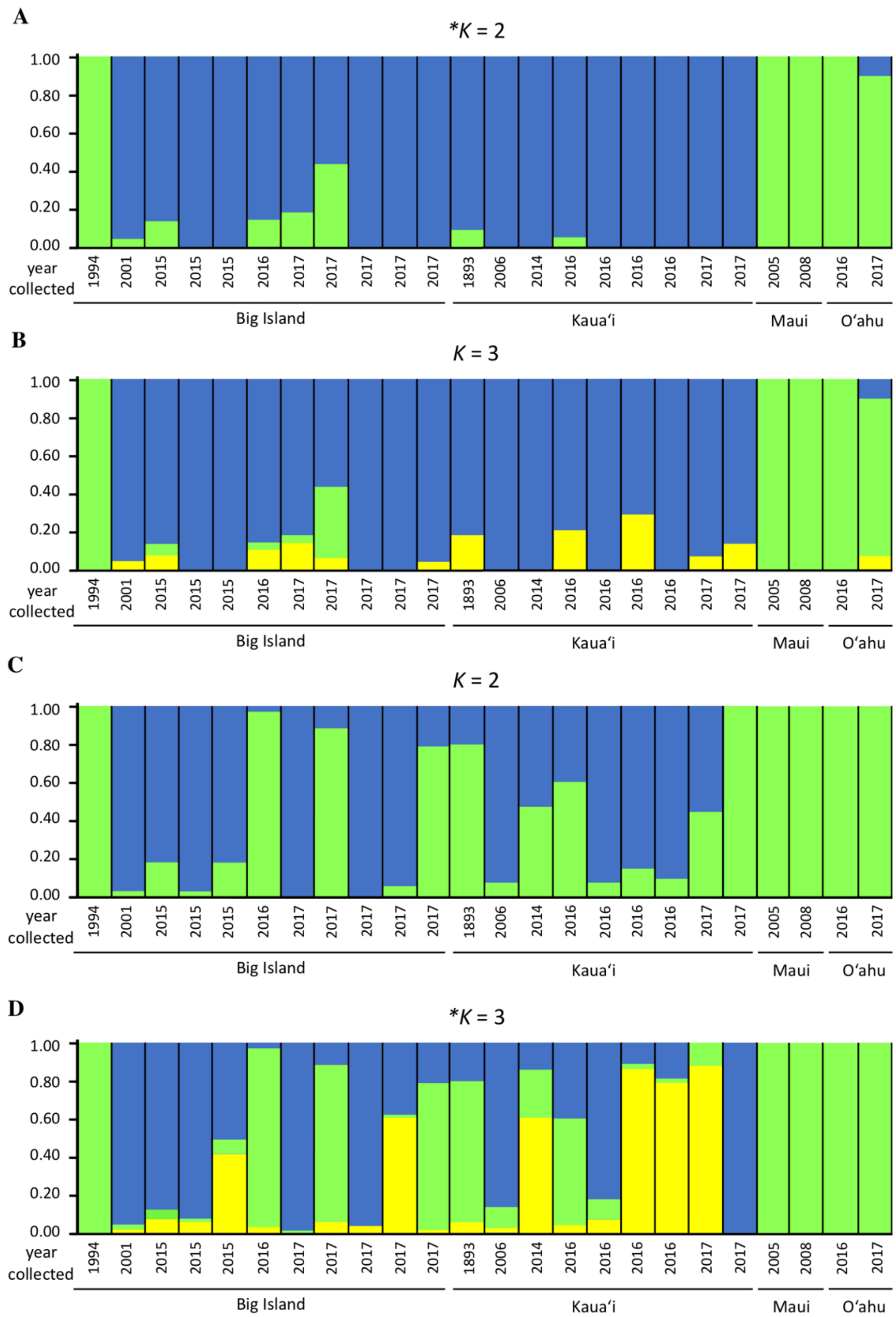
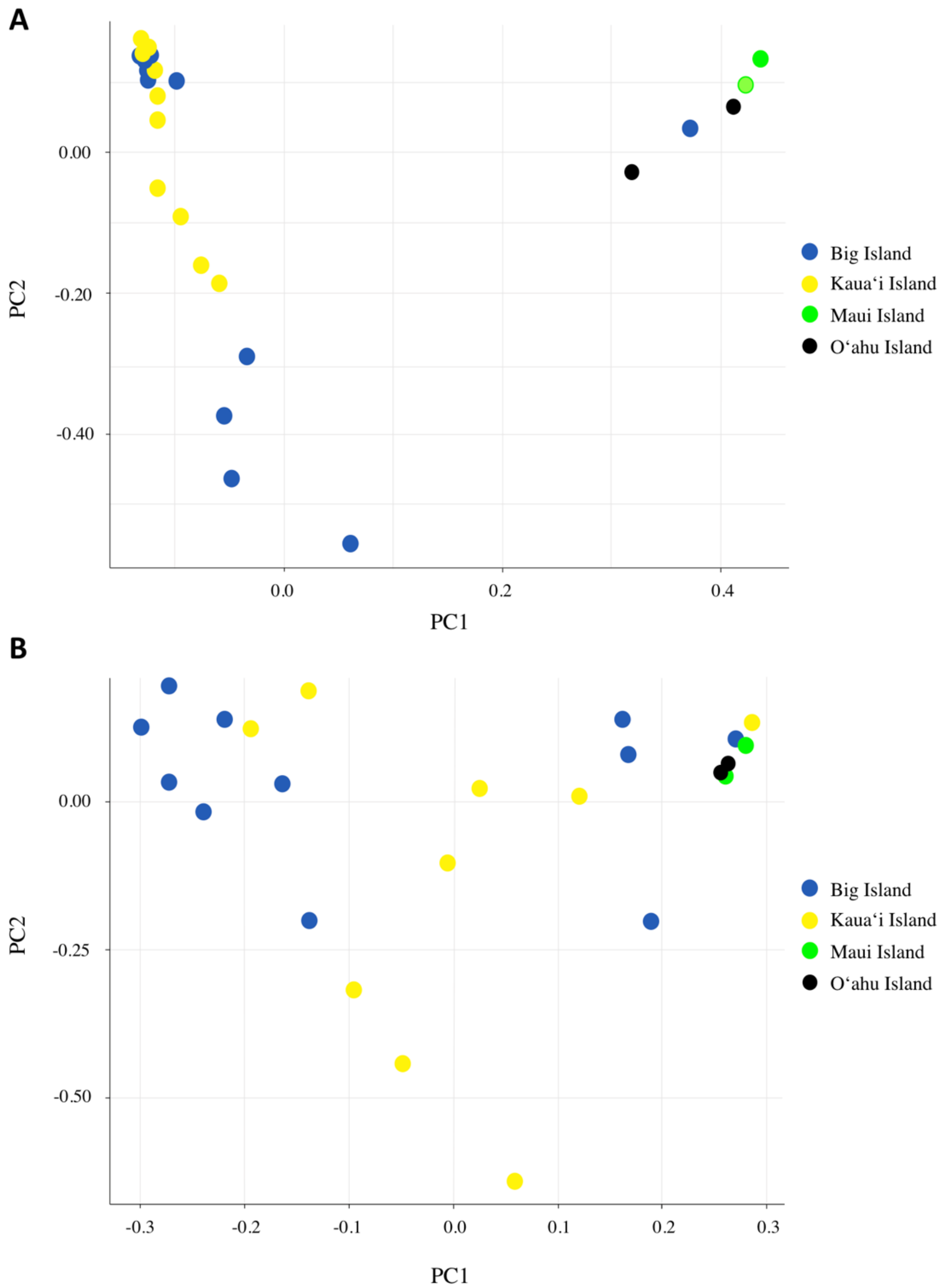


Figure 3 Principal component analysis based on (A) nDNA variation and (B) mtDNA variation for *Oceanodroma castro.* Each dot represents a single bird with colors indicating where the bird was found across the Main Hawaiian Islands.



Discussion

In this study, we found that *O. castro* in the Hawaiian Islands had relatively low inbreeding estimates and high genetic diversity, despite a relatively small population size and an assumed high degree of philopatry based on taxonomic order. Individuals from the presumed breeding colonies on the Big Island and Kaua'i show little differentiation, but individuals recovered from Maui and O‘ahu do not assign to breeding colonies on either the Big Island or Kaua‘i island, suggesting the presence of another distinct population in the region.

Analysis of Hawaiian populations of *O. castro* using SNP data indicates an excess of rare alleles (mean D_T = -3.425 ± 2.76), low rates of inbreeding (mean F_{IS} = -0.164 ± 0.221), and high nucleotide diversity (mean π = 0.176 ± 0.016) (Table 2). Although the species has undergone a decline in population size, there is no evidence of inbreeding, potentially due to promiscuous mating behavior or sex-biased dispersal (Greenwood, 1980; Amos et al., 2001; Milot et al., 2007). Nucleotide diversities of *O. castro* in the Hawaiian Islands were higher than those found in studies of some non-endangered seabird species using RADseq methods (Dierickx et al., 2015; Tigano et al., 2017) but not all (Clark, 2018).

Based on the structure analysis and PCA (Fig. 2; Fig. 3), we found evidence for at least two distinct groups, with individuals from Kaua‘i and the Big Island grouping together and individuals from Maui and O‘ahu islands not assigning to that same population (Fig. 2A; Fig. 3A). These genetic patterns do not match the island chain's geography, and instead may be due to genetic drift in small fragmented colonies, ocean regime around the islands (Friesen, 2015), or that the individuals collected on Maui and O‘ahu were visiting birds that may belong to another distinct breeding population outside Hawai‘i. In sum, the Maui and O‘ahu island individuals differ from the individuals breeding on Kaua‘i and the Big Island. Due to small sample size, however, our results should be interpreted with caution. The PCA and structure analysis based on mtDNA did not show the same pattern of separation as nDNA, possibly because mtDNA does not account for male-mediated dispersal, or because the mtDNA dataset had fewer SNPs included in the analysis.

With some indication of differences among islands in the structure analysis and PCA plots, genetic data are consistent with the expectation that *O. castro* is a highly philopatric species. While Procellariiformes are more likely to return to their natal colony than disperse, most species are not completely philopatric, and a small percentage of individuals are likely to disperse to new colonies (Antaky et al., in press). It only takes a small amount of dispersal, i.e. less than ten migrants per generation, to homogenize genetic structure (Mills & Allendorf, 1996). Seabirds also mate while on visiting forays to neighboring colonies, increasing gene flow beyond that expected based on dispersal from the natal colony (Young, 2010). The individual sampled in 1994 on the Big Island (Table 1), which clustered with the Maui/O‘ahu group in both the PCA and structure analysis, is most likely a migrant from the Maui/O‘ahu group that was visiting or migrated to breed on the Big Island. Thus, complex population structure must be taken into account when interpreting population genetics in highly mobile species (Bowen et al., 2005).

Relatively high genetic diversity despite population declines has been observed in other long-lived endangered seabird species (e.g. the Hawaiian Petrel *Pterodroma sandwichensis*, Welch et al., 2012; the Balearic Shearwater *Puffinus mauretanicus*, Genovart et al., 2007; the Magenta Petrel *Pterodroma magenta,* Lawrence et al., 2008), and may be explained by evolutionary history. An ancient large population of *O. castro* may lead to retained genetic diversity (Goossens et al., 2005). Despite a likely population decline since the introduction of nonnative mammalian predators to the Hawaiian Islands within the last 1100 years, (Pyle & Pyle, 2017; this manuscript), relatively high genetic diversity in *O. castro* is not completely unexpected as only a few hundred individuals may be needed to maintain a majority of genetic diversity (Gaither et al., 2010; Tison, 2014).

Conclusions

This study found little population structure between Kaua'i and the Big Island, and no inbreeding within the Hawaiian populations of *O. castro*, indicating that at least some individuals are dispersing among the breeding colonies on these islands to maintain gene flow. However, the fact that bycatch birds from Maui and O'ahu do not assign to the same breeding colony as Kaua'i and the Big Island also supports the existence of a second discrete population in the Hawaiian Islands or possibly outside of Hawai'i (e.g. Japan). Although a lack of detection at the suspected Maui Nui breeding colony precludes direct testing, this island may host a breeding colony distinct from the others (USFWS, 2016), or there may be unknown temporal separation of nesting populations in the Hawaiian Islands that have yet been tested (Raine et al., 2017) similar to that reported for *O. castro* in Cape Verde (Monteiro & Furness, 1998; Deane, 2013). Continued efforts to find active colonies in the Hawaiian Islands are essential to assess population connectivity and for species recovery (Young et al., 2019).

Populations of *O. castro* currently do not appear to be in any danger of a genetically induced extinction vortex (Gilpin & Soulé, 1986). However, they remain vulnerable to other threats (Jones et al., 2008; Croxall et al., 2012; Spatz et al., 2014). Reduced fledging success and adult mortality due to invasive predators continue to impact population growth (Galase, 2019). Predator control, translocation, and related management efforts to increase chick survival, attract conspecifics, help expand colony range, minimize adult mortality, and increase nesting success will be crucial in achieving recovery in this species (Raine et al., 2017; Antaky, Galase & Price, 2019).

Conclusion

In summary, despite a historical population decline, continued small population size, and separation of hundreds of miles among islands, this study finds no evidence that populations of *O. castro* in the Hawaiian Islands are inbred. *O. castro* colonies in Hawai'i appear to have escaped any severe genetic bottleneck, and the populations do not seem at risk for an extinction vortex associated with loss of genetic diversity (Gilpin & Soulé, 1986). Nevertheless, the small population size of *O. castro* warrants continued conservation programs to achieve recovery, as seabirds play an important role in food webs in both marine and terrestrial ecosystems in the Pacific (Hobson, Piatt & Pitocchelli, 1994; Fukami et al., 2006) and hold cultural significance to Hawaiian communities (Kamakau, 1987; Rose, Conant & Kjellgren, 1993; USFWS, 2005; NPS, 2006).

Publications

In pre-print. Antaky, C., Conklin, E., Toonen, R., Knapp, I., & Price, M. (2020). Unexpectedly high genetic diversity in a rare and Endangered seabird in the Hawaiian Archipelago. *PeerJ.* DOI 10.7717/peerj.8463

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B. Field Studies

Introduction

The goals of our field studies are to continuously monitor, over time, the status of the nesting habitat of *O.castro* populations in the field. Our efforts were focused on Pōhakuloa Training Area on Hawaii Island, as it the only currently confirmed nesting ground. The newly-discovered colony is in a region that is relatively cool, dry, and tropical with nest burrows in five to ten thousand-year-old pahoehoe lava on high-elevation habitat within Mauna Loa summit (Galase, 2019). The Band-rumped Storm Petrel is the only nesting seabird found within the area. This site has relatively low light pollution due to its remote location away from human activity. Through a nesting ecology study in Pōhakuloa Training Area, we explored nest-site selection and associated ecological variables. The main objective of this study was to evaluate nest-site selection to determine potential burrow site characteristics that help to indicate colony presence of the Hawaiian Band-rumped Storm Petrel.

Nesting Ecology Study

Locations of potential and confirmed borrows were collected by the seabird project at Pōhakuloa Training Area during the 2015–2017 breeding seasons (Fig. 1). Confirmed burrows (N=2) were defined by visual presence of seabird activity via camera traps. Potential burrows (N=9) were defined by multiple indicators of presence including storm petrel feathers, scent detection, and acoustic evidence but with no visual confirmation. Using a paired design, factors potentially influencing nest-site selection were evaluated at the eleven sites by comparing characteristics of nest sites with those of four corresponding randomly-located burrows within 100 m of each nest site (Fig. 1). Characters including width and height of the burrow opening, width and height of inner burrow opening, percent cover of dirt vs lava rock on the ground of the burrow entrance, percent cover of vegetation on the ground of the burrow entrance, percent cover of vegetation for 2 m surrounding the burrow entrance, depth, and elevation, were evaluated for each nest site, as well as randomly-located points. At the random points, the closest opening to the potential burrow, that was physically accessible in the pahoehoe lava, was measured. Mean values were calculated for the four associated random points, and compared to paired values for the respective storm petrel nest burrow site. Additionally, one categorical variable was assessed. Depth was classified as deep (>1 m) or shallow (<1 m) due to measuring constraints in the cavernous and narrow lava system.

Parametric tests (paired *t*-tests) were used to identify characteristics that significantly differed between nests and paired random locations. We applied the Bonferroni correction to determine the significance of characteristics, as multiple characteristics were tested ($\alpha = 0.05/11 = 0.0045$). We also computed the standardized difference by using Cohen's *d*, to enable comparison with other studies and datasets. All statistical analyses were conducted in the statistical environment of R (R Core Team, 2013).

Results

Table 1. Nest-site selection by the Band-rumped Storm Petrel, with comparisons of nest sites and randomly-selected locations ($N = 11$) via paired *t*-tests.

Nest-site scale	**Nest** $\bar{x} \pm$ **SE**	**Random** $\bar{x} \pm$ **SE**	**Test Statistic**	***P***	**Standardized difference**
Width of opening (cm)	104.20 ± 30.78	38.82 ± 8.09	t_{10}= 1.57	0.156	*d*=0.523
Height of opening (cm)	28.50 ± 8.07	15.47 ± 1.39	t_{10}=1.61	0.138	*d*=0.487
Width of inner opening (cm)	93.55 ± 22.61	41.11 ± 8.76	t_{10}= 1.29	0.239	*d*=0.455
Height of inner opening (cm)	23.50 ± 4.05	12.98 ± 1.73	t_{10}=2.53	0.032	*d*=0.801
% of dirt at opening	30.27 ± 11.69	10.34 ± 4.65	t_{10}=1.51	0.162	*d*=0.455
% of lava at opening	69.55 ± 11.65	89.66 ± 4.65	t_{10}=-1.53	0.158	*d*=0.460
% of dirt at 2 m	19.55 ± 6.11	8.27 ± 2.11	t_{10}=1.68	0.124	*d*=0.506
% of lava at 2 m	80.45 ± 6.11	91.73 ± 2.11	t_{10}=-1.67	0.124	*d*=0.506
% of vegetation at opening	1.91 ± 1.21	0.46 ± 0.46	t_{10}=1.07	0.309	*d*=0.323
% of vegetation at 2 m	5.73 ± 3.62	1.80 ± 0.74	t_{10}=1.27	0.233	*d*=0.383
Elevation (m)	2145.00 ± 11.61	2145.00 ± 11.26	t_{10}=0.05	0.962	*d*=0.015
Depth (frequency)[a]	1.00 ± 0.00	0.22 ± 0.147	t_{10}= 11.02	<0.001*	*d*= 1.764

[a]Frequency of Deep Nests (>1 m)

* indicates significance under the Bonferroni correction ($\alpha = 0.05/11 = 0.0045$)

Figure 1 Map of Band-rumped Storm Petrel nests (*N*=11) in Pōhakuloa Training Area (PTA), Hawaiʻi Island

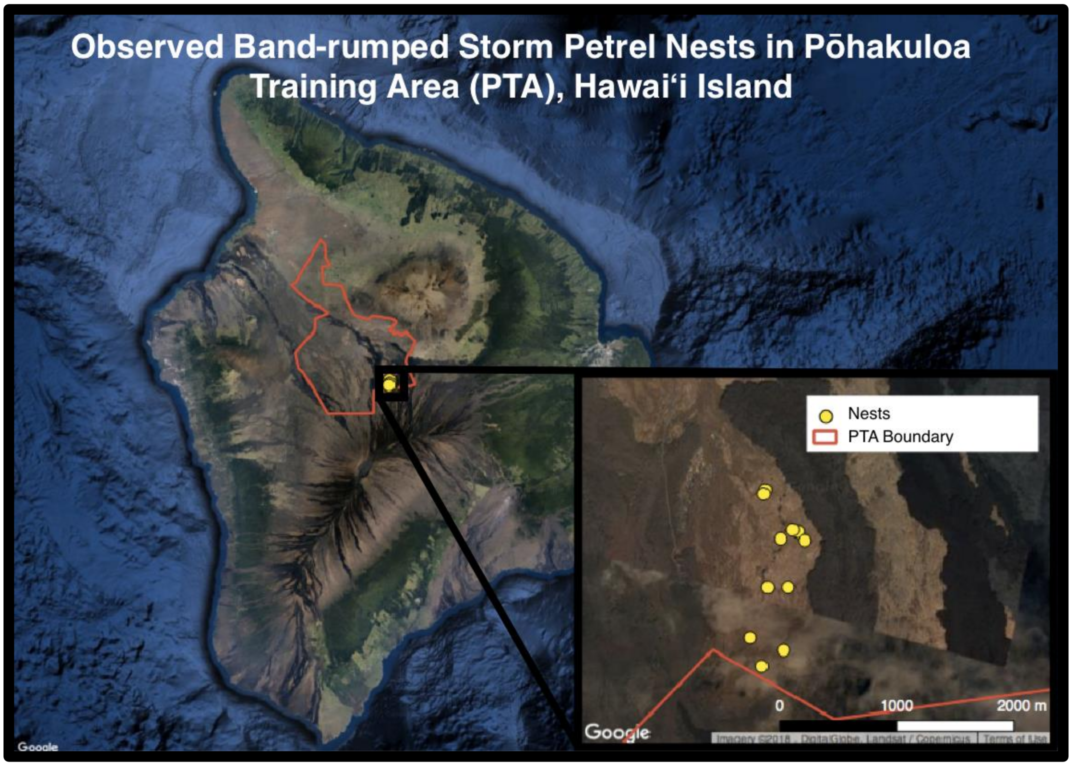

Figure 2 Photograph of an active Band-rumped Storm Petrel nest in Pōhakuloa Training Area (PTA), Hawaiʻi island

Discussion

Band-rumped Storm Petrels nested in significantly deeper lava crevices than those randomly available in the area. Previous studies on procellariiform species have identified similar preferences for dry locations with deeper and winding nest chambers (Bourgeois & Vidal, 2007; Fricke et al., 2015). Preference for depth could reflect the pressure from predators as narrow and deep lava holes may provide protection from invasive mammalian predators, such as cats and rats, that are found in the area (Galase, 2019).

Previous nesting ecology studies on procellariiform species found that light intensity, predator density, and inter-species competition influence nesting preferences (Schramm, 1986; Ramos et al., 1997; Buxton et al., 2015). We did not test for these factors because there is no artificial light source in view at the study location, no difference in predator management across the nesting area, and no other seabird species nesting in the study area.

Currently, the *O. castro* nests found on PTA are the only known active *O. castro* nests across the entire species range in the Hawaiian Islands. Surveying other areas may be useful in expanding our understanding of the species habitat use on Hawaiʻi island. High-resolution satellite imagery may aid in the identification of similar terrain, suitable for the development of predator free conservation areas.

Management guidelines for this species are under development by the U.S. Fish and Wildlife Service. Typical management actions that are known to protect breeding populations of seabirds include predator control and predator-proof fencing in suitable nesting areas. This study provides guidance in identifying characteristics associated with preferred nest sites in this species.

Conclusions

Future recovery efforts for this species may include translocation to protected areas away from known threats, such as introduced predators, an approach successful in other seabird species (Jones & Kress, 2012). To implement this conservation tool, the identification of source populations and nesting pairs with high breeding success is crucial. Further research examining characteristics associated with successful nesting attempts will be essential to recover the endangered populations of the Band-rumped Storm Petrel.

Publications

Antaky, C., Galase, N., & Price, M. (2019). Nesting ecology in the Hawaiian population of a long-lived and endangered seabird, the Band-rumped Storm Petrel. *The Wilson Journal of Ornithology, 131*(2):402-406

Conclusion

Efforts to preserve the small remaining populations of Hawaiian *O. castro* in the field requires new and continuing efforts. The very small populations of *O. castro* could be annihilated in the near future by mammalian predators without proper protection or translocation plans. As we are storing the blood/tissue/feather/toe pad samples in our laboratory at the University of Hawaiʻi at Mānoa, we require to keep the permit TE25955C-0. We hope our findings on the genetic diversity and nesting ecology of the Band-rumped Storm Petrel in Hawaii will guide future management for the Endangered species. We thus conclude that all of the conservation efforts conducted under permit TE25955C-0 are essential to the long-term survival of the Hawaiian Band-rumped Storm Petrel.

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Attachment 1. State permit.

State of Hawaii
Department of Land & Natural Resources
Division of Forestry and Wildlife
1151 Punchbowl Street
Honolulu, Hawaii 96813

PROTECTED
WILDLIFE Permit No. WL19-01

Date of Issue: July 27, 2017

Expiration Date: July 27, 2019

PROTECTED WILDLIFE PERMIT
For the purpose of:

SCIENTIFIC COLLECTING

The Board of Land and Natural Resources hereby grants permission under the authority of Hawaii Revised Statutes §183D-6(b), 183D-61(a) (1) and 195D-9, Hawaii Administrative Rules §13-124-4, and all other applicable laws, to:

Melissa R. Price
Assistant Professor
University of Hawaii-Manoa
1910 East-West Road
Sherman Hall Rm 107
Honolulu, HI 96822
Phone: 808-956-7530
Email: melrprice@gmail.com

To: **For** Ae'o, Hawaiian Stilt - harass by survey, locate and monitor nests, monitor nests via cameras, and salvage

For 'Ake'ake, band-rumped storm petrel – Harass by survey, capture, handle, measure, weigh, collect blood samples, band and color-band, release, recapture, and salvage

For the Purpose of: enhance the recovery, survival, and propagation of the species

Common Name	Scientific Name	No. of Specimens	Location
Hawaiian Stilt	*Himantopus mexicanus knudseni*	As encountered	Kawainui Marsh, Oahu
Band-rumped storm-petrel	*Oceanodrama castro*	50/year	The Islands of Kauai, Maui, and Hawaii

Subject to the following conditions:

I. GENERAL CONDITIONS:

A. This permit is nontransferable or assignable; a copy must be carried by the permittee(s) while engaged in activities authorized under this permit. Each permittee is individually responsible and accountable for his or her actions under this permit.

B. This permit satisfies the permit requirement in Hawaii Administrative Rule §13-124-4. It authorizes the permittee to conduct collecting activities on lands in Hawaii only when other collecting or land access requirements and obligations, such as access permits, are met.

1. Activities conducted in Division of Forestry and Wildlife (DOFAW) Natural Area Reserves System (NARS) require a Special Use Permit. Contact Betsy Gagne, NARS Executive Secretary (phone: 808-587-0063, fax: 808-587-0160, e-mail: betsy.h.gagne@hawaii.gov).

2. A collecting or special use permit may be required for activities in DOFAW Forest Reserves (HAR §13-104-20, 21). Activities conducted on other lands under the jurisdiction of the Department of Land and Natural Resources (DLNR)/DOFAW, such as Game Management Areas and Wildlife Sanctuaries, may require access permits. To determine whether additional permits are necessary on DOFAW lands, contact the DOFAW Branch Manager on islands where activities are planned:

Hawaii: Steve Bergfeld– phone: 808-974-4221, fax: 808-974-4221.

Kauai: Sheri Mann - phone: 808-274-3433, fax: 808-274-3438.

Maui Nui: Scott Fretz– phone: 808-984-8100, fax: 808-984-8111.

Oahu & Kure Atoll: Marigold Zoll– phone: 808-973-9787, fax: 808-973-9781.

3. The permittee must obtain approval from other landowners on lands where activities are planned, including other Divisions of the DLNR, private landowners, tenants, and County, State, and Federal agencies prior to conducting activities on lands under their jurisdiction.

C. This permit does not in any way make the Board of Land and Natural Resources of the State of Hawaii liable for any claims of personal injury or property damage to the permittee(s) or his or her party which may occur while engaged in activities permitted under this permit; further, the permittee(s) agrees to hold the State harmless against any claims of personal injury, death or property damage resulting from the activities of the permittee(s).

D. This permit is valid for species protected by federal law only if accompanied by proper federal permit(s).

E. This permit shall become valid upon completion of the following:

1. All persons who are actively involved in activities authorized by this permit, have read this permit *in toto* and acknowledge understanding and agreement to abide by its conditions by signing two copies of Attachment 1, which is attached hereto and made a part of this permit.

2. Both copies of the signed permit must be returned to DOFAW. Upon approval and signature by the Wildlife Program Manager and the Administrator of DOFAW, a copy of the fully executed permit will be returned to the applicant.

3. For activities requiring Federal permits, permit numbers for the required Federal permits must be filled in:

Endangered Species Permit TE25955C-0

F. Any person violating any of the conditions stipulated under this permit shall be subject to the penalty provisions provided by law. Further, any infractions of this permit may be cause for revocation of this permit and/or denial of future permit requests.

G. Any bird(s) or wildlife that the federal government lists as endangered or threatened as well as any bird(s) listed under the Migratory Bird Treaty Act that are salvaged or accidentally killed must be reported to the U.S. Fish and Wildlife Service, Division of Law Enforcement (USFWS-LE) office on Oahu (808-861-8525) and the DOFAW Honolulu Office (808)-587-0167 within 24 hours. A determination of the disposition of such birds will be made by the USFWS-LE office.

H. All specimens salvaged or accidentally killed and not authorized by this permit shall be reported to the Division of Forestry and Wildlife as soon as possible (808-587-0163, Fax: 587-0160) and disposed of as directed by DOFAW, except those specimens under the jurisdiction of the U.S. Fish and Wildlife Service (See General Condition G).

I. The Bishop Museum, Honolulu, shall be given first refusal for all specimens. (Contact the Vertebrate Collections Manager, Bernice Pauahi Bishop Museum, 1525 Bernice Street, Honolulu, Hawaii 96817-0916, phone # 808-848-4198). Specimens not accepted by the Bishop Museum must be deposited at other recognized museums or universities specified by the Division of Forestry and Wildlife and the Federal Law Enforcement office.

J. The permittee shall report annually on all collecting done in that year to the Division of Forestry and Wildlife. Reports are due no later than January 31 to the Honolulu Administration Office attn: Jason Omick. The annual report shall include: numbers of individuals captured, banded, bled and/or radio tagged; the date and location of the activity; and the disposition of all specimens removed from the wild as well as reports of any injury or mortality during the permitted period.

K. The permittee shall provide copies of all published reports of any study resulting from the activities of this permit to the Division of Forestry and Wildlife Administration Office. The permittee also shall provide or make available for inspection any raw data that may be obtained under this permit when requested by DOFAW.

II. SPECIAL CONDITIONS

A. This permit does not authorize the collection of live birds or bats for other than official research and management projects nor does it authorize depredation control efforts for which birds or bats are to be killed or active nests/eggs destroyed. For information and application(s) involving these permit types please contact Jason Omick at the DOFAW Honolulu office at (808) 587-4159.

B. DOFAW Branch Wildlife Biologists of any branch where research or management studies are planned shall be contacted prior to such activities to review permittees logistics, provide access and to determine possible conflicts and/or interactions between USFWS activities and State-conducted activities. All forest bird research on the Islands of Maui and Kauai shall be coordinated with the Maui Forest Bird Recovery Project and/or the Kauai Forest Bird Recovery Project. Permittee must obtain a camping permit if camping overnight and landing permits if landing via helicopter or boat.

C. Mist nets, and or any trap devices are authorized for use under the following conditions:
   1. Each net and or trap shall be marked with the permittee's name and permit number.
   2. All birds shall be released immediately after field processing and/or banding; unless injured or otherwise authorized.
   3. a. In order to prevent the spread of disease, mist nets, traps, holding bags, and other equipment used must be new or completely disinfected using a bleach solution (or equivalent) prior to initial use in Hawaii.
      b. Nets, holding bags, traps and any other equipment that may come in contact with captured birds must also be disinfected with a bleach solution (or equivalent) prior to being set up at new locations and <u>immediately</u> after any birds with obvious lesions are captured.
      c. All equipment used in areas known to have knemidokoptic mange/mites shall be thoroughly disinfected immediately after any bird is captured to prevent the spread of the mite.
   4. When unfurled, every effort should be made to check nets every 20 to 30 minutes. Nets shall not be left unattended for more than 40 minutes and shall be closed if moisture forms on them. Traps shall not be left unattended more than 60 minutes accept for swim in traps which may be left over night following correct swim in trap protocol.
   5. Non-target species inadvertently captured during trapping or mist netting operations may be banded, but must be released immediately thereafter at the site of capture.
   6. The local Division of Conservation and Resources Enforcement (DOCARE) officer must be informed of all trapping and mist netting activities at least two days prior to such activities.
   7. Care should be taken when and where birds are collected so that undesirable public reaction does not result.

D. Measures must be taken to prevent the spreading of viral diseases and knemidokoptic mange between birds especially in times of avian pox outbreaks and in known areas of knemidokoptic mange occurrence. This includes using sterile needles for each bird; rinsing of hands, bird bags and measuring tools in bleach solution (or equivalent) prior to handling each specimen; rinsing that portion of the mist-net or trap from which infected individuals have been removed.

E. Blood samples taken from specimens to be released should not exceed 1% of the bird's or bats total body weight.

F. The permittee(s) are responsible for explaining to field assistants all permit terms and conditions so as to ensure their compliance at all times.

G. All activities authorized herein must be carried out in accordance with and for the purpose described in the application submitted.

H. All collection authorization under this permit is restricted to the following locations indicated on the 1st page of this permit.

I. All conditions listed in Federal Permit No. TE25955C-0 must be followed during the course of this research.

James Cogswell, Wildlife Program Manager
Division of Forestry and Wildlife

David G. Smith, Administrator
Division of Forestry and Wildlife

cc: District Wildlife Biologists:
/ /Maui – John Medeiros
/ /Hawaii- Joey Mello/ Kanalu Sproat
/ /Oahu- Jason Misaki
/ /Kauai-Thomas Kaiakapu

/ /DOCARE
/ /Senior Resident Agent, USFWS-Law Enforcement, Honolulu
/ /USFWS Pacific Islands Office, Honolulu
/ /DOFAW Admin. Wildlife Biologist – Jason Omick

Attachment No. 1 to PROTECTED WILDLIFE PERMIT No. WL19-01

The undersigned have read, understand and hereby agree to abide by the General Conditions (A-K) and Special Conditions (A-I) in PROTECTED WILDLIFE PERMIT No. WL19-01.

Principal Permittee: [redacted]

[redacted]

Melissa Price

Subpermittees

Carmen Antaky

Kristen Harmon