# Daniel K. Inouye Solar Telescope (DKIST)
# Habitat Conservation Plan and Biological Opinion Final Report

*H. Chen, C. Ganter, J. Panglao & R. Geelhood, January 2019*

**I. INTRODUCTION**

This Final Report to the State of Hawai`i and U.S. Fish and Wildlife Service (USFWS) is being submitted by the National Science Foundation (NSF) through the Daniel K. Inouye Solar Telescope (DKIST) Resource Management Team (DKIST Team), in accordance with the terms and conditions of the Incidental Take License (ITL-13) issued December 1, 2011 by the State of Hawaii Department of Land and Natural Resources. The ITL, accompanied by the "Habitat Conservation Plan for Construction of the Advanced Technology Solar Telescope and the Haleakalā High Altitude Observatory Site Maui, Hawai`i", authorized incidental take of 35 (30 fledglings and 5 adults) ʻuaʻu or Hawaiian petrel (*Pterodroma sandwichensis*), which are covered by to the federal Endangered Species Act (ESA) and State of Hawaiʻi Revised Statutes (HRS 195D). This report is also being submitted to the U.S. Fish and Wildlife Service (USFWS) in accordance with the Final Biological Opinion (BO) (USFWS, 1-2-2011-F-0085). The purpose of this Final Report is to provide the collaborative primary agencies with the final results of the efforts of the DKIST Team to mitigate and monitor potential impacts to the Haleakalā Silversword, the Hawaiian Goose (Nēnē), and Hawaiian Petrel associated with activities being implemented for the DKIST project.

The anticipated impacts to the covered species were associated with construction of the DKIST facility and birdstrike to buildings. Covered activities included demolition, grading, excavation, construction, movement and operation of heavy equipment, and the resulting noise and vibration.

The goals of the HCP were to:

- Avoid and minimize the potential affects to the covered species associated with construction of the facility.
- Invasive species interdiction and control
- Monitor impacts of the project on Hawaiian Petrels from collisions with structures, and noise and vibration during construction
- Mitigate for Hawaiian Petrels:
  - a) Census of burrows within mitigation area;
  - b) Ungulate (goat *Capra* sp.) fencing around the mitigation boundary, connecting with existing National Park boundary, and ungulate removal;
  - c) Predator control, including trapping and removal of known predators *Felis catus* and Indian mongoose *Herpestes* sp., and baiting of rats *Rattus* sp.;
  - d) Social attraction project and artificial burrow placement, to encourage recruitment into the site;
  - e) Burrow and habitat searching outside the mitigation site to identify i) suitable spatial control site and ii) Potential back-up mitigation site; and
  - f) Mitigation success monitoring
- Determination of net benefit to the covered species

The term of the ITL is ten years. The term of the HCP is upon completion of external project construction or five years from the completion of the conservation fence, provided the objectives of the HCP have been satisfied, as amended by BLNR on March 23, 2018.

Additional objectives prescribed by the USFWS Biological Opinion are:

- o Development and installation of traffic calming devices on the Park road to minimize
- o Impacts of all traffic to the Hawaiian goose.
- o Monitoring project impacts to the Hawaiian goose.
- o Propagating and planting 300 Haleakalā Silverswords.
- o Installation of a long-term rodent grid (50 years)

**<u>Glossary of Terms</u>**

- Active Burrow: Burrows with signs of Petrel activity (feathers, droppings, egg shells, footprints, regurgitation, odor and other body parts) or emplaced monitoring toothpicks were knocked over or height-altered.
- Burrow Density: The total number of Hawaiian Petrel burrows recorded within a given area in a specific breeding season.
- Fledgling Success %: Determined by dividing the total number of burrows that fledged one petrel chick by the number of active burrows in the same season expressed as a percentage. This approach was adopted by adaptive management in place of reproductive success to measure DKIST HCP and BO net benefit (DOFAW 10/20/2014).
- Nesting Activity %: The total number of "Active" burrows divided by the total number of burrows monitored that year expressed as a percentage.
- Non-productive Burrows: burrows that showed signs of activity during the initial season search, but no further signs were found while conducting the subsequent re-checks, suggesting that these burrows were either occupied by non-breeders, the nest was abandoned, or the chicks did not reach fledgling age.
- Not Active Burrow: Burrows without signs of Petrel activity (feathers, droppings, egg shells, footprints, regurgitation, odor and other body parts) or emplaced monitoring toothpicks were undisturbed.
- Reproductive Success: Determined by dividing the number of fledged chicks by the number of burrows that contained an egg. This net benefit measurement approach was replaced by "Fledgling Success" (please see Fledgling Success, approved adaptive management (DOFAW 10/20/2014)).
- Predation: Mortality events where signs of bite marks, chew marks, or claw marks were observed on the remains (carcasses or eggs). Scavenging events are also included in this category, since it is difficult to discriminate between the two.
- Successful Burrow: A burrow that has fledged a chick determined by the presence of Petrel chick down feathers at the burrow entrance and disturbed toothpicks after mid-September of each year without signs of predation, or monitoring camera records of successful fledging events.
- Successful Burrow Density: The total number of successful Hawaiian Petrel burrows recorded within a given area in specific breeding season.

## II. SUMMARY OF DKIST HCP/BO ACCOMPLISHMENTS

The DKIST Team began monitoring tasks in early 2011, in accordance with the State of Hawai`i HCP and USFWS BO, nearly two years prior to the actual construction start date in December of 2012. Upon completion of the ungulate fence in November of 2013, the construction components of the HCP and BO were complete, and from that time through the 2018 petrel season, which ended last November, the project has been in full compliance with the State of Hawai`i HCP and USFWS BO.

This Final Report, which includes data to date, including the entire 2018 Hawaiian Petrel season, concludes that DKIST construction has had no measurable adverse impacts on the Hawaiian Petrel population, and that the implementation of the mitigation measures prescribed in the HCP and BO have benefited the Hawaiian Petrel population in DKIST's Conservation Area, both in terms of increased productivity and reduced predation rates.

In addition, the Conservation Area fencing and outplanting of Haleakalā Silversword seedlings have facilitated the Haleakalā Silversword recovery process.

Mitigation measures to minimize and offset potential impacts to the Hawaiian Goose (Nēnē) were also implemented at the onset of construction. These included DKIST staff briefings at the start of each Nēnē breeding season to raise awareness and reduce the risk of Nēnē-vehicle collisions, the installation of a traffic calming device, and DKIST contributions to support the Haleakalā National Park's Nēnē protection and breeding program. In addition, restrictions to night-time vehicle traffic and the timing of daily construction activities were implemented to mitigate long-term impacts to the Nēnē.

More specific information is provided below on the outcomes of the efforts to address impacts to the Haleakalā Silversword, Nēnē and the Hawaiian Petrels, listed in regressing chronological order of the activity:

<u>Silversword Mitigation</u>

- 306 Haleakalā Silversword seedlings were planted on December 8, 2015 (Section IV. A., pp. 7).

<u>Nene Mitigation</u>

- To further minimize traffic-related fatalities of the Nēnē along the Park road, and to serve as a traffic-calming device, DKIST purchased an electronic speed awareness monitor for NPS in October of 2014. No DKIST traffic-related fatalities of Nēnē were recorded during external construction (Section IV. B., pp. 7).
- DKIST's contribution to the Park's Nēnē protection and breeding program will have funded one year of raising and caring for the Nēnē housed in the NPS goose pens (Section IV. B., pp. 7).

<u>Impact Monitoring</u>

- No construction-related damage to Petrel burrows was detected by burrow scope during inspections following each of the breeding seasons. (Section IV. C., pp. 8).
- The noise and vibration monitoring results show that construction activities never exceeded authorized thresholds set forth in the HCP and BO (Section IV. I., pp. 18).
- No Petrel-structure collisions were recorded during any of the monitoring periods from 2011 through year 2018 at the DKIST construction site (Area A & B), the FAA/Coast Guard towers, or along the conservation fence. (Section IV. L., pp. 20).
- The eight years of data supports the conclusion that DKIST construction activities neither deterred new Petrels from coming to breed and nest in areas adjacent to the DKIST construction site, nor jeopardized the Petrels' reproductive success. (Section V. E., Figure 16, pp. 31-33).
- The fledging timing pattern has remained consistent with that of Haleakalā National Park (HNP) data throughout the monitoring period, indicating that construction has not had an impact on the nesting cycle. (Section V. E., Figure 17, Table 8, pp. 34-35).

<u>Predator/Rodent Control</u>

- No ungulate populations have reestablished inside the fenced Conservation Area since September 12, 2013, shortly after fence construction began. (Section IV. E., pp. 10-11 and Section IV. H. i., Table 4, pp. 16).
- An estimated total of 829 rodents have been removed by long-term rodent control grid traps and rodenticide (Section IV. G. ii. Table 3a and 3b, pp. 13-15).

- In the 12 seasons since the stage three grid system was installed, the long-term rodent control grid has further reduced the rodent density in the Conservation Area to 5.8% of the Control Site level (Section IV. H. ii., Figure 6, pp. 17-18).

Petrel Fledgling Success

- A significant ($\chi2 = 10.506$, $P<0.05$, df=1) increase of 73.9%3 in “Fledgling Success %” resulted after the conservation measures were implemented in the Conservation Area. (Section V. B., Table 5, Figure 10, pp. 22-25).
- The average annual Hawaiian Petrel productivity in the Conservation Area increased 87.5% after the HCP was fully implemented. (Section V. B., Table 5, Figure 11, pp. 22-28).
- Using a density approach, DKIST HCP/BO mitigation measures facilitated a significant increase in the Hawaiian Petrel fledging rate on average by 21 more successful fledglings annually (or 105 more successful fledglings occurred between 2014 and 2018. (Section V. B., Table 5, Figure 11, pp. 22-28).
- Using a Fledgling Success% approach, DKIST HCP/BO mitigation measures facilitated the successful increase of the Hawaiian Petrel population in the Conservation area; specifically, 96 more fledglings than would have been expected resulted between 2014 and 2018 (Section V. B., Table 5, Figure 11, pp. 22-18).

Reduced Predation

- The predation of 28.7 chicks and 15.7 adult Hawaiian Petrels was prevented due to the predator control measures implemented by the DKIST Team (Section V. D., Table 6 & 7, pp. 28-30).

Based, in part, on these findings, on January 24, 2018, the State of Hawai’i Endangered Species Recovery Committee (ESRC) recommended approval of NSF’s amendment request to allow termination of its HCP as early as November 18, 2018. This recommendation was approved on March 23, 2018 by the State of Hawai’i Board of Land and Natural Resources (BLNR) contingent upon there being no Incidental Take as of November 18, 2018, and the issuance of a Final Report. There has been no “take” as a result of the exterior construction of the DKIST project or from implementation of the HCP, and, therefore, NSF now presents this Final Report and requests that its HCP be formally terminated. NSF further requests that the terms of the BO be deemed met (other than the requirements in the BO that must continue for 50 years).

Amended HCP/BO Mitigation Measures

- Social attraction to attract new Hawaiian Petrels to the protected site and artificial burrow placement, as required in the HCP and BO, were intended to encourage recruitment into the Conservation Area. At the time the documents were written, it was thought that a lack of suitable burrows (164 burrow baseline) might be a limiting factor to breeding success; however, since 2011 DKIST's monitoring team identified additional burrows. The Team demonstrated that there were numerous available burrows, and the addition of artificial burrows was determined to be unnecessary. In a letter dated May 12, 2015, DOFAW concurred that there appeared to be sufficient breeding habitat available. DOFAW also concurred with DKIST that there were enough breeding birds present in the Conservation Area such that placing decoys or playing artificial calls would be highly unlikely to increase recruitment at the site. The USFWS also concurred with these determinations in a letter dated May 11, 2015.

**III. THE DKIST HCP CONSERVATION AREA AND CONTROL SITE**

The DKIST HCP requires the establishment of a Conservation Area to mitigate the potential negative effects to Hawaiian Petrels related to construction of the DKIST facility. In addition, the HCP also specifies the need to establish a Control Site to compare and evaluate the DKIST Team's conservation efforts within the HCP Conservation Area. Both of these areas have been established and maintained since 2011. The Conservation Area, Control Site and other features are shown in Figure 1.

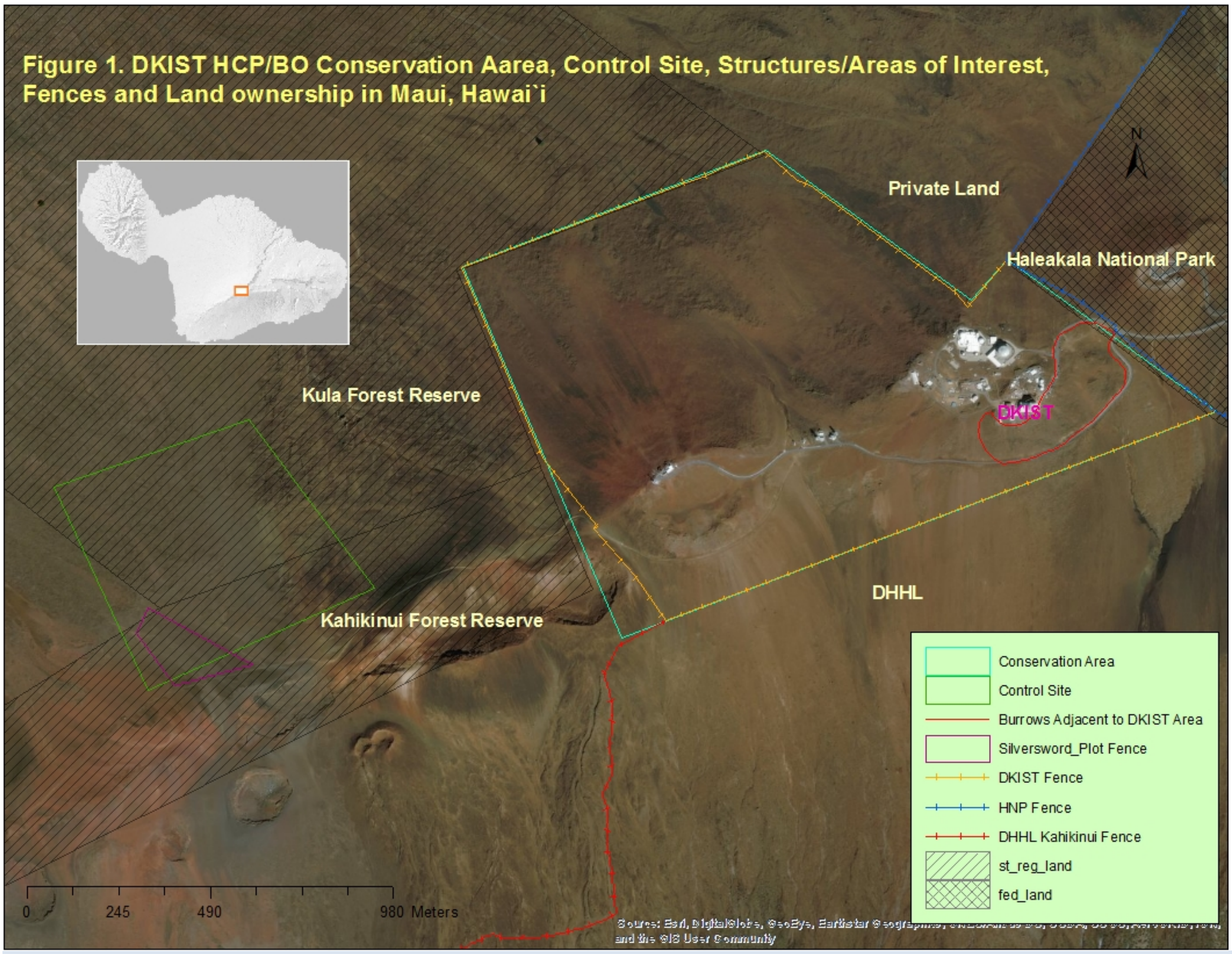


Figure 1. DKIST HCP/BO Conservation Aarea, Control Site, Structures/Areas of Interest, Fences and Land ownership in Maui, Hawai`i

**Note: The ground-truth DKIST HCP Conservation Area boundary on the map is different from the State of Hawaiʻi website published TMK GIS layer. The actual metes and bounds on the ground may vary from the GIS layer up to 33 meters.**

The Conservation Area is located between approximately 8,800 and 10,000 ft. (2,682 to 3,048 m) in elevation, and includes observatory facilities, broadcast facilities, communication towers, and the portion of Skyline Trail dividing the area from the northeast to the southwest. Adjacent lands include the Kula Forest Reserve, Kahikinui Forest Reserve, HNP, Department of Hawaiian Home Lands (DHHL), and private land. The Conservation Area contains a number of cinder cones, of which Puʻu Kolekole is the highest in elevation. Pu'u Kolekole is about 0.3 mi (0.5 km) from the highest point on the mountain; Puʻu ʻUlaʻula (Red Hill) Overlook, which is inside the HNP, but outside of state land (Figure 1). Based on the State of Hawaiʻi website published TMK GIS layer, the Conservation Area was estimated to be 328 acres (133 ha). However, after the ground survey using existing metes and bounds was completed, it was determined the area consists of 321.79 acres (130.22 ha). The topography within the Conservation Area is rugged and barren, and the elevation drops with an average slope greater than 30 percent (DKIST 2010).

The Control Site (Figure 1) encompasses 80 acres and is one kilometer west of the western boundary of the Conservation Area, just north of the Skyline Trail, at an elevation of 8,700 to 9,300 ft. (2652 to 2835 m). The topography within the Control Site is similar to that of the Conservation Area.

However, there were challenges that soon underscored poor correlations between a number of physical variables, such that a useful comparison between sites could not be obtained. The first challenge was selection of the site itself. The ideal Control Site, with suitable physical similarities, would have been located higher in elevation, e.g., further away from the tree line and permanent water sources, and thus not experiencing more severe predation pressure than the Conservation Area. A more useful Control Site would also have been closer to the Conservation Area in size, and similar in burrow numbers. However, after an exhaustive search by DOFAW, USFWS, and DKIST prior to the start of monitoring, the only available site within a reasonable distance from the Conservation Area for field operations was the 80 acres shown in figure 1. Because of the challenges above, the Conservation Area and Control Site failed to yield a useful comparison, necessitating a re-evaluation of how to calculate the net benefit of the mitigation, as described in Section 5 of this report.

## IV. DKIST HCP AND BO COMPLIANCE

The DKIST Team has met or exceeded its compliance obligations with HCP and BO required mitigation measures. Following is a summary in reverse chronological order highlighting compliance activities.

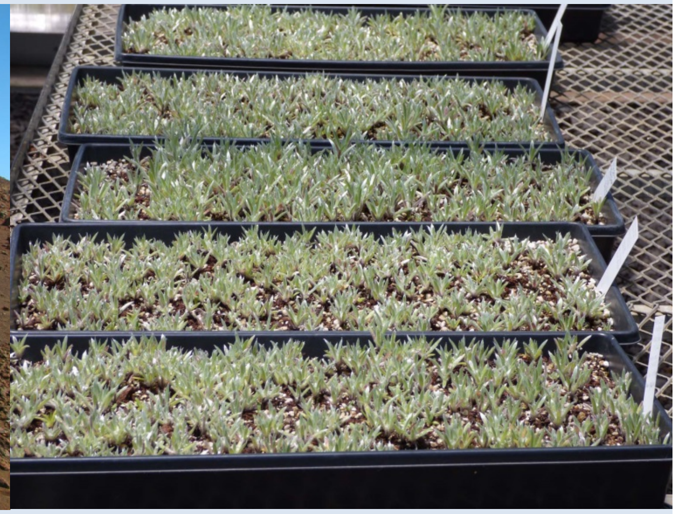
### *A. Silversword Seed Propagation and Outplanting: November 2014-December 2015*

Eight hundred seeds from four flowering Haleakalā Silversword (A.K.A. 'ahinahina, *Argyroxiphium sandwicense subsp. macrocephalum*) plants within the DKIST Conservation Area were collected on November 18, 2014 by the subcontractor Starr Environmental, under DLNR permit. The seeds were turned over to Haleakalā National Park (HNP) for propagation. In compliance with the HCP, the DKIST Team carefully checked the source area during its June 2015 monitoring for natural regeneration from the Silversword seed bank in the area from which the seeds were collected. The DKIST Team could not locate any seedlings during its June and August 2015 monitoring, and, therefore, outplanting was initiated to add to the local population. In total, **306 Haleakalā Silversword seedlings were planted on December 8, 2015** by Starr Environmental, the DKIST Team, and an HNP employee. Each plant was tagged, foliage crown width was measured, and GPS coordinates were recorded. As of November 2018, 74% (225) of the 306 planted Silverswords remain alive in the third year (Starr and Starr 2018, Figure 2).

There were no Silversword plants located within construction areas; therefore no additional transplanting of Silverswords was necessary.

**Figure 2. Silversword outplanting in the winter of 2015 in the area where seeds were collected in the winter of 2014.**

**Silversword seed collection (DKIST in background)**



**Silversword propagation**

**Silversword outplanting**

**Silversword outplanting**

### *B. Nēnē Mitigation Measures: December 2012*

Mitigation measures described in the BO to minimize and offset potential impacts to the Nēnē were implemented at the onset of construction. Beginning with DKIST staff briefings at the start of each Nēnē breeding season, as well as during the season, staff members were alerted to the presence of Nēnē on the Park road, in order to reduce the risk of vehicle collision. **To further minimize traffic-related fatalities of the Nēnē along the Park road, and to serve as a traffic-calming device, DKIST purchased an electronic speed awareness monitor for NPS in October of 2014** at a cost of $11,294. **In addition, restrictions to night-time vehicle usage and the timing of daily construction were implemented to mitigate long-term impacts to the Nēnē.** Finally, **DKIST's contribution to the Park's Hawaiian Goose protection and breeding program will have paid for one year of raising and caring for the Nēnē housed in the recently-constructed NPS goose pens at a cost of $15,000.**

Widening of the Park Entrance Station was not needed; therefore, the original requirement for site restoration replanting at the Park Entrance Station turned out to be unnecessary.

### *C. Monitoring Petrel Burrow Structures in the Impact Area: December 2012*

At the conclusion of each Petrel season, a burrow scope and surveillance cameras were utilized to determine whether any structural changes to the Petrel burrows had occurred during the season due to construction vibration. No structural changes to Petrel burrows due to construction were documented during construction of DKIST.

In 2015, KC Environmental, Inc. (KCE), on behalf of the DKIST Team, developed a new, advanced burrow scope with a remote directional control capacity to maneuver more easily in burrows during inspection. The burrow scope was only used during the non-breeding season to avoid risk of burrow damage. After an initial test period in 2015 and with the approval of DOFAW and USFWS staff, routine monitoring for potential impact due to vibration and ground disturbance to burrow structures adjacent to the DKIST construction site was implemented. With the approved adaptive management measure of using the new burrow scope, burrow maps beginning in 2015 were considerably more detailed than earlier versions.

In 2018, after all birds were absent from the site, the final burrow scoping and mapping was conducted. A total of 21 Hawaiian Petrel burrows within 80 meters of the DKIST construction site were measured and mapped to determine whether any changes in burrow configuration occurred during the 2018 Hawaiian Petrel season. A change to one burrow from the previous year was observed as follows:

Burrow IE01: The passage connecting the lower entrance to the top entrance of the burrow that had been observed to be partially filled with soil during the 2017 scoping is now clear. It appears that the soil was cleared by Petrel activity. This burrow also slopes sharply downhill approximately 20° (36% grade).

An additional observation in 2018 was made at the following burrow:

Burrow SC38: The unhatched egg that was located in the left, rear of the burrow in 2017 was no longer present. Shell fragments were observed downslope of this burrow earlier in the season, and it was believed that the egg was swept out by the adult Hawaiian Petrels occupying this burrow during normal nesting behavior/burrow cleaning. This burrow produced a successful fledgling in 2018. Rain erosion around this burrow was noticeable. The burrow was otherwise noted to be in good condition.

All other burrows scoped were noted to be in the same (good) condition as in the prior years***.***

<u>**No construction-related damage to burrows was detected by the new burrow scope during inspections following each of the breeding seasons**</u>**.**

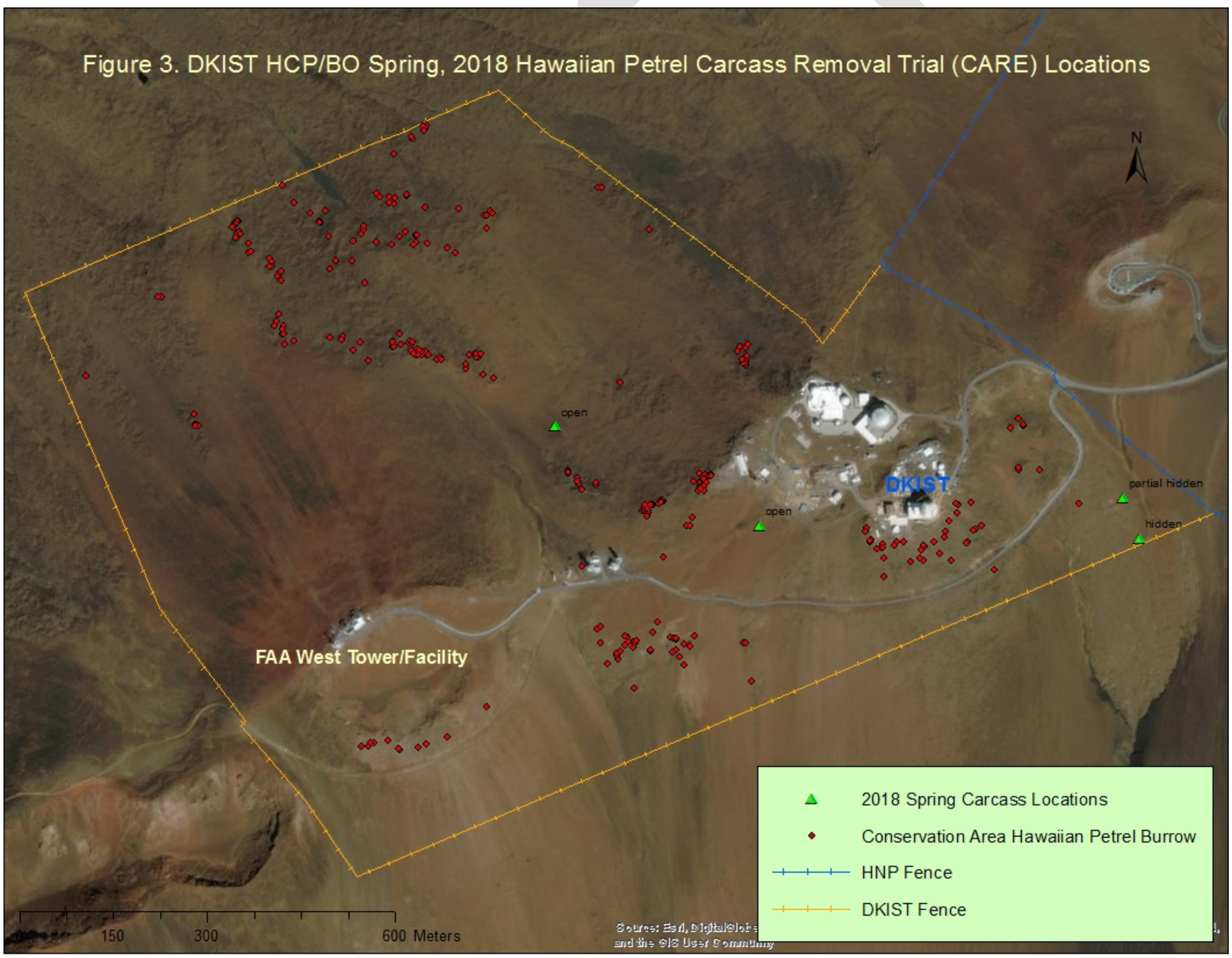
### *D. Carcass Removal Trials (CARE): <u>Since September 2013</u>*

Carcass Removal Trials were undertaken to determine the scavenging rate by cats, rats, mongoose or other scavengers of birds that may have been killed due to collisions with project structures. Pursuant to the adaptive management changes approved by DOFAW and USFWS for the HCP and BO on July 29, 2014, two CARE trials were to be conducted each year during the remainder of the 6-year construction period. These trials were to be conducted by a third-party contractor and the information was to be used to guide search intervals for monitoring Petrel mortalities that could have resulted from collision with project structures at the DKIST site.

CARE trials were conducted by KCE since the fall of 2013. Trials were conducted in locations within the DKIST Conservation Area that were approved by USFWS and DOFAW and that were at least 50 meters from any Hawaiian Petrel burrow and 30 meters from baited traps. Figure 3 is an example of surrogate bird placements (from the final trial conducted in the summer of 2018). Four surrogate bird (Wedge Tailed Shearwater, *Ardenna pacificus,* which is morphologically and taxonomically similar to Hawaiian Petrel) carcasses were placed in a variety of positions, including two that were exposed (thrown), one that was hidden to simulate a crippled bird, and one that was partially hidden in each trial.

The results of the CARE trials conducted through the summer of 2018 are presented in Table 1. In trials since 2013, only two birds have been partially scavenged, and even during an extended 60-day trial in the summer of 2014, all four trial carcasses remained intact after the full 60 days. The 2013 fall scavenge event occurred in a partially concealed location within two weeks of placement, with only feathers left behind, while the 2015 summer scavenge event was in a concealed location within two weeks of placement, with a partially dismembered carcass remaining. The overall scavenge rate was 4.55% (based on eleven 30-day trial periods (if the extended trial is counted as two trials) with four birds in each trial, in which two of the 44 total carcasses were scavenged. Most importantly, the rate of total carcass removal was zero through the final trial completed in July of 2018.

The results of the CARE trials were consistent with the experience of the DKIST Team, which has found Hawaiian Petrel carcass remains in the Conservation Area that were often more than a year old, indicating that Hawaiian Petrel carcasses are rarely totally removed. The CARE trials showed further evidence that scavenging rates at these higher altitudes are extremely low. After eleven such trials (twelve, if the extended trial is considered to be two trials), only two surrogate bird carcasses showed any sign of scavenging.



The results of the CARE trials, corroborating empirical data and knowledge of constraints associated with high alpine xeric ecosystems suggest that the 10% carcass removal rate used in the calculation of unobserved take for DKIST may have been overestimated. Because the carcass scavenging rate is very low, and even the rare carcass scavenging that does take place does not seem to remove all evidence of bird mortality for as long as a year or more, we believe that nearly all carcasses present within the search area for DKIST were found and recorded. The longevity of carcasses in the field also indicated that the frequency of searches for downed birds at the elevations of the Conservation Area could be reduced based on evidence now available from these CARE trials and other empirical data. (Fein and Allan 2013b, 2014b, 2014c, 2015b, 2015c, 2016b, 2016c, 2017b, 2017c, 2018b & 2018c). Based on this information, DOFAW and USFWS modified the requirements for search frequency, which is discussed in more detail in Section IV. L, Birdstrike Monitoring.

**Table 1. The Outcome of DKIST HCP Carcass Removal Trial Fall of 2013 – Spring 2018**

| Year | Season | Period (days) | # Birds Scavenged | % Birds Scavenged | % Birds Removed | Remarks |
|---|---|---|---|---|---|---|
| **2013** | Fall | 30 | 1 | 25 | 0 | Remains still detectable at the end of the trial |
| **2014** | Spring | 30 | 0 | 0 | 0 | |
| | Summer/fall | 60 | 0 | 0 | 0 | Extended trial |
| **2015** | Spring | 30 | 0 | 0 | 0 | |
| | Summer | 30 | 1 | 25 | 0 | Remains still detectable at the end of the trial |
| **2016** | Spring | 30 | 0 | 0 | 0 | |
| | Summer | 30 | 0 | 0 | 0 | |
| **2017** | Spring | 30 | 0 | 0 | 0 | |
| | Summer | 30 | 0 | 0 | 0 | |
| **2018** | spring | 30 | 0 | 0 | 0 | |
| | summer | 30 | 0 | 0 | 0 | |
| **Summary** | | 330 | 2 | 4.17 | 0 | Based on 12 30-day trial periods |

### *E. Conservation Fence and Ungulate Eradication: <u>July-November 2013</u>*

A Conservation District Use Permit (CDUP) for the conservation fence was issued on May 17, 2013. On July 25, 2013, Rock N H Fencing, LLC was awarded the contract to construct the conservation fence. The construction started on September 1, 2013 and was completed on November 18, 2013 at a cost of $422,575. A total of 4.23 km (2.63 mi) of fence was built and 126.53 ha (312.66 acres) of Conservation Area was enclosed, which included 0.66 ha (1.64 acres) of Haleakalā National Park land outside of the park fence (Figure 1, 3 & 4). To prevent bird collision with the conservation fence, three strands of steel wire-enforced Poly-tape were installed horizontally along the entire length of the fence, which was completed on March 13, 2014 in compliance with HCP and BO requirements.

As a result of the fence construction process and the intensive monitoring/conservation activities that were implemented during the fence construction, all ungulates vacated the Conservation Area before the fence was completed. Based on footage obtained from 10 long-term predator/ungulate monitoring camera traps and six additional ungulate monitoring camera traps (Figure 4), no ungulates were detected within the Conservation Area since September 12, 2013, until June 1, 2017 when a juvenile goat was observed inside the fenced Conservation Area. The DKIST Team systematically searched the area thereafter, however, no further signs of the goat's presence were found. Methods used to search the area included surveying for any fresh tracks, droppings, or any images of the goat captured via camera traps. We believe it is likely that the goat's ingress was due to some Skyline Trail users obstructing the fence gate from closing and the goat's egress was the result of the goat leaving the fenced area either through the same gate, or by jumping over the fence in one of the few areas where the higher rocky terrain would make that possible. While it is also possible that the goat died inside the area due to dehydration, hypothermia and starvation, it is not likely as no carcass was found. **<u>No ungulate populations have reestablished inside the fenced Conservation Area since September 12, 2013, shortly after fence construction began.</u>**

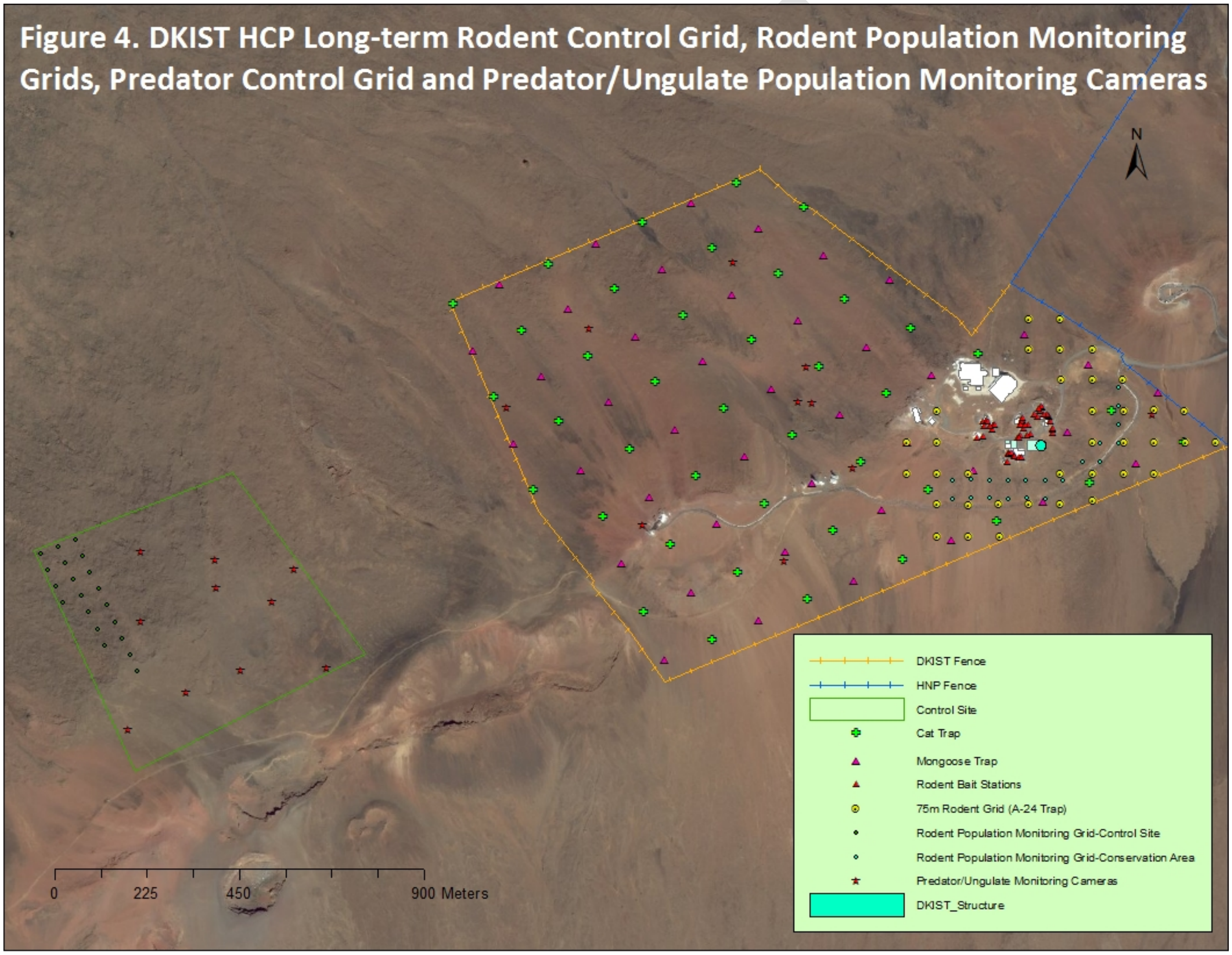


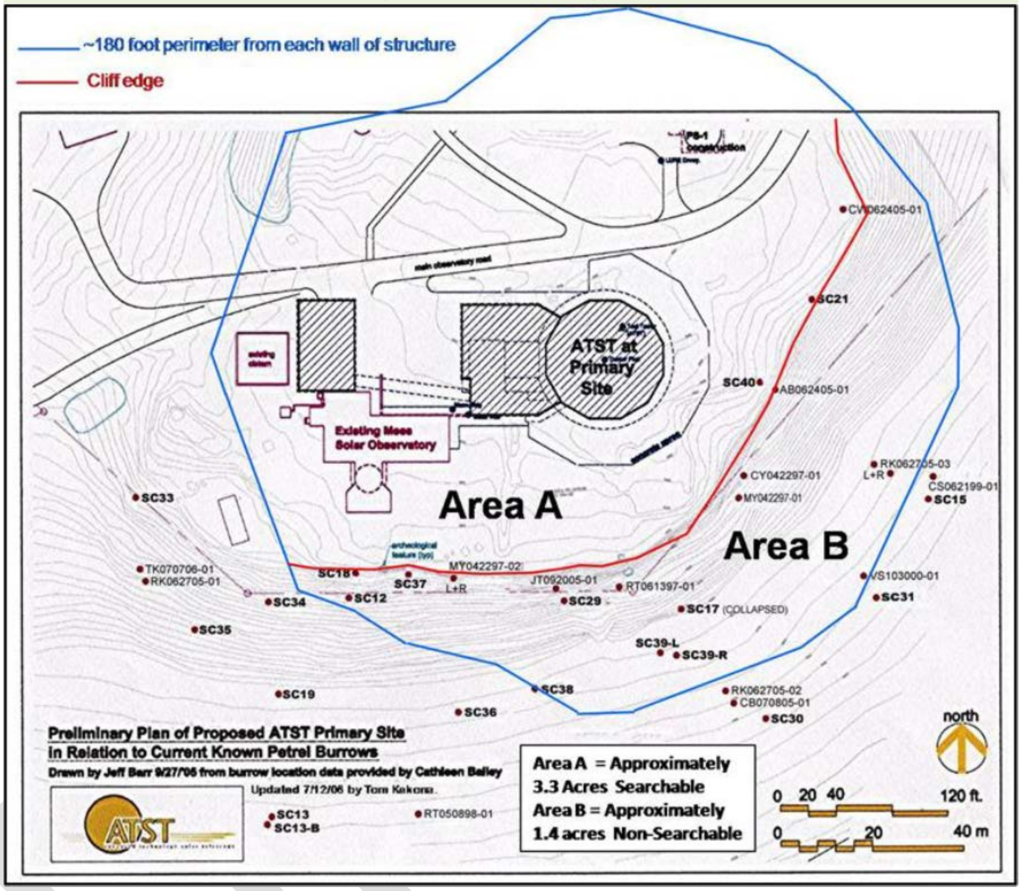

Figure 4. DKIST HCP Long-term Rodent Control Grid, Rodent Population Monitoring Grids, Predator Control Grid and Predator/Ungulate Population Monitoring Cameras

### *F. Searcher Efficiency Trials (SEEF): <u>Annually Since May 2013</u>*

In order to accurately evaluate the overall efficiency of carcass detection in the DKIST project area, SEEF trials were conducted annually, as prescribed by the HCP. Trials were conducted within the DKIST's approved birdstrike monitoring Search Area A, as discussed in detail in Section IV. X, and shown in Figures 5 and 7.

In accordance with the requirements of the HCP and BO, these trials were conducted by a third-party contractor, and took place unbeknownst to the searchers. KCE was the Maui-based third party contractor selected to conduct the SEEF Trials on behalf of the DKIST Team. In order to recover bird carcasses found during the trials, the DKIST Team operated as a sub-permittee of KCE's Migratory Bird Permit (USFWS February 27, 2013, # MB97892A-0) and Protected Wildlife Permit (DLNR March 04, 2013, # WL 15-02).

**FIGURE 5. Demarcation of Area A and B of the DKIST Construction Site Birdstrike / Search Area. Searcher Efficiency Trials Were Only Conducted in Area A.**




During the 8-week SEEF trials, Wedge-tailed Shearwater carcasses were used as surrogates for the Hawaiian Petrels. Over the trial period, 20 carcasses were placed within the search area on random days and in random quantities, with up to 3 carcasses being placed per day. After each search was completed, the searchers reported the results only to KCE, and the number of shearwater carcasses found, photos, bird tag numbers, and the coordinates at which the carcasses found were included in the report. The carcasses were then returned to the freezer, which was maintained by KCE at the site.

Table 2 shows the results of SEEF trials since 2013, resulting in an overall searcher efficiency rate of 92.5%. In the most recent and final trial, in 2018, 19 out of the 20 dropped carcasses were found, resulting in a searcher efficiency rate of 95%. (Fein and Allan 2013a, 2014a, 2015a, 2016a, 2017a, 2018a).

**Table 2. 2013-2018 DKIST Searcher Efficiency Trial Results**

| Year | # birds dropped | # birds located | Searcher Efficiency % |
|---|---|---|---|
| 2013 | 20 | 17 | 85 |
| 2014 | 20 | 18 | 90 |
| 2015 | 20 | 18 | 90 |
| 2016 | 20 | 19 | 95 |
| 2017 | 20 | 20 | 100 |
| 2018 | 20 | 19 | 95 |
| **6 Year Summary** | **120** | **111** | **92.5** |

### *G. Long-term Rodent Control Grid: <u>Since March 2013</u>*

#### *i. <u>Methods, grid configurations and the chronicle of their modifications</u>*

The original rodent control grid layout in the final HCP and BO was a conceptual guideline; it needed to meet the minimum pesticide product Special Local Need Supplemental Label (SLN) requirements. In order to meet the SLN label requirements, a 50-meter grid layout plan was initially submitted to the agencies by the DKIST Team. However, after consultations with USFWS, it was agreed that the project would implement a denser 48-meter bait box grid of 51 stations. The newer 48-meter grid layout plan was approved by USFWS in March 2013, and the implementation of the grid was completed on April 2, 2013.

Each station was equipped with a Protecta ™ tamper-resistant rat bait box and a mouse box. Due to the ongoing DKIST construction activities taking place on site, 44 of the planned 51 stations are in place as of this report. Each rat bait box was deployed with eight 1-oz Ramik™ (0.005% diphacinone) blocks, for a total of 22 lbs. of diphacinone. The stations were checked after one week and then again after two weeks to evaluate the diphacinone take (stage one grid). However, the diphacinone SLN label expired on May 30, 2013, and the use of diphacinone had to be discontinued. The blocks were removed on May 28, 2013. T-Rex rat and mouse snap traps baited with peanut butter were subsequently deployed (stage two grid).

The requirements under the new SLN label published in December 2013 prohibited future diphacinone use in the Conservation Area due to boundary issues. The label required the grid to be extended 225 meters beyond the resource to be protected, which for the Conservation Area would cross the neighboring boundaries of adjacent land owned by Haleakalā National Park, the U. S. Air Force, and the Department of Hawaiian Homelands. In response to these new labeling constraints, the DKIST Team worked closely with USFWS and DOFAW to develop a new long-term rodent control grid methodology that was not regulated by an SLN label.

Protecta ™ tamper-resistant rat bait boxes were placed every 30 ft. along the perimeter of all permanent structures and trailers (office, storage) within Haleakalā Observatory (HO), with the exception of the US Air Force compound and areas affected by construction activities. For 40 ft. trailers/containers, two bait boxes were put in place, each at diagonal corners, and for 20 ft or shorter trailers/containers, one bait box was put in place. Because the Generation® BlueMax Mini Blocks (0.0025% Difethialone) were not regulated by an SLN label for use next to buildings, each rat bait box was deployed with six 1-oz The Generation® BlueMax Mini Blocks. the DKIST Team began installing the boxes on April 30, 2015 and completed the installation of 47 boxes, containing a total of 17.6 lbs. of bait on May 07, 2015. The Generation® BlueMax Mini Blocks were replaced by FASTRAC® All-weather Blox™ (0.01% Bromethanlin) in 2017 due to availability. Locations and quantities of bait boxes were adjusted as construction areas were completed and office/storage trailers moved, added or removed. As of October 31, 2018, 53 bait boxes were installed. In order to further reduce the risk of introducing rodents due to these residual construction activities, outside of the construction area, we began installing a 75-meter A-24 rodent killing trap grid on May 12, 2015 and completed the grid on May 18, 2015. A total of 35 A-24 traps were installed. A 25-meter A-24 trap system will be installed around HO buildings once all remaining equipment and site trailers are removed (stage three grid, Figure 4).

***ii. Effectiveness of the long-term rodent control grid***

During the stage one diphacinone grid implemented from April 2, 2013 to May 28, 2013, 6.6 oz. of diphacinone bait was taken. The number of rodents removed during the stage two snap traps grid is shown in Table 3a.

"Counters" were attached to the traps to register actual numbers of kill action by the traps because A-24 traps do not actually trap the rodent. It can take up to ten seconds before the rodent becomes motionless, and in this ten-second interval, the dying rodent may vanish into lava rocks or roll downslope without being recorded by the DKIST Team. The number of rodents removed after the new stage three rodenticide/A-24 killing trap grid system was installed is shown in Table 3a.

During the six-month period of 2015 when The Generation® rodenticide was used, 27.6 oz. of The Generation® rodenticide was consumed by rodents. In 2016, 72.65 oz. of The Generation® rodenticide was consumed by rodents, and in 2017, 53.6 oz. of FASTRAC® rodenticide was removed. In 2018, 46.35 oz. of FASTRAC® rodenticide was consumed. While it is not possible to determine exact removal rates specific to the amount of rodenticide consumed, it can be assumed that there are additional rodents killed which were not accounted for through a carcass count.

The weights of the three rodenticides consumed or removed from bait boxes, presumably by local rodents at different stages and the oral LD50 for rats (the amount of a chemical that is lethal to one-half (50%) of experimental animals fed) are shown in Table 3 b. The LD50 dosages of different rodenticides are based on information from internet sources:

http://pmep.cce.cornell.edu/profiles/extoxnet/dienochlor-glyphosate/diphacinone-ext.html, https://circabc.europa.eu/sd/a/8d235346-557e-4906-ad4b-86714378e8ed/Difethialone%20assessment%20report%20as%20finalised%20on%2021.06.07.pdf, https://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+6570.

We used the maximum LD50 dosages to calculate the number of roof rats with an average body mass of 200 g (150-250 g, http://icwdm.org/handbook/rodents/RoofRats.asp) killed by the rodenticide during the different implemented stages, which are shown in Table 3b. We estimated that the weights of the three rodenticides removed by rodents in stage one and three were enough to kill 500 rats of average body weight of 200 grams. Although it was not possible to document the exact number of rodents killed by the rodenticide we administered, we are confident that a large number of rodents were killed without being accounted for based on the quantity of rodenticide intake and our rodent population data (IV. G. ii.).

Based on the empirical data, the traps in DKIST's long-term rodent control grid have removed a total of 124 rodents between all trap types. In addition, it can be estimated that the A-24 traps may have also removed as many as 76 unidentifiable rodents for which the carcasses were not located. Including the estimated 625 average roof rat-sized rodents killed by rodenticides, **an estimated total of 829 rodents have been removed by long-term rodent control grid traps and rodenticide** (Tables 3a and 3b).

**Table 3a. Effectiveness of DKIST Long-Term Rodent Control Grid Between 2013 and 2018 at the Summit of Haleakalā, Maui – Rodents Removed**

| Grid Stage | One[1] | Two[2] | Three[3] | Total |
|---|---|---|---|---|
| Time Period | 04/02-05/28/2013* | 05/29/2013-04/20/2015* | 05/07/2015 – 10/31/2018* | |
| Rodent Captured | | | | |
| Field Mice | n/a | 42 | 13[5] | 55 |
| Roof Rats | n/a | 16 | 4 | 20 |
| Norwegian Rats | n/a | 9 | 0 | 9 |
| Unidentifiable Rats | n/a | 21 | 19[5] | 40 |
| Subtotal | n/a | 88 | 26 | 124 |
| A-24 Trap Hits[4] | n/a | n/a | 76 | 76 |
| Total Rodents Removed by Different Trap Types | | | | 200 |

1: 48-meter bait box grid of 51 stations- eight 1-oz Ramik™ diphacinone blocks per- Protecta ™ tamper-resistant rat bait box.
2: 48-meter bait box grid of 51 stations- T-Rex rat and mouse snap traps baited with peanut butter in each Protecta ™ tamper-resistant rat bait box and mouse bait box.
3: 47 Protecta ™ tamper-resistant rat bait boxes baited with six 1-oz Ramik™ diphacinone blocks every 30 ft. along the perimeter of all permanent structures and trailers within Haleakalā Observatory (HO) plus 35 A-24 traps with peanut butter bait in 75-meter grid outside of HO.
4: A-24 estimate based on trap counter registered trap triggered without carcasses being found.
5. One Field Mouse and an unidentifiable Rat killed by predator control grid A-24 trap.
* Trap checking dates cross years (November –February) such that the data cannot be divided into an annual format

**Table 3b. Effectiveness of DKIST Long-Term Rodent Control Grid Between 2013 and 2018 at the Summit of Haleakalā, Maui – Rodenticide Intake**

| Grid Stage | One | Two | Three* | Total |
|---|---|---|---|---|
| Time Period | 04/02-05/28/2013 | 05/29/2013-04/20/2015 | 05/07/2015 – 11/01/2018 | |
| Rodenticide Intake (OZ) | 6.6[1] | n/a | 100.25[2]+63.65[3] | 170.5 |
| Rodents Removed[4] | 7[1] | 0 | 275[2]+343[3] | 625** |

1. Ramik™ (0.005% Diphacinone, 0.3-7 mg/kg LD50)
2. Generation® BlueMax Mini Blocks (0.0025% Difethialone, 0.55-1.29 mg/kg LD50)
3. FASTRAC® All-weather Blox™ (0.01% Bromethanlin, 1.32-4.13 mg/kg LD50))
4. Based on 200g average body weight of Roof Rats, and assuming one mortality per LD50 rodenticide toxic weight consumed.

* Kill rates in prior reports were based only on diphacinone consumption calculations. This chart has been updated to reflect kill rates based on the lethality of each rodenticide brand being consumed between May of 2015 and October of 2018

**Rodenticide Rodent Kill Calculation:

1. Convert ounces of rodenticide removed from bait boxes to milligrams.
2. The weight in milligrams X toxic agent or percent of agent by weight in each rodenticide brand = actual amount of toxic agent consumed by rodents.
3. The actual amount of toxic agent consumed by rodents in milligrams / (the LD50 toxic weight in milligram/kilogram rodent body weight) = total body weight of rodents killed in kilograms.
4. The total body weight of rodents killed in kilograms X 5 = the number of rats of average body weight of 200 grams killed (1 kg=200g X 5).

***H. Predator and Rodent Population Monitoring (Please note that the population monitoring discussed in this Section is not required by the HCP or BO; it is a separate monitoring activity intended to supplement and evaluate the effectiveness of the long-term rodent control grid mentioned above.)***

Removing many of a population's individuals from a specific space during a specific time doesn't always mean the population has been suppressed. While efforts to monitor predator and rodent population trends are not required by the HCP or BO, the DKIST Team implemented invasive mammal monitoring programs in addition to the control program (discussed in sections IV. F. & I.) to understand what predators exist within the Conservation Area and Control Site for the purpose of determining whether Net Recovery Benefit could be achieved through an adaptive management approach. This was based on the premise that if the frequency of predators recorded (via cameras) within the Conservation Area was higher than the Control Site, the predator control effort in the Conservation Area may not be enough to suppress the predation pressure. A new predator control grid/plan might be needed. The empirical data did show that the invasive mammal population was larger in the Control Site and therefore a new predator control grid/plan in the Conservation Area was not needed.

Predator/ungulate population monitoring camera traps and rodent population monitoring grids in the DKIST Conservation Area and Control Site were part of these efforts. It was determined that Net Recovery Benefit could, in fact, be achieved through this approach.

***<u>i. Predator population monitoring</u>: Since April 2013***

**Table 4. Number of Photos of Different Identifiable Animal Categories Captured by DKIST HCP Monitoring Camera Traps.**

| Site | *Year* | Goat | Bird[2] | *Rodent[3]* | *Human[4]* | *Cat* |
|---|---|---|---|---|---|---|
| **Control** | 2013[1] | 476 | 3 | 0 | 1 | 0 |
| | 2014 | 938 | 39 | 6 | 0 | 0 |
| | 2015 | 485 | 23 | 0 | 0 | 0 |
| | 2016 | 192 | 16 | 0 | 0 | 0 |
| | 2017 | 44 | 1 | 0 | 6 | 1 |
| | 2018 | 33 | 7 | 0 | 0 | 0 |
| **Conservation** | 2013[1] | 61 | 11 | 0 | 6 | 0 |
| | 2014 | 0 | 29 | 1 | 29 | 0 |
| | 2015 | 0 | 16 | 0 | 16 | 0 |
| | 2016 | 0 | 13 | 0 | 14 | 0 |
| | 2017 | 0 | 12 | 0 | 9 | 0 |
| | 2018 | 0 | 11 | 0 | 5 | 0 |

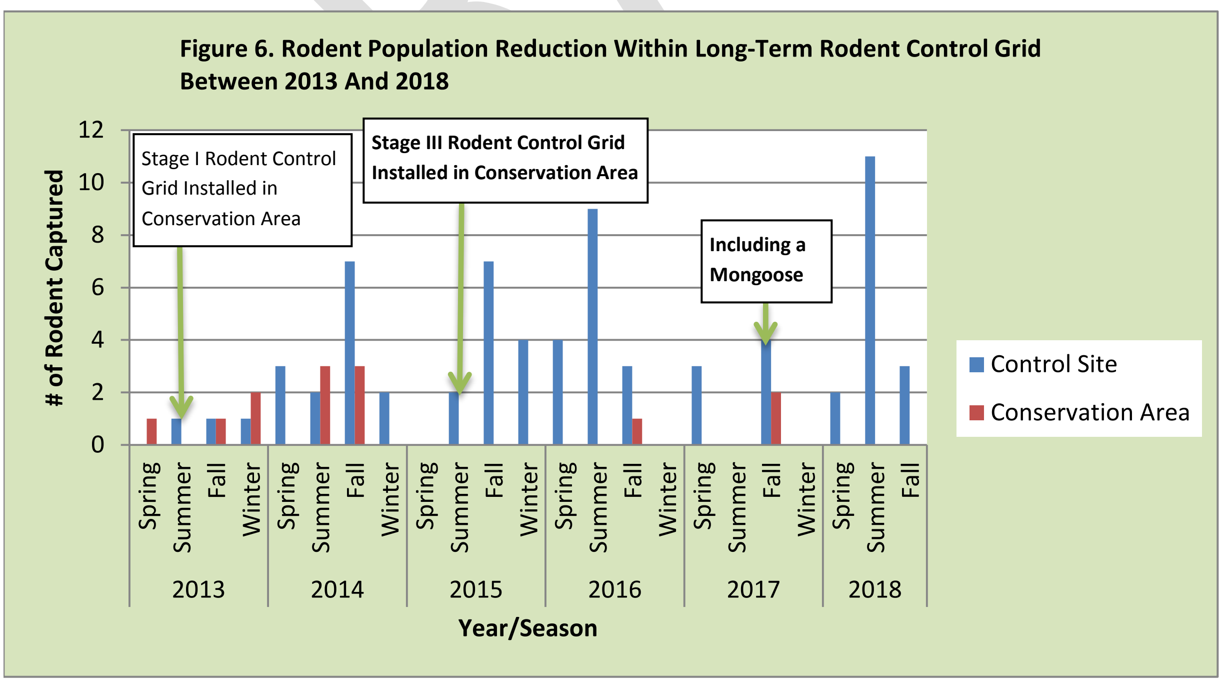
**1: initiated in April**
**2: mostly Chukars (*Alectoris chukar*), with a few Pacific Golden Plovers (*Pluvialis fulva*)**
**3: unidentified rodent species**
**4: including DKIST personnel**

Ungulate/predator population monitoring data was collected with camera traps. Twenty Bushnell Trophy Cam HD camera traps, ten at each site (Conservation Area and Control Site), were installed at random locations generated by ArcGIS 10.0 on April 23, 2013 in the Conservation Area and on April 24, 2013 in the Control Site (Figure 4). Six additional camera traps were mounted at six selected fence posts along the fence line between December 3, 2013 and February 11, 2014, where previous goat tracks had been detected. These camera traps were initially used to monitor and determine whether ungulate eradication was needed after the completion of the ungulate fence and continued to be utilized to obtain predator population data. Table 4 summarizes the number of photos for different animal categories recorded in the camera traps. No goats were recorded since September 12th of 2013, although a juvenile goat was observed inside the Conservation Area on June 1, 2017. Photos depicting humans were among those images captured. The humans in those photos are DKIST Team personnel. The total numbers of animals (goats, birds and rodents) captured in photos seemed to peak in 2014, and progressively declined in 2015, 2016, 2017 and 2018. In 2017 the camera traps captured an image of a predator (a cat) in the Control Site. This was the first predator image captured in the Control Site since rodents were seen in 2014.

***ii. Rodent Population Monitoring: Since March 2013***

The purpose of rodent population monitoring was to evaluate the impacts of the long-term rodent control grid relative to the local rodent population. Due to the proximity and habitat similarity of the two sites, we assumed the rodent capture probability (per-capita) in the Conservation Area was similar to that at the Control Site on the same sampling date. By employing the same trapping efforts in these two sites on the same date, we were able to use the rodent capture rate as the index for local rodent population.

We utilized the 20 remaining bait box stations in the former Long-Term Rodent Control 48 m grid system in the DKIST Conservation Area, and 20 bait box stations in the 48 m grid system in the Control Site (Figure 4). These two rodent population monitoring grids were located 2,030 meters apart to ensure independence of the Control Site grid from the Long-Term Rodent Control Grid treatment. For this monitoring, each station was equipped with a T-Rex rat and a T-Rex mouse trap housed in Protecta tamper-resistant bait boxes. Peanut butter was used as bait and the traps were pre-baited one week before the traps were set. Each monitoring period consisted of two trap nights. The rodent population was monitored seasonally in March, June, September and December of each year. Figure 6 summarizes the rodent population monitoring results.




***Based on two-trap-night/season rodent population monitoring data**

Calculations assume the rodent densities in both the Control Site and Conservation Area are similar, with slightly higher density in the Conservation Area due to human activity in this area (e.g., Spring of 2013 prior to the installation of the rodent control grid in the Conservation Area) (Figure 6). The overall rodent density in the Conservation Area was reduced to 17.39% of the Control Site (3.14 rodents per season in the Control Site versus 0.55 rodents per season in the Conservation Area) after the Long-Term Rodent Control Grid systems were implemented (Figure 6). During the eight seasons when stages one and two of the Rodent Control Grid systems were employed (summer 2013 to spring 2015), these two older Rodent Control Grid systems had reduced the rodent population in the Conservation Area to 52.94% of the Control Site level. (2.13 rodents per season in the Control Site versus 1.13 rodents per season in the Conservation Area). Based on the data collected during the two-trap night population monitoring, **in the 12 seasons since the stage three grid system was installed, the long-term rodent control grid has further reduced the rodent density in the Conservation Area to 5.77% of the Control Site level**. (3.71 rodents per season in the Control Site versus 0.21 rodents per season in the Conservation Area).

Besides rodents, a mongoose was caught in the Control Site Rodent Population Monitoring Grid in the fall of 2017.

***I. Noise and Vibration Monitoring: Occurred Routinely Since December 2012***

Hawaiian Petrel burrows nearest to the construction site were routinely monitored for vibration and noise during ground disturbing activities to ensure that the agreed upon thresholds documented in the HCP and BO were not exceeded during ground-disturbing construction activities. Noise and vibration monitoring of the construction site was conducted by a third-party, KCE, and began on December 1, 2012, the first day of construction.

To determine the level of vibration, measuring stations can be equipped with seismometers; depending on the location of the vibration source, one or more of six measuring stations were used to monitor ground disturbance. Two seismometers were consistently deployed at the two burrows nearest to the construction site (SC-40 and SC-21 shown on Figure 5). As required by the HCP and BO, noise producing activity was also monitored at the closest burrow to the construction footprint (SC-40, Figure 5); both at the burrow entrance, and at a distance of five meters from the burrow. The data generated from the vibration monitoring activities showed that no construction activity during the more than six years of measurements resulted in vibration levels that met or exceeded the threshold of 0.12 in/sec.

Most often, noise levels generated by construction activities were not above the ambient wind levels at the burrow entrances, which can range up to 70+ dBA. KCE reported that noise levels at the burrow entrance averaged about 56 dBA during construction activities, much of which was attributable to wind noise. The burrow entrance is at the edge of a cliff, and the strong trade winds at those locations often induced more noise than produced by the construction activities (due to the Venturi-like effect of higher wind speeds). The result was that further away from this Venturi effect and 5 meters closer to the source of construction, noise levels actually averaged about 10 dBA less. Based on KCE monitoring data, **the noise and vibration monitoring results show that construction activities never exceeded authorized thresholds**.

Most external construction was completed as of early March of 2016, and therefore, as of March 7, 2016 USFWS and DOFAW agreed that during the period of interior construction noise and vibration monitoring was not necessary at the DKIST site except when large, noisy, or earth-moving operations resumed at the site.

### *J. Predator Control: Since September 2012*

Examination of footage from surveillance cameras in September 2012 identified the presence of a feral cat below the Mees Observatory. Camera footage revealed that the feral cat had visited five different burrows and entered at least one. A Havahart trap was set near burrow SC37 on September 13, 2012 just below the Mees Observatory. Friskies brand cat food was used as bait. The trap was labeled (CT001) along with the GPS coordinates of the trap location. The cat was captured and removed from the site. There has been only one cat sighting (in 2015) since this sighting and capture in 2012. However, in the Conservation Area a cat image was recorded on a burrow camera (two weeks after the Petrel chick fledged from the burrow) in 2015. After consulting with USFWS, a 125-meter predator control grid system was installed consisting of 18 Havahart traps (for cats) and 19 A-24 automatic traps (New Zealand Goodnature Company for mongoose) that cover the northern part (the lower portion with higher risk of predation) of the Conservation Area. The actual on-ground layout of the grid was not, however, as uniform as it appeared in the plan; traps were not placed within 50 meters of any known Petrel burrow to avoid attracting predators into Petrel colonies. Each Havahart trap was equipped with a Telonics TBT-600NH or 503-1 trapsite transmitter to allow the traps to be monitored at least every other day to avoid Petrel by-catch and to ensure the welfare of the trapped animals. The installation of the northern trap grid was completed on September 16, 2013, and was operational until November 18, 2013, when all known Petrels left the Conservation Area for that season.

In order to improve the predator control efficiency, USFWS predator control experts recommended that the project employ a more unified predator control grid system. Based on this recommendation, the DKIST Team installed 22 additional cat traps and 23 new mongoose traps, and relocated the traps in the northern half in 2014. The new grid of 40 cat traps and 42 A-24 mongoose traps was completed on June 19, 2014 (Figure 4).

Peanut butter was used as bait in the A24 mongoose traps at first. Using this bait, the A-24 traps killed three roof rats but no mongoose. In an attempt to better lure mongoose, a change to utilize predator-specific bait was initiated on July 24, 2014, starting with cod liver oil and then changing monthly to include salmon oil, synthetic catnip oil, and then moving to meat-based “Violator 7” and “Feline fix” products. After these changes from the peanut butter bait, no additional predators were caught in these traps. Mongoose images were recorded by a burrow camera for two days at a burrow entrance where only rodent activity was recorded in 2016 in the Conservation Area. In the Control Site, mongoose images were captured by burrow cameras at three different burrows, each on two different days.

The predator control traps were baited for use during the first week of February of each year and decommissioned when the last known Petrel departed from the colony in late October to mid-November each year until the next Petrel season began.

In 2014, the Havahart traps caught two roof rats and no cats. Only one field mouse was caught in one of the A-24 traps in the first half of 2017.

On May 25, 2017, a Petrel was caught in a predator trap and was released unharmed. This is the only Petrel that was caught in a DKIST predator trap. Two goat carcasses were found inside the conservation fence near the west fence gate on February 1, 2017. A mongoose carcass was found in a Petrel burrow in May of 2017 with a linear fracture on the skull.

### *K. Hawaiian Petrel Burrow/Reproductive Success Monitoring: Commenced in June 2011*

Hawaiian Petrel burrow/reproductive success monitoring was conducted annually since the 2011 breeding season by the DKIST Team, in both the Conservation Area and Control Site (Figure 1).

The new burrow scope that was eventually used at the DKIST site is capable of detecting damage to burrow walls or features that may indicate collapse has occurred after nesting season. However, due to the acute angle shapes of Petrel burrows and the loose volcanic rock, utilizing a burrow scope in the Haleakalā summit area to accurately observe eggs within burrows without risk of damage to them was not feasible. Therefore, data on the number of Petrel pairs that laid eggs is not available. Rather, "Fledgling Success" is being used as a measure of reproductive success in this area. This issue was discussed with USFWS and DOFAW on February 25, 2014 and September 25, 2014. As a result, DOFAW (October 20, 2014) and USFWS (October 30, 2014) issued letters confirming acceptance of this adaptive management approach.

***L. Birdstrike Monitoring: <u>Since June 2011</u>***

In 2011, birdstrike monitoring took place from June 7 through November 30. Monitoring was conducted between February 1 and November 30 in both 2012 and 2013. From 2014 and each year thereafter, the monitoring period ended on October 31, as required by the HCP and BO.

In 2011 and 2012, prior to the start of construction of DKIST, only the two FAA communication towers were monitored. An area equal to a 75-ft. radius of the FAA towers (Figure 7) was delineated, and this radius represents 1.25 x the height of the two FAA towers (60 ft.). The site was monitored every morning, seven days a week from June 7, 2011 to the second week of March 2014. Since 2014, monitoring was conducted twice a week (primarily on Mondays and Thursdays) to reflect the HCP and BO required frequency. Since 2013, HO search Areas A and B were monitored (Figure 7). The perimeter boundary of Area A and B is approximately 1.25 x the height of the DKIST Observatory (136 ft.) extending from the perimeter of the DKIST Observatory site. DKIST

Team members conducted birdstrike monitoring within these two sites. Due to the cultural sensitivity of the summit area, no additional transect marking was deemed appropriate; therefore, the DKIST Team used only existing landmarks to mark search routes and systematically search those two sites. During the search, the team systematically searched Area A twice and scanned Area B once. When conducting the second search, the crew members rotated their positions in the formation to increase the probability of detecting downed birds.

In 2014, monitoring of the conservation fence (Figure 1) was conducted twice a week until July 5. On July 6, 2014, USFWS notified the DKIST Team that such monitoring could be reduced to once every other week. An adaptive management amendment to the BO to confirm the change was issued on July 29, 2014. On September 23, 2014, the monitoring schedule was again reduced to once each month from February to October; this reduction was justified because the extended two-month CARE trial identified no carcasses removed by scavengers. The USFWS was satisfied that fence monitoring once each month was adequate to recover any downed birds.

**<u>No structure-Petrel collisions were recorded during all the monitoring periods from 2011 to October 31, 2018 at the DKIST construction site (Areas A & B), the FAA/Coast Guard towers, or along the conservation fence.</u>** If, however, any collisions had occurred, the protocol required recording the following information: date, time, location coordinates, species, photo of the bird in question, and person attending. This information would have been included in a report forwarded to the USFWS, Pacific Islands Fish and Wildlife Office, USFWS Office of Law Enforcement, and DOFAW. In accordance with the protocol, the downed birds or carcasses would have been handled according to the official State of Hawai'i Downed Wildlife and the USGS Wildlife Health Center, Honolulu office protocols, and if still alive, injured individuals would have been delivered to appropriate local Maui veterinarians. DKIST would have funded any acute care and the transport of the bird, if necessary, to a permitted wildlife rehabilitation center (currently located on O'ahu and on the island of Hawai'i).


- Area A (3.3 acres (1.3 ha)): Lies on the more level area of Kolekole cinder cone and included other observatories. This area included roads, pathways, and roofs of buildings, plus open rocky habitat with little obstruction for detecting bird carcasses. No restriction within this search area existed, and all monitoring of Area A was done by systematic foot search.
- Area B (1.4 acres (0.6 ha)): Lies on the steep slopes south and east below the relatively flat area of Area A in an existing Hawaiian Petrel habitat. As instructed in the HCP, monitoring of Area B was conducted via use of binoculars to scan through the areas, since frequent monitoring by foot search was discouraged because foot traffic could degrade breeding habitat present in that area. Searchers were able to access the edge of the cliff at the demarcation between Area A and Area B for visual scanning (binocular-assisted) of Area B. However, because Area B included rocks and boulders of various sizes that would obstruct simple observation of bird carcasses, it could not be covered adequately enough to accurately count downed birds. Because burrow monitoring was also conducted in this area, any birds that were missed by visual scanning were likely to be detected on the ground in the course of routine monitoring. Visual scanning, however, was useful in detecting and recovering any downed birds in the open, so that they did not become a predator attraction.

## V. HAWAIIAN PETREL REPRODUCTIVE SUCCESS MONITORING: RESULTS AND DISCUSSION

Please see Appendix 1 for methodology. In order to verify the calculations of net benefit to the Hawaiian Petrel population obtained by DKIST's mitigation measures in the Conservation Area as described in this report, we invited Dr. Andrew L. Spivak, Associate Professor of Sociology at the University of Nevada, Las Vegas to conduct several statistical analyses (Appendix 2). For these analyses, Dr. Spivak was able to reject the null hypothesis for both predation and fledgling success and conclude that both are correlated with higher success after DKIST mitigation ($P<0.05$ was used to reject the null hypothesis in all statistical tests in this report).

### *A. Number of Petrel Burrows Monitored*

Based on monitoring data, Hawaiian Petrel burrows were classified as "Active" and "Not Active" . Table 5 summarizes the adjusted and updated number of possible Hawaiian Petrel burrows monitored in these three categories within DKIST monitoring areas during the past eight nesting seasons. As new burrows were located each year, the number of burrows monitored increased from 272 in 2011 to 407 in 2018. In the updated table, only burrows that were within the 2013 built conservation fence, not the boundary and Control Site burrows were included. (Note that earlier reports did not include data from 2011 in the Conservation Area under the categories of "Not Active" and, therefore, data in this Final Report may vary from data in those earlier reports.)

### *B. Burrow Status*

In the analysis, only burrows that were inside the boundary were included. "Nesting Activity %" is the number of "Active" burrows divided by the total number of burrows monitored that year, while "Fledgling Success %" is calculated by dividing the "successful" number of burrows by the number of "Active" burrows.

**Table 5. Hawaiian Petrel Burrows and Reproductive Success in DKIST HCP Conservation Area and Control Site on Haleakalā, Maui, Hawaii (Cons. =Conservation Area, Cont. =Control Site).**

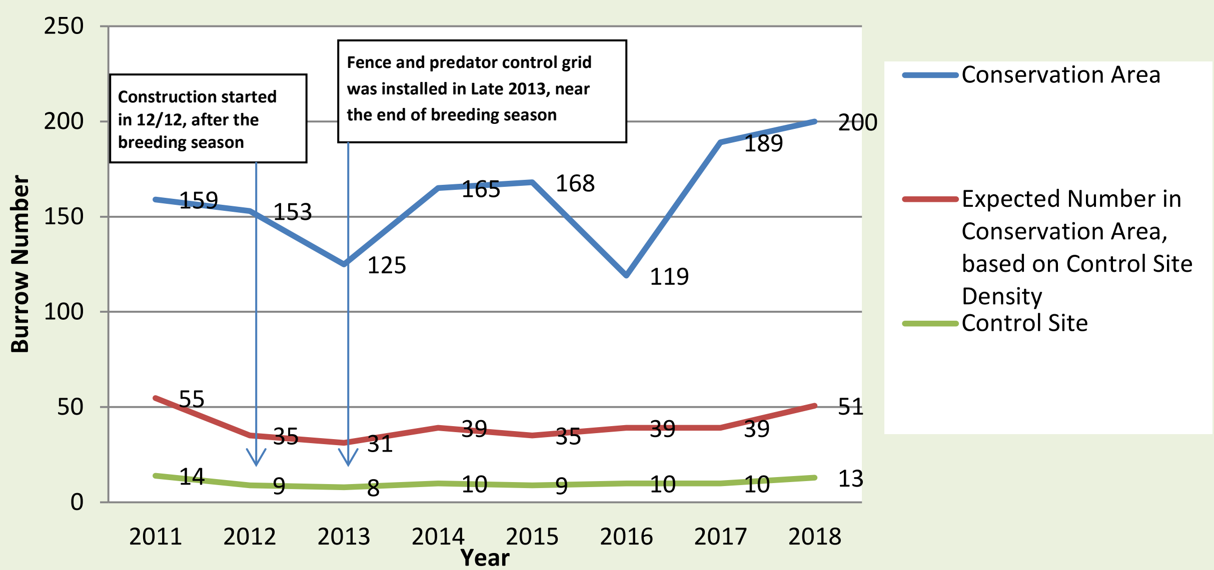
| Year | | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | | 2016 | | 2017 | | 2018 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Status** | Location | **Cons.** | **Cont.** | **Cons.[1]** | **Cont.** | **Cons.[2]** | **Cont.** | **Cons.[3]** | **Cont.** | **Cons.[4]** | **Cont.** | **Cons.** | **Cont.** | **Cons.** | **Cont.** | **Cons.** | **Cont.** |
| ***Old*** | **Active Burrow** | 73 | 0 | 140 | 6 | 122 | 7 | 158 | 7 | 154 | 7 | 106 | 8 | 163 | 10 | 187 | 11 |
| *Found in* | **Successful** | 24 | 0 | 16 | 0 | 26 | 0 | 42 | 1 | 29 | 2 | 48 | 0 | 50 | 0 | 49 | 0 |
| *prior* | **Nonproductive** | 49 | 0 | 124 | 6 | 96 | 7 | 116 | 6 | 125 | 5 | 58 | 8 | 113[5] | 10 | 138 | 11 |
| *years)* | **Not Active** | 48 | 0 | 118 | 15 | 159 | 18 | 130 | 19 | 143 | 22 | 205 | 23 | 169 | 23 | 172 | 22 |
| ***New*** | **Active Burrow** | 86 | 14 | 13 | 3 | 3 | 1 | 7 | 3 | 14 | 2 | 13 | 2 | 26 | 0 | 13 | 2 |
| *(found* | **Successful** | 8 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 1 | 0 |
| *during* | **Non-productive** | 78 | 14 | 13 | 3 | 2 | 1 | 5 | 3 | 14 | 2 | 12 | 2 | 23 | 0 | 12 | 2 |
| *year)* | **Not Active** | 44 | 7 | 9 | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 8 | 0 | 1 | 0 | 0 | 0 |
| ***Subtotal*** | **Old** | 121 | 0 | 258 | 21 | 281 | 25 | 288 | 26 | 297 | 29 | 311 | 31 | 332 | 33 | 359 | 33 |
| | **New** | 130 | 21 | 22 | 4 | 6 | 1 | 8 | 3 | 14 | 2 | 21 | 2 | 27 | 0 | 13 | 2 |
| **Total** | | 251 | 21 | 280 | 25 | 287 | 26 | 296 | 29 | 311 | 31 | 332 | 33 | 359 | 33 | 372 | 35 |
| **Nesting Activity %** | | 67.37 | 66.67 | 57.74 | 36.00 | 44.80 | 30.77 | 56.12 | 34.48 | 54.02 | 29.03 | 35.84 | 30.30 | 52.65 | 30.30 | 53.76 | 37.14 |
| **Fledgling Success %** | | 20.13 | 0.00 | 10.46 | 0.00 | 21.60 | 0.00 | 26.67 | 10.00 | 17.26 | 22.22 | 41.18 | 0.00 | 28.04 | 0.00 | 25.00 | 0.00 |

1. Seven of the old burrows recorded in 2012 were burrows that were marked prior to 2011, but were found in 2012.
2. One of the old burrows recorded in 2013 was marked prior to 2011, but was found in 2013.
3. This includes one burrow separated from an old burrow in 2014.
4. This includes one burrow separated from an old burrow in 2015.
5. This includes two unknown outcomes due to camera failure.

Table 5 summarizes the adjusted status of burrows found between 2011 and 2018, along with successful/non-productive statistics. In the Conservation Area, the largest number of active burrows since 2011 was recorded in 2018. There were 200 active burrows this year (including 13 new burrows), which represents a 6% increase over the number of active burrows identified in 2017 (n=189). The rate of Nesting Activity (54%) was similar to the 53% rate for 2017 ($\chi2$ =0.028, P=0.867, df=1, Figure 8). The number of successful burrows decreased 6% to 50 in 2018 (compared to 53 in 2017). The "Fledgling Success %" was 25%, also slightly lower than it was in 2017 (28%, $\chi2$ = 0.268, P=0.605, df=1). In the Control Site, 13 active burrows were recorded (including two new burrows) in 2018, which showed a 30% increase over the number of active burrows recorded in 2017 (n=10). The Nesting Activity % of 37% was slightly higher than it was in 2017 (30%, $\chi2$ = 0.176, P=0.675, df=1), and Fledgling Success % of 0 in 2018 was identical to the data recorded in 2017 (Figure 8).

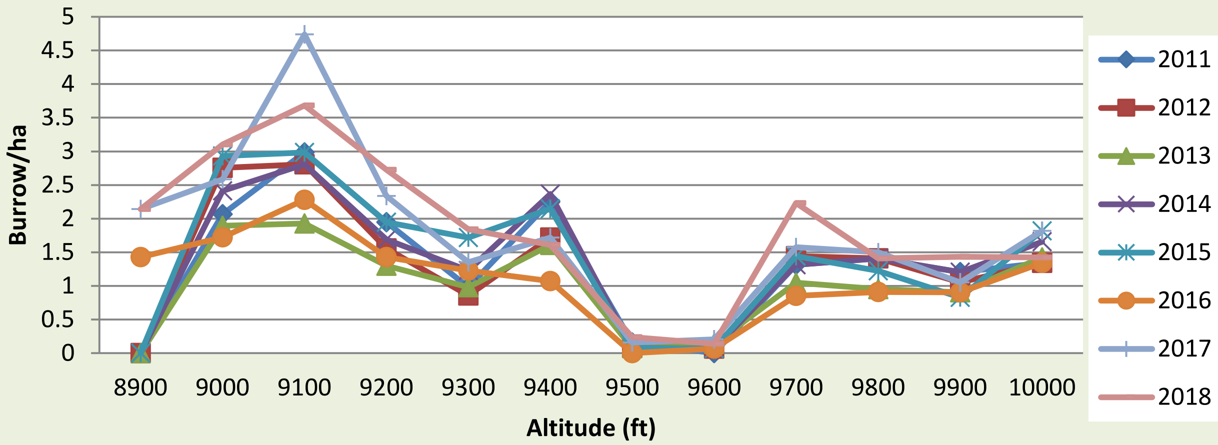
The density of active Petrel burrows recorded from 2011 to 2018 in the Control Site (80 acres) was used to predict the number of active Petrel burrows in the Conservation Area (312.66 acres). It was found that more active Petrel burrows (3-5 times more) were recorded in the Conservation Area than expected from 2011 to 2018, even in the years prior to the installation of the conservation fence and predator/rodent grids (Figure 8). This phenomenon might be explained by the relatively lower quality of Petrel nesting habitat or less suitable burrowing sites located in the Control Site. It could also be that this site sustained long term predation pressure and habitat disturbance due to its proximity to the source of predators and feral ungulates.

**Figure 8. Active Hawaiian Petrel Burrow Number Recorded in DKIST HCP Monitoring Area On The Summit of Haleakalā, Maui From 2011 to 2018**




Prior to our study, no comprehensive data was collected in these two sites. A priori, we had no way to know the petrel population density in these two sites. Upon examination of the density distribution of active Petrel burrows within the Conservation Area in different years and at different elevations, almost identical density distribution patterns in different years can be observed. The highest number of active burrows was recorded in 2018, and the most notable increase of active burrow density was located between 9,100 and 9,300 ft. and 9,600 and 9,700 ft. elevation (Figure 9). Figure 9 also shows that Petrel burrows in the HCP monitored areas were neither evenly nor randomly distributed. Further investigation of the active burrow distribution indicated that burrows were only located in lava rock areas and that cinder areas were vacant of Petrel burrows, although different altitudes contain both lava rock and cinder areas. Figures 9 and 12-13 show various parameters related to the petrel population plotted as a function of altitude.  In an environment on the summit where the slope falls away steeply, altitude also provides a measure of the proximity to the DKIST construction activity.

**Figure 9. Active Hawaiian Petrel Burrow Density at Different Altitude Recorded from 2011 to 2018 in DKIST HCP Conservation Area on the Summit of Haleakalā, Maui**



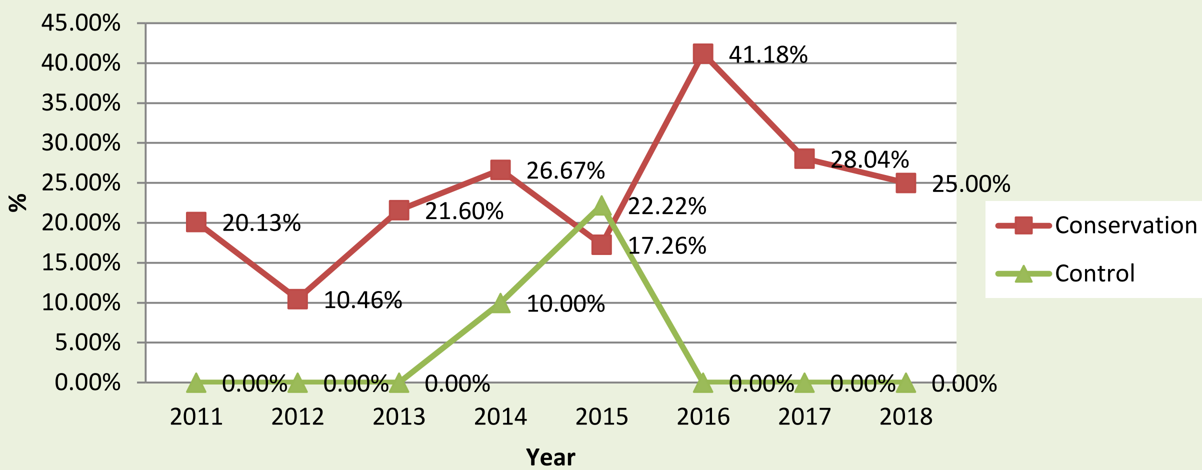

Based on recent genetic and isotope studies (Judge 2011, Welch, *et al*.  2012, Wiley, *et al*. 2013), the DKIST Team assumed that all Hawaiian Petrel colonies on the summit of Haleakalā, Maui form a meta-population. We speculated that Petrels from those colonies may have foraged in the same general foraging areas, and experienced the same survival conditions and challenges during the same year. Intra-year comparisons between the Conservation Area and Control Site were examined and presented in order to reduce the uncontrollable effects of inter-year environmental variability (e.g., climate forcing prey flux, marine pollution and debris, fishery interaction, changes in predatory fish populations, other ecological factors) on the reproductive performance, survival rate, and recruitment of Hawaiian Petrels.

We attempted to compare trends of active burrow numbers and successful burrow numbers between the Conservation Area and Control Site, to evaluate whether the DKIST conservation fence and predator/rodent control grids promoted recovery for the Hawaiian Petrel in the Conservation Area.  As described previously, there were challenges that underscored the poor correlation between a number of physical variables, such that a useful comparison between sites could not be obtained and the sample size of active/successful burrows recorded in the Control Site from 2011 to 2018 was too small to conduct appropriate statistical comparisons. The reproductive success rate of zero recorded in five of the eight seasons in the Control Site also violated the Chi-square statistic preassumptions. Even population trends were difficult to identify due to the small sample size in the Control Site. For example, in 2015 the 22.2%"Fledgling Success %" in the Control Site was higher than in the Conservation Area (17.2%), but the statistic was only based on nine active burrows (Table 5, Figure 10). After the first burrow successfully fledged a chick in the Control Site in 2014, two Petrel burrows produced fledglings in 2015, but the number went down to zero again from 2016 to 2018.

As a Chi-square test of pre- and post-mitigation efforts on fledgling success in the Conservation Area, we can compare the average "Fledgling Success %" prior to the implementation of all the conservation measures (15.4%, 2011 & 2012, see eq. 1 below) with that of post implementation years (26.8%, 2014 to 2018, see eq. 2 below). We observe **a significant ($\chi^2$ =10.506, P<0.05, df=1) increase of 73.9**% (see eq. 3 below) **in "Fledgling Success %" after the conservation measures were implemented in the Conservation Area (see Appendix 2).**

1. **($32^{\text{2011 successful burrow}}$+$16^{\text{2012 successful burrow}}$)/($159^{\text{2011 active burrow}}$+$153^{\text{2012 active burrow}}$)=15.38%**
2. **($44^{\text{2014 successful burrow}}$ +$29^{\text{2015 successful burrow}}$ +$49^{\text{2016 successful burrow}}$+$53^{\textbf{2017}\text{ successful burrow}}$ +$50^{\textbf{2018}\text{ successful burrow}}$)/($165^{\text{2014 active burrow}}$ +$168^{\text{2015 active burrow}}$ +$119^{\text{2016 active burrow}}$+$189^{\text{2017 active burrow}}$ +$200^{\text{2018 active burrow}}$)=26.75%**
3. **(26.75%-15.38%)/15.38%=73.9%**

**Figure 10. Hawaiian Petrel Fledgling Success % Recorded in DKIST HCP Monitored Areas on the Summit of Haleakalā, Maui, From 2011 to 2018**




Although fledgling success percentage rate is a good habitat index, it can be misleading if density is not considered. For example, in Figure 12 and 13, a high Fledgling Success % was recorded in between 9,500 and 9,600 ft. elevation in 2014 and 2015, but a very low Successful Burrow Density was recorded in the same elevation in the same year. This is because there was only one active and successful burrow found in that elevation in those two years, also consider two areas of the same size. One has 10 Petrel pairs with 5 fledglings = 50% success, while the other one has 100 Petrel pairs with 40 fledglings = 40% success. The percentage of successful pairs is misleading if the burrow density is not also considered. Comparing the successful burrow densities or numbers prior to 2013 and after 2013 when the installation of the mitigation measures was completed (Figure 11), seems to be a more appropiate way of determining whether the DKIST HCP mitigation measures facilitated petrel reproductive performance in the Conservation Area. The attempt to determine the effect by comparing successful burrow densities or numbers in the Conservation Area and Control Site may be skewed due to the low number of active burrows recorded in the Control Site. Also, the habitat quality in the Control Site and the Conservation Area is very different (as illustrated in Figure 8 of this Section).

Climatologically, 2015 was considered to be anomalous in the North Pacific Ocean. Unusually high ocean surface temperatures (A.K.A. “Blob”) induced shifts in fish distribution and algae blooms, resulting in mass seabird and marine mammal stranding and die-off in this area (Cavole, *et al*. 2016). The 2015 Pacific hurricane season was the most active Central Pacific hurricane season on record since 1980, with 16 named storms (National Weather Service Central Pacific Hurricane Center, http://www.prh.noaa.gov/cphc/summaries/), which was 2 to 16 times the number recorded from 2011 to 2018. This extraordinarily active hurricane season might have impacted petrels’ travel between their breeding colonies and foraging grounds in the North Pacific. All of these anomolies in 2015 may have resulted in the high egg abandonment and roll out number observed in 2015 (n=15).

The second largest number of eggs found out-of-nest was recorded in 2017 (n=10), although the cause(s) remains unknown. We recorded seven out-of-nest eggs, including one that was attached to the abdomen of one of the parent birds and carried out of the nest. In addition, one premature Petrel chick emmerged in 2018 (Table 6). In aacorance with the State of Hawaii "Downed Wildlife Protocol", DKIST resource management team members were not permitted to have contact with the remains of a mortality event.Therefore, information regarding the viability of the out of nest eggs is not known.

In 2018, there was a noticeable improvement in reproductive performance in elevations above 9,900 ft. in the Conservation Area, which is the elevation adjacent to the DKIST construction site. No chick predation or nest trampling and no adults predated above this elevation were recorded in this area since 2014, (Figure 12 and 13, Table 6). No predation events were recorded in 2018.

**Figure 11. Hawaii Petrel Successful Nest Density Recorded in DKIST HCP Monitored Areas on the Summit of Haleakalā, Maui, From 2011 to 2016**

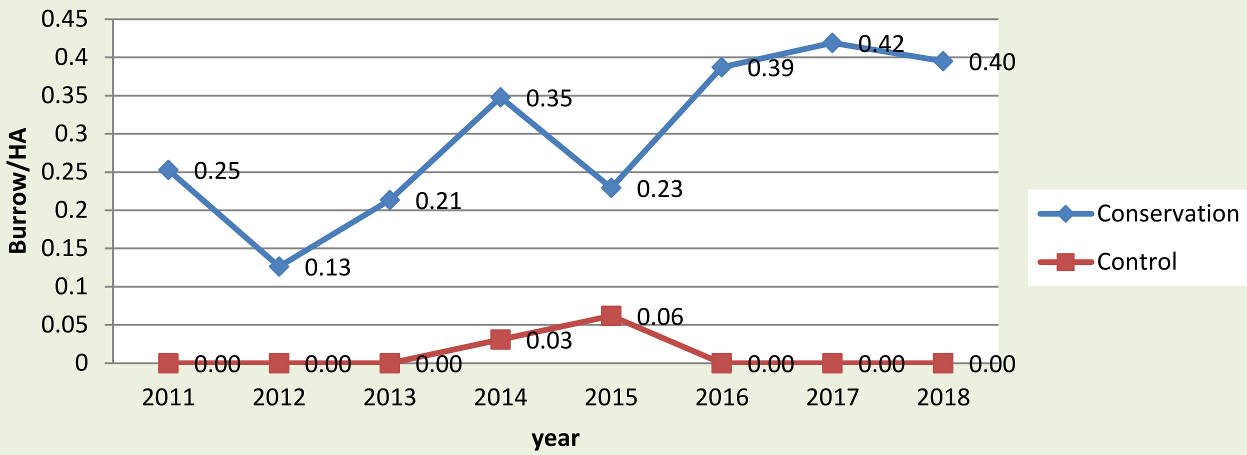



**Figure 12. Hawaiian Petrel Fledgling Success % at Different Altitudes Reocored Between 2011 and 2018 in DKIST Conservation Area, Near the Summit of Haleakalā, Maui**

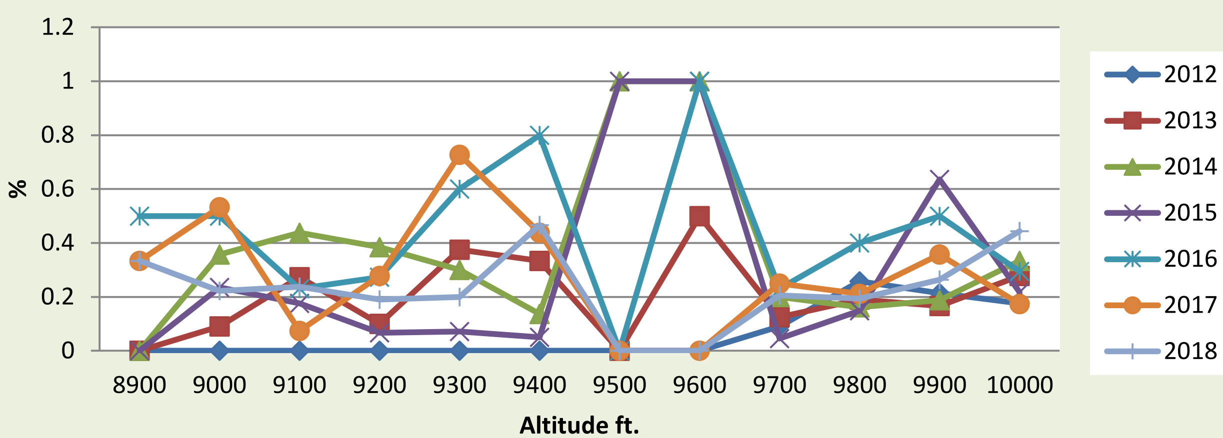
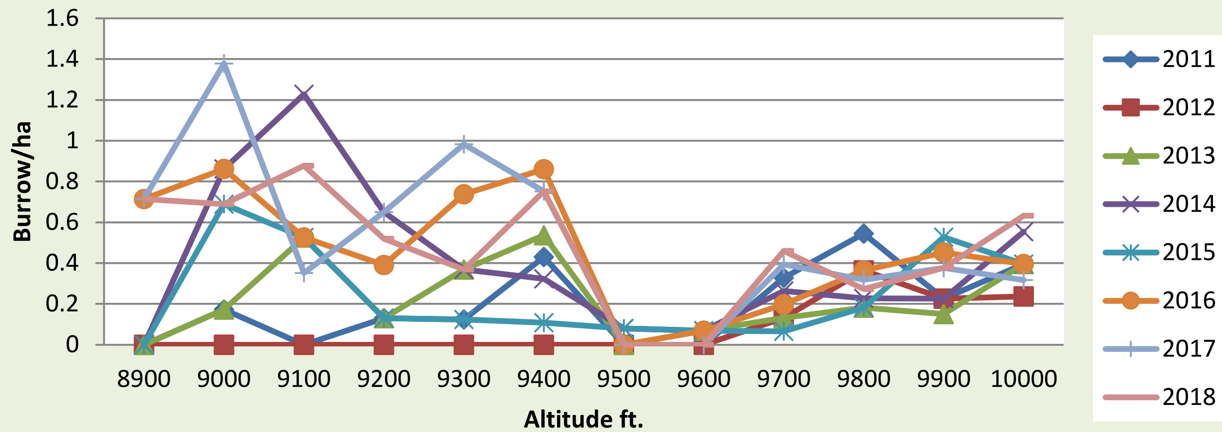


**Figure 13. Successful Hawaiian Petrel Burrow Density at Different Altitudes Recorded Between 2011 and 2018 in DKIST Conservation Area, Near the Summit of Haleakalā, Maui**




Because the conservation fence was not enclosed until November of 2013 and only half of the predator control grid was installed in 2013, it was very difficult to measure how the local Petrel population responded to our implementation of conservation measures that year. Therefore, the statistics involving petrel population trends exclude 2013 data.

When we look at the number of successful fledglings before and after DKIST implemented the HCP/BO conservation measures, the average annual successful fledgling number from 2011 to 2012 in the Conservation Area was 24 (25, if 2013 is included), while the average annual successful fledgling number from 2011 to 2013 in the Control Site was zero. The average annual successful burrow number from 2014 to 2018 in the Conservation Area was 45.00, while the average successful burrow number from 2014 to 2018 in the Control Site was 0.60. **The average annual Hawaiian Petrel productivity in the Conservation Area increased 87.5% after the HCP was fully implemented** . Based on the empirical data, and by employing an approach based on density, **DKIST HCP/BO mitigation measures are calculated to have facilitated the Hawaiian Petrel fledging rate by 21.00 (see eq. 1 below) more successful fledglings annually (or 105 more successful fledglings, see eq. 2 below) from 2014 to 2018**.

1. $\mathbf{45.00^{\text{average successful fledgling \# 2014-2018}} - 24.00^{\text{average successful fledgling \# 2011-2012}} = 21.00^{\text{annual increased successful fledgling \#}}}$
2. $\mathbf{21^{\text{annual increased successful fledgling \#}} \times 5\ \text{year}^{2014\text{-}2018} = 105^{\text{2014-2018total increased successful fledgling \#}}}$

If the Fledgling Success % approach is employed, the average active pair (per burrow) produced 0.15 successful fledglings from 2011 to 2012 in the Conservation Area. Based on this calculation, the number of successful Petrel chicks in the Conservation Area would be around 25 in 2014, 26 in 2015, 18 in 2016, 29 in 2017, and 31 in 2018. By comparing the observed data shown in Table 5, our calculations demonstrate that the **DKIST HCP/BO mitigation measures have facilitated the success of the Hawaiian Petrel population in the Conservation area by an increase of 96 more fledglings than would have been expected from 2014 to 2018** (18.6 in 2014, 3.2 in 2015, 30.7 in 2016, 23.9 in 2017 and 19.2 in 2018).

A two-proportion z test was employed to test if conservation measures implemented in the Conservation Area facilitated Petrel Fledgling Success (2011-2012 vs 2014-2018 season); the null hypothesis was rejected and the conclusion was that the period of conservation implementation is significantly related to burrow Fledgling Success ( $Z = 4.460$, $p<0.00001$). A Gamma (γ) coefficient test was also performed to examine Fledgling Success and conservation implementation; a moderately strong inverse/negative association between pre-conservation implementation and Fledgling Success was observed (γ= - 0.34, p=0.001565). The t-test for significance of γ is 3.17 (please see Appendix 2 for detailed statistical procedures).

The results for fledgling success demonstrate positive outcomes for the first of the three elements that establish net benefit from DKIST HCP mitigation measures. All three are described in Section VI. C., below.

### *C. Hawaiian Petrel Mortality*

Table 6 summarizes all known mortality events recorded between the 2011 breeding season and close of the 2018 breeding season. In 2018, six eggs were found out of their nests and there was an unusual sighting of one additional out-of-nest egg that was attached to the abdomen of one of the parent Petrels, for a total of seven eggs. A second unusual occurrence recorded in the Conservation Area in 2018 was that one of the adult pairs that had an out-of-nest egg went on to successfully lay another egg and fledge a chick. This indicates that Hawaiian Petrels have the ability to recycle—to lay an additional egg after the loss of a previous egg. One Petrel chick premature emergence mortality was recorded in the Conservation Area. One egg was found out of the nest in the Control Site through the end of the 2018 season.

**Table 6. Known Hawaiian Petrel Mortality Events Recorded between 2011 and 2018 in the DKIST Conservation Area and Control Site (Cons.: Conservation Area, Cont.: Control Site. Other causes of mortality referred to in USGS or MNSRCP reports listed no evidence of predation at the scene or on the remains)**

| Year | 2011 | | 2012 | | 2013[1] | | 2014 | | 2015 | | 2016 | | 2017 | | 2018 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Age/Site** | **Cons.** | **Cont.** | **Cons.** | **Cont.** | **Cons.** | **Cont.** | **Cons.[2]** | **Cont.** | **Cons.** | **Cont.** | **Cons.** | **Cont.** | **Cons.** | **Cont.** | **Cons.** | **Cont.** |
| **Other** | | | | | | | | | | | | | | | | |
| Egg | 4 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 14 | 1 | 4 | 0 | 10 | 0 | 7 | 1 |
| Chick | 2 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 2[3] | 0 | 1 | 0 | 1 | 0 |
| Adult | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1[4] | 0 | 0 | 0 |
| **Predation/burrow trampling** | | | | | | | | | | | | | | | | |
| Egg | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chick | 6 | 3 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| Adult | 1 | 9 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| **TOTAL** | 15 | 12 | 7 | 1 | 9 | 0 | 4 | 1 | 16 | 2 | 7 | 1 | 14 | 0 | 8 | 1 |

**1. This does not include a burrow trampled by ungulates in the early stage of breeding season, and an adult and a chick mortality event that occurred prior to 2013.**
**2. This does not include one burrow collapse in each site due to an unknown cause and consequence in the early stage of the breeding season. The collapsed burrow in Conservation Area was 210 m from the nearest DKIST staging area and more than 400 m from construction site.**
**3. Two chicks first emerged from their burrows in November still covered with down; one left the same night, which died of emaciation two days later, the other chick, stayed around its burrow for six nights and then disappeared. Based on the condition of this chick, we assumed this chick didn't fledge successfully.**
**4. The cause of mortality was not determined.**

### *D. Reduction of Predator Control Rates to Achieve Net Recovery Benefit*

In accordance with the HCP and the BO, NSF is required to demonstrate a Net Recovery Benefit to the species. In consultation with DOFAW and USFWS, the DKIST Team determined that the most accurate way to determine whether Net Recovery Benefit has been achieved is to use rates of predation 'before and after' implementation of the mitigation measures. The following sections discuss the steps taken to control predation and the resulting success of the predator control measures to achieve Net Recovery Benefit.

Predator Control Success for DKIST:

- Significant reduction in the rates of predation during construction due to predator control measures, specifically the installation and monitoring of mammal and rodent control traps.
- Construction of an ungulate proof fence around a 328-acre Conservation Area surrounding HO, which is responsible for the reduction of burrow loss due to trampling and mammal intrusion.
- The clear and significant increase in the number of fledglings since 2011 compared to what would have been expected in the absence of predator control measures (see statistical analysis in Appendix 2).

Table 7 summarizes the Petrel monitoring data through the end of the 2018 season. Years 2011-2012 represent data collected prior to the implementation of mitigation efforts, while years 2013-2018 represent post-mitigation data. There is a clear difference in the number of chicks and adults predated before and after the end of 2012.

In order to better quantify the annual benefit to the population, we first determined the expected predation- rate for both chicks and adults, respectively. For chicks, expected losses were based on the number of chicks predated, divided by the total number of chicks recorded for years 2011-2012, years in which the predator control measures were not yet in place. This yielded an expected predation-mortality rate for future years, in the absence of any mitigation efforts, of approximately 12.7%. This factor was then multiplied by the number of chicks for each of the out years (2013-2018) in order to determine the yearly expected chick mortalities. For adults, expected losses were based on the number of adults predated, divided by twice the number of chicks that year (assuming two adults per chick were present at the colony for that breeding season). Thus, the adult mortality rate expected in future years was determined to be 3.6%. This expected rate was multiplied by twice the number of chicks (again assuming 2 adults per chick) for each of the out years to determine the expected adult deaths each year, 2013-2018. The annual chick/adult benefit (i.e., the two rows in grey in Table 7) is the difference between the expected mortality and the observed number of mortalities each year. Finally, these annual benefit values for years 2013-2018 were summed to determine the total Net Recovery Benefit.

**Table 7. Hawaiian Petrel Predation Rates Before (2011-2012) And After (2013-2018) DKIST Mitigation Efforts in the DKIST Conservation Area at the Summit of Haleakalā, Maui.**

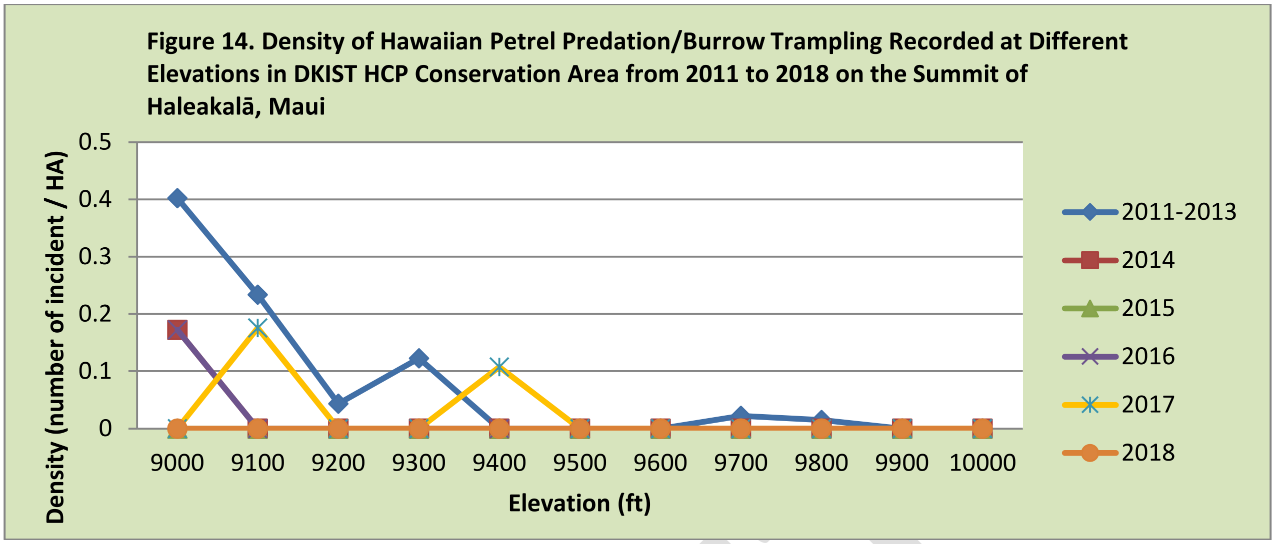
| Year | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Active Burrows | 159 | 153 | 125 | 165 | 168 | 119 | 189 | 200 | |
| Chicks Produced | 38 | 17 | 30 | 44 | 29 | 49 | 54 | 51 | |
| Chicks Fledged | 32 | 16 | 27 | 44 | 29 | 49 | 53 | 50 | |
| Chicks predated | 6 | 1 | 3 | 0 | 0 | 0 | 1 | 0 | |
| Expected Chick Predation at 12.7% | | | 3.82 | 5.60 | 3.69 | 6.24 | 6.87 | 6.49 | |
| Annual Chick Benefit | | | 0.82 | 5.60 | 3.69 | 6.24 | 5.87 | 6.49 | 28.71 |
| Annual Chick Predation Rate | 0.16 | 0.06 | 0.10 | 0.00 | 0.00 | 0.00 | 0.02 | | |
| Adults predated | 1 | 3 | 0 | 1 | 0. | 1 | 1 | 0 | |
| Expected Predation at 3.6% | | | 2.18 | 3.20 | 2.11 | 3.56 | 3.93 | 3.71 | |
| Annual Adult Benefit | | | 2.18 | 2.20 | 2.11 | 2.56 | 2.93 | 3.71 | 15.69 |
| Annual Adult Predation Rate | 0.01 | 0.09 | 0.00 | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 | |

As of the end of the 2018 season, it is estimated that **<u>the predation of 28.7 chicks and 15.7 adult Hawaiian Petrels were prevented due to the predator control measures implemented by the DKIST Project</u>**. This net reduction in predation of 44.4 birds represents a significant Net Recovery Benefit to the species.

To demonstrate the statistical significance of using petrel predation mortality before and after the implementation of mitigation efforts, we consulted with Dr. Andrew Spivak of the University of Nevada at Las Vegas (UNLV), an expert in the statistical analysis of data. Dr. Spivak's analysis and conclusions are presented in Appendix 2. He employed various bivariate statistical measures including (1) a two-proportion Z-test, (2) a correlation coefficient for two binary variables with a chi-squared significance, and (3) a Gamma coefficient for two ordinary variables. He performed these tests on both petrel chick and adult predation data taken pre- and post-mitigation. In all cases, Dr. Spivak found a statistically significant basis for our finding of improved petrel predation after the implementation of mitigation measures (i.e. a Net Recovery Benefit).

In light of all of the HCP conservation measures implemented by DKIST, it would be reasonable to anticipate a diminishing trend for predation, but not necessarily a direct Hawaiian Petrel population increase. Lower predation may not automatically lead to a population increase because of indeterminable and uncontrollable impacts outside of the Petrel breeding colonies where the Petrels spend approximately nine months of each year. However, DKIST has experienced both diminished predation and increased population. For example, the egg roll-out/abandonment observed in 2015 in the Conservation Area (n=14) is equal to the sum of all predation events observed in 2011 and 2012 (n=8+6=14), which were the years prior to the implementation of predator control measures. Although the implementation of predator control measures had effectively reduced the amount of predation events, egg roll-out/abandonment still occurred, meaning that there were certainly factors at play that were not related to predation, and more than likely, they were factors we could not control. It appears as though impacts originating from outside of the Hawaiian Petrel colonies actually play a more significant role in the Petrel mortality observed in DKIST HCP monitored areas than previously thought. The actual strength of the association ($\gamma$) was lower for Fledgling Success than for either chick or adult predation (-0.34 compared to .80 and 0.73). It should be noted that Control Site predation diminished more quickly than in the Conservation Area during the period from 2011 to 2018. However, once we factor in burrow density and the difference in areal size (the Conservation Area is approximately four times larger than the Control Site), we can see that predation in the Conservation Area actually diminished more than in the Control Site.

Figure 14 demonstrates the effectiveness of the conservation fence and predator control grid implemented in 2013 and completed in early 2014 in the Conservation Area; subsequently, no predation events occurred above 9,500 ft., and predation events between 9,000 and 9,500 ft. were reduced to 15% of the pre-predator control levels.




### *E. Trend of Hawaiian Petrel Burrows Adjacent to the Construction Site*

Petrel burrows located in the area within the south boundary of HO structures, north of Skyline Trail, west of the HO access road and east of Faulkes Telescope North are considered adjacent to the construction site (Figure 1 and 15). These burrows are a subsection of the Conservation Area, and due to their proximity to the construction site were considered to have the highest risk of impacts from construction activity. In order to understand whether DKIST construction activities resulted in the decline of active Hawaiian Petrel burrow numbers, the trend of Petrel burrow status and reproductive performance adjacent to the DKIST construction site in the Conservation Area was also examined While Active burrows adjacent to the construction site in 2018 were the second fewest since 2014, there is still an overall upward trend in Active burrows since 2011, and the successful burrow number and Fledgling Success % reached its highest point in this area in 2018 (Figure 16). **The eight years of data supports the conclusion that DKIST construction activities neither deterred new Petrels from coming to breed and nest in areas adjacent to the DKIST construction site, nor jeopardized the Petrels' reproductive success.** We cannot determine what caused the fluctuation of reproductive success of the Petrels in this area and the greater Conservation Area; it does not appear to be related to noise, vibration, or other impacts from DKIST construction activity, since DKIST external construction was primarily completed in early 2016.

Based on the trend of reduced predation events (which appeared to help increase the number of active burrows (Figure 14), the upward trend in the number of active burrows, and the Fledgling Success % recorded adjacent to the DKIST site from 2011 to 2018 (Figure 16), and considering the fact that DKIST construction did not begin until December of 2012 after the 2012 Petrel season was complete, it seems highly unlikely that the decrease noted in overall active burrow numbers from 2011 to 2013 (Figure 8) was related in any way to construction activities. The initial decline in the number of active Petrel burrows recorded in the larger DKIST HCP/BO monitoring area probably resulted from a combination of invasive predators, ungulates, and factors external to the breeding colonies.

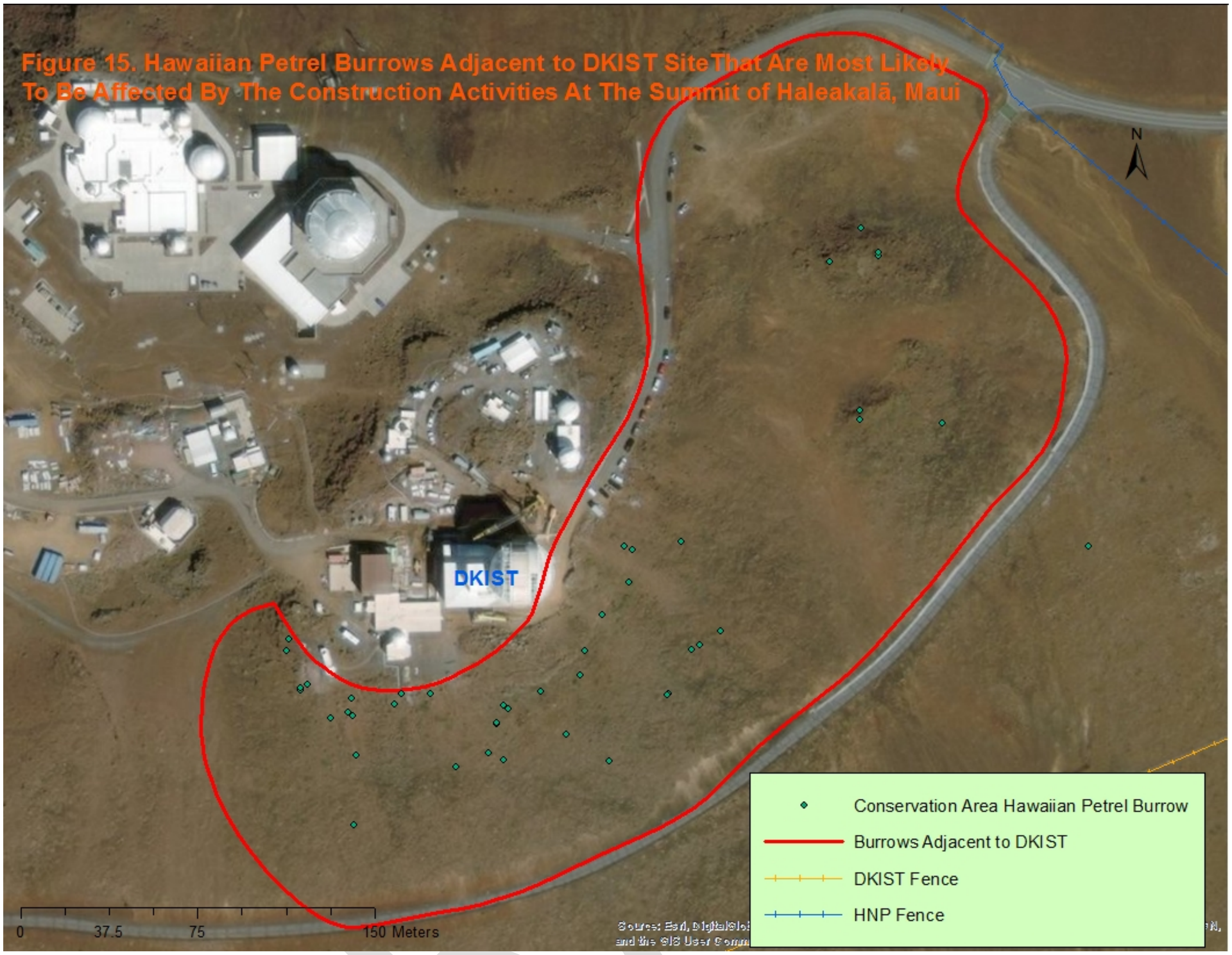


Figure 15. Hawaiian Petrel Burrows Adjacent to DKIST Site That Are Most Likely To Be Affected By The Construction Activities At The Summit of Haleakalā, Maui
N
DKIST
Conservation Area Hawaiian Petrel Burrow
Burrows Adjacent to DKIST
DKIST Fence
HNP Fence
0
37.5
75
150 Meters


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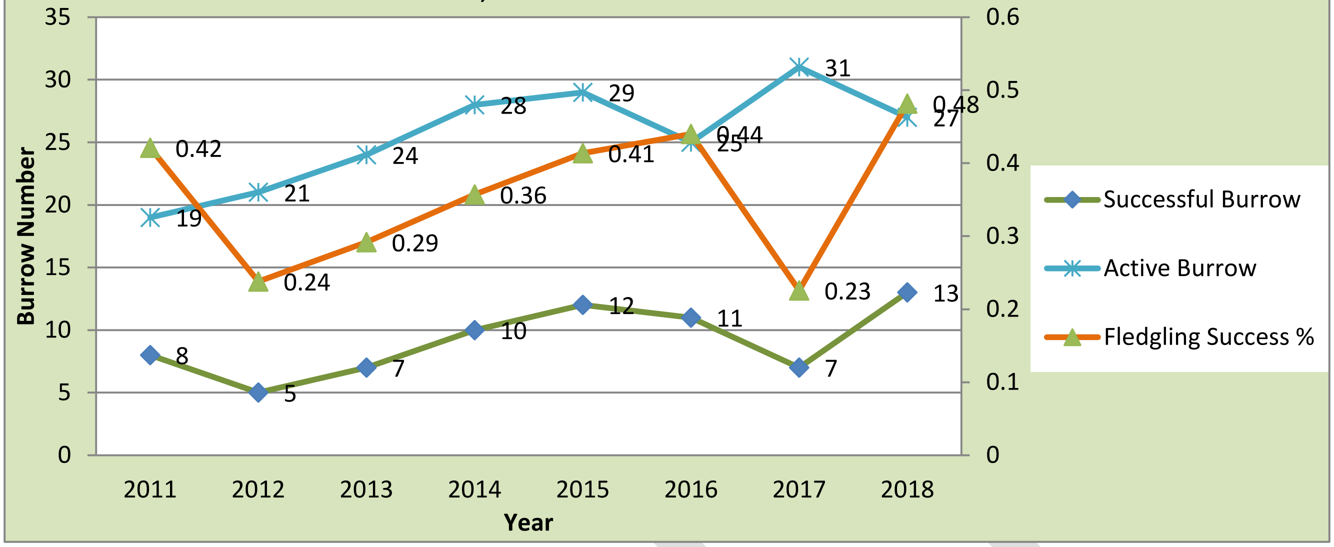
**Figure 16. Number of Active/Successful Hawaiian Petrel Burrow and Fledgling Success % Adjacent to DKIST Construction Site in The Conservation Area Recorded from 2011 to 2018, Near the Summit of Haleakalā, Maui**




The data discussed in the sections above resulted in several conclusions:

**1.** No Petrel predation was recorded above 9,800 ft.; nearest to the DKIST construction site since 2011 (before and after construction began), which may have been the result of the remoteness from the source of predators, harsh environment, and later the dense rodent control grid installed in this area, all of which may have reduced predator activities or predation frequency.

**2.** A trend of reduced predation/trampling was detected in both the Conservation Area and Control Site, although the reduction in the Control Site was not statistically significant due to a small sample size.

**3.** The implementation of the DKIST HCP conservation fence and predator control grid greatly reduced the number of predation and trampling events in the predator impacted lower portion of the Conservation Area, even though no feral cats or mongooses were trapped.

**4.** Direct collision by Petrels with DKIST construction structures was of most concern to biologists prior to commencement of construction. It was not observed even once since construction began in December of 2012. With the external, ground-disturbing construction activities completed, it is not expected that any Petrel collisions with DKIST structures will occur in the future. The observatory and support buildings are large, white structures with no reflective glass windows. As such, they can be more easily detected by Petrels than smaller surrounding natural structures. The main risk for collision was during construction when new obstructions with less surface area to be detected by Petrels were first present, e.g. cranes and steel framework.

**5.** Due to the life history and home range of the Hawaiian Petrel, there are still variables that impact Petrel mortality and reproductive performance that could not be controlled or even influenced by DKIST HCP/BO conservation efforts. These include global weather changes, over-fishing of apex predator fish, plastic particles suspended in the marine ecosystem, etc. However, conservation efforts implemented under the DKIST HCP and BO have been more likely to reduce predation effects that influence mortality and reproductive performance while Petrels are present in the Conservation Area.

### *F. Fledgling Dates*

#### *Historical Data:*

During the three years of his study, Simon (1985) reported that the Hawaiian Petrel fledging period extends from October 8 to October 30. The median fledging dates were October 23, 1979 (±6.5 days), October 19, 1980 (±6.7 days), and October 19, 1981 (±6.1 days). To investigate the potential impacts of DKIST construction on fledgling dates, the DKIST Team monitored chicks' first appearance outside active burrows and fledgling departures since 2011. Since the number of active burrows varied from year to year, the number of burrows monitored by cameras also varied from year to year.

#### *Project Data:*

Figure 17 presents the overall fledging departure dates from 2011-2018 in weekly intervals. The summary of Hawaiian Petrel fledging date records from 2011 to 2018 in the Conservation Area (including three records from the Control Site) are shown in Table 8.

**Figure 17. Hawaiian Petrel Fledging Dates Recorded From 2011 to 2018 in DKIST Monitored Areas Near the Summit of Haleakalā, Maui**

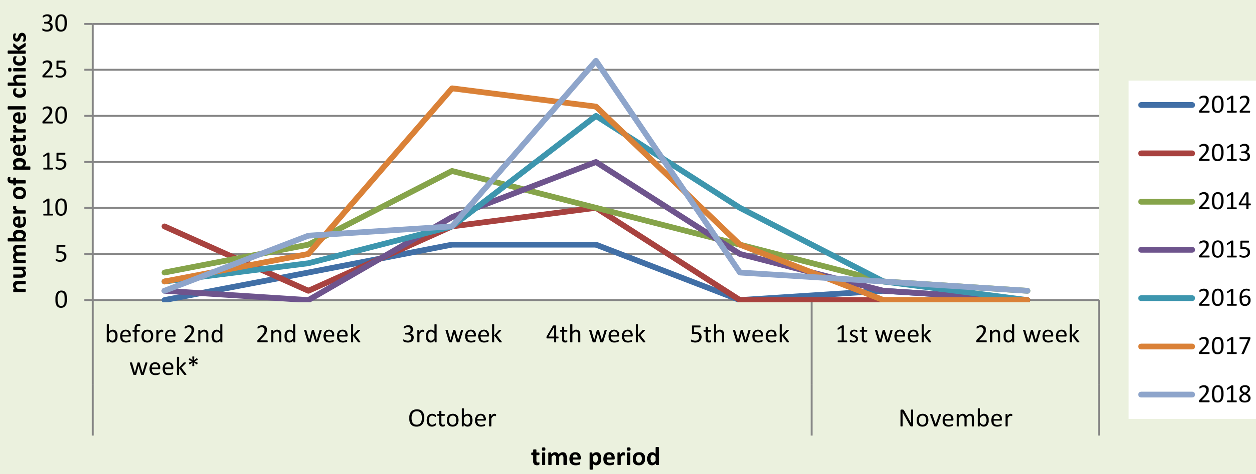



**Table 8. Hawaiian Petrel Fledging Date recorded from 2011 to 2018 in the DKIST HCP/BO Conservation Area**

| Year | First fledging date | Last fledging date | Median fledging date | Sample size |
|---|---|---|---|---|
| 2011 | Oct. 19 | Oct. 25 | Oct. 22 | 8 |
| 2012 | Oct. 12 | Oct. 19 | Oct. 17 | 6 |
| 2013 | Oct. 10 | Oct. 24 | Oct. 19 | 17 |
| 2014 | Sep. 24 | Nov. 09 | Oct. 17 | 38 |
| 2015 | Sep. 29 | Nov.01 | Oct. 22 | 31 |
| 2016 | Oct. 01 | Nov. 02 | Oct. 19 | 48 |
| 2017 | Oct. 04 | Nov. 04 | Oct. 21 | 53 |
| 2018 | Oct. 05 | Nov. 04 | Oct. 22 | 48 |

The fledging dates collected from 2011 to 2018 were within the range of what Simons (1985) reported, suggesting that no impact on Petrel fledging dates from DKIST construction activities could be detected.

Based on the observed Petrel fledging dates within our monitored sites, **<u>the fledging timing pattern was similar to that of Haleakalā National Park (HNP) data throughout the monitoring period, indicating that construction did not have an impact on the nesting cycle.</u>**

## VI. SUMMARY OF RESULTS

<u>Birdstrike</u>

The DKIST Team did not identify any Hawaiian Petrel collisions with DKIST-related structures during all monitoring years between June 7, 2011 and October 31, 2018.

<u>Impact on Nesting Activity and Fledgling Success</u>:

- No direct take of listed Hawaiian Petrel caused by DKIST construction activities and conservation measures implemented in the Conservation Area was recorded since monitoring started in the summer of 2011.
- No adverse impacts were statistically detected on Hawaiian Petrel Nesting Activity and the percentage of Fledgling Success that resulted from DKIST construction activities and conservation measures implemented in the Conservation Area.
- The number of active burrows continued to increase in areas immediately adjacent to the DKIST construction site (around Mees Observatory within the Conservation Area), except for a small decline observed in 2016 and 2018. Although slightly fewer in active burrows from previous years, 2016 and 2018 still represent overall increases in active burrows.
- The Fledgling Success continued to increase in areas adjacent to the DKIST construction site (around Mees Observatory) and reached the highest point in 2018.
- The Control Site had somewhat limited utility for comparison with the Conservation Area. For example, while predator/ungulate population monitoring camera traps and rodent population monitoring grids in both the DKIST Conservation Area and Control Site were useful during the adaptive management process used to validate Net Recovery Benefit, each site has a different quality of Hawaiian Petrel breeding habitat. Even before construction began and mitigation measures were in place, burrow density and Fledgling Success rates in the Conservation Area were four to five times higher than the Control Site. We cannot assess whether the DKIST conservation fence and predator/rodent control grids promoted recovery for the Hawaiian Petrel by comparing the Control Site to the Conservation Area, or even assess population trends relative to the Control Site, because the sample size of active/successful burrows in the Control Site was too small for those particular statistical comparisons.

  In the final six years of DKIST external construction the following changes were noted:

  - The largest number and highest density of active burrows were recorded in 2018,
  - The highest Fledgling Success rate was recorded in 2016; and
  - The highest successful nest number and density were recorded in 2017.
- The active and successful burrow density increased at the lower boundary area after the predator grid was fully installed in 2014.

- Compared to “Fledgling Success %” before mitigation measures were installed in 2011-12, Hawaiian Petrel “Fledgling Success %” increased by 73.9% after the DKIST HCP was fully implemented (2014-2018) in the Conservation Area.
- The average annual Hawaiian Petrel productivity in the Conservation Area increased 87.5% after the HCP was fully implemented
- DKIST HCP measures increased the number of successful Hawaiian Petrel fledglings between 2014 and 2018 by 105 or 96 (depending on estimate approach employed) after the mitigation measures were installed.

All of the above have demonstrated that DKIST construction activities had no adverse impact on Petrel reproductive performance in this area, and from 2014 to 2018, DKIST conservation measures aided Petrels in high predator impact areas in the lower part of the Conservation Area.

<u>Predation Mortality:</u>

The DKIST mitigation measures reduced the predation mortality number by a total of 44.4 Petrels from 2013 to 2018 (see Appendix 2).

<u>Fledging Dates</u>:

No obvious fledging date deviation could be detected in the last six years. Extended fledging periods in 2014 and 2016 were recorded; this might be due to higher Fledgling Success also observed in the Conservation Area during these two years.

<u>Measuring Net Benefit:</u>

The implementation of DKIST HCP/BO mitigation measures demonstrated an increase in “Percent of Fledgling Success,” more successful fledglings, and lowered predation rate (or less individuals being predated). However, both “Nesting Activity %”, “Fledgling Success %”, and the density of both indexes may be affected by variables that occur outside of Petrel breeding colonies. Over the long-term, conservation measures implemented in the DKIST Conservation Area can only reliably reduce predation, not completely eradicate it. For this reason, using the predation event statistics is a more objective approach to measuring DKIST’s Net Recovery Benefit. Although there has been an increase in the number of Petrels produced inside the Conservation Area over the past six years, predation reduction by DKIST’s mitigation measures appears to be the greater benefit to the sustainability of the Hawaiian Petrel population.

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## APPENDIX 1.

### HAWAIIAN PETREL REPRODUCTIVE SUCCESS MONITORING: METHODS

A. Personnel Training

All current members of the DKIST Team received extensive training prior to conducting actual fieldwork. This training included both field and administrative training. Members were trained on Petrel carcass search and handling, Petrel burrow identification, classification of burrow status based on signs of Petrel activity, and avoidance of cultural resources during field work. In addition, the Predator Control Technician was certified for Commercial Applicators of Restricted Pesticides and each member was trained in handling rodenticide and rodent carcasses. Two of the team members were either State of Hawai'i Hunter Education certified or National Rifle Association (NRA) firearm certified. All members were trained in the use of GPS and ArcGIS software and all completed First Aid/First Responder and CPR certifications.

B. Active Petrel Burrow Search

The DKIST Team began monitoring known burrows and searching for new burrows in the Conservation Area and Control Site on August 10, 2011 and again on February 22, 2012. Based on experience and data collected during 2012, we realized that starting burrow monitoring in late February was likely to result in an overestimate of the number of active burrows. This was likely the result because Petrels returned at that time of the year and were prospecting and forming pairing bonds, so multiple possible burrow sites might be visited by each pair. Therefore, we changed our burrow monitoring starting date to better coincide with the start of nesting season in the first part of May in 2013 (May 7, 2013, May 7, 2014, May 19, 2015, April 14, 2016, May 2, 2017, and April 23, 2018). Monitoring ended each season after the Petrel chick from the last known burrow fledged, which was November 16 in 2011, November 10 in 2012, October 24 in 2013, November 11 in 2014, November 16 in 2015, November 28 in 2016, November 20 in 2017, and November 13 in 2018.

The DKIST Team began annual monitoring by visiting all the burrows that were recorded from previous breeding seasons. Any newly identified burrows were documented when they were discovered and a systematic search of the DKIST Conservation Area and Control Site for new active burrows was also conducted. During the search, members of the Team used their handheld Garmin Oregon 450 and 550 GPS units to search along a 15-meter transect line system that covered both sites. Newly identified burrows could have been a previously undiscovered burrow, or a newly excavated burrow. The DKIST Team utilized recorded information provided by the Park regarding established burrows that were confirmed prior to 2011. In order to avoid mislabeling some of the thousands of rock crevices within the Conservation Area as new burrows, a structural feature isn't officially documented as a 'burrow' until its use is established by some evidence of Petrel activity. When DKIST began monitoring in 2011, the same burrow identification system was used, following earlier National Park Service convention. That is, the coordinates of the newly identified active burrows were recorded with handheld GPS units and signs of Petrel activity (feathers, droppings, egg shells, footprints, regurgitation, odor and other body parts) at each burrow were recorded. Toothpicks were placed vertically along the entrance of each burrow to monitor Petrel movement in and out of burrows; fallen or height-altered toothpicks suggested recent activity, while undisturbed toothpicks denoted no activity (Hodges 1994, Hodges & Nagata 2001).

C. Principles of Reproductive Success Monitoring

Reproductive success was initially categorized based on signs at the entrance, status of placed toothpicks, and the latest date of activity. Burrows that were "Active" were then re-checked weekly until signs of success or non-productivity were observed. Using the same methodology as employed by the Haleakalā National Park (Hodges 1994, Hodges & Nagata 2001), a burrow was defined to be “successful” by the presence of Petrel chick down feathers at the burrow entrance, and disturbed toothpicks after mid -September of each year. Burrows classified as “non-productive” showed signs of activity during initial search, but no further signs were found while conducting the subsequent re-checks, suggesting that these burrows were either occupied by non-breeders, the nest was abandoned, or the chicks did not reach fledgling age.

D. Camera Monitoring of Reproductive Success

To establish a baseline for Petrel behaviors and burrow activity near the DKIST site in the years before construction, and to supplement means of monitoring reproductive success after construction began, cable surveillance video cameras were installed. The cameras were monitored by KCE every year since 2006 at burrows adjacent to the Mees Observatory, from the month of February each year until all Petrels left the monitored burrows.

In addition, the DKIST Team installed Bushnell “Trophy Cam HD™” camera traps at active burrows outside of the cable accessible area. Sixteen camera traps were installed in the Conservation Area between October 15 and November 07, 2013, 39 camera traps were installed between September 10 and November 11, 2014; 38 camera traps were installed in the Conservation Area and one was installed in the Control Site. Thirty-five camera traps were installed in the Conservation Area and two were installed in the Control Site between September 08 and November 18, 2015. Seventy camera traps were installed in the Conservation Area between September 27 and November 23, 2016 and five were installed in the Control Site between September 22 and November 28, 2016. Seventy-seven camera traps were installed in the Conservation Area between September 14 and November 20, 2017 and seven were installed in the Control Site between September 11 and November 20, 2017. Eighty-nine camera traps were installed in the Conservation Area between August 27 and November 08, 2018 and three camera traps were installed in the Control Site between September 20 and November 13.

**APPENDIX 2.**

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**REVIEW OF STATISTICAL METHODS IN THE DANIEL K. INOUYE SOLAR TELESCOPE (DKIST)**

**HABITAT CONSERVATION PLAN (HCP) AND BIOLOGICAL OPINION FINAL REPORT**

This review examines data for predation and burrow success in the DKIST HCP final report, and offers several options for simple bivariate statistical tests to indicate the significance of associations between time periods and outcomes. The review begins with a discussion of the validity of the report's net recovery calculations, then fully elaborates the alternative bivariate statistical tests (i.e., measures of association) for chick predation and summarizes equivalent results for adult predation. Finally, the section on burrow Fledgling Success explains the adaptation of data from the report and summarizes results for the same bivariate measures of association.

**Predation and Net Recovery Benefit**

The Net Recovery Benefit of 44.4 birds has fair validity if the expected mortality rate definitions are acceptable to the sponsor. The authors estimate expected predation mortality for chicks and adults and then add these together to compare to actual predation. The expected estimates based as follows (see Table 7 for the raw counts cited below):

(1) For chicks, the total chicks predated in years before predator control measures were implemented (6 in 2011, plus 1 in 2012, sum to 7 total) are divided by the total chicks produced in those years (38 in 2011, plus 17 in 2012, sum to 55 total). As 7/35 = 0.127, the authors estimate annual chick predation mortality to be 12.7 percent of chicks produced each year.

(2) For adults, the total adults predated in years before predator control measures were implemented (1 in 2011, plus 3 in 2012, sum to 4 total) are divided by the twice the number of chicks produced (38 in 2011, plus 17 in 2012, sum to 55 total, and twice this number is 110). As 4/110 = 0.036, the authors estimate the annual adult predation mortality to be 3.6 percent of chicks produced each year.

In Table 7 of the DKIST HCP report, the lines with expected chick and adult predations, chicks and adults predated, and annual benefit for chicks and adults, simply apply the expected and actual predation mortality for each of the years 2013-2018, then sum these six years' benefit for chicks (28.71 fewer chicks predated than expected) and adults (15.69 fewer adults predated than expected). As 28.71+15.69 = 44.4 birds, the authors cite this number as the net reduction in predation.

A reviewer might raise the issue of that frequencies are rather small for year-by-year estimates of expected to actual predations. Estimates that in 2013, for example 3 chicks were predated, while we'd have expected 3.82 to have been predated, or that zero adults were predated in 2013 when we'd have expected 2.18 adults to have been predated, are sensitive to even a single predation event occurring or not occurring, and the report makes no mention of estimated sampling error.

Alternative bivariate analyses that would provide inferential tests of pre-and post-mitigation predation mortality include (1) a two proportion Z-test, (2) a Phi (ϕ) correlation coefficient for two binary variables, with Chi-square ($\chi^2$) or Cramer's V for significance, and (3) a Gamma (γ) coefficient for two ordinal variables. The following section on chick predation fully illustrates the logic and calculations for each of these three measures, while the subsequent sections on adult predation and Fledgling Success use the same methodology but report results without the extended mathematical exposition.

**Bivariate Tests for Chick Predation**

Consider the report's definition of pre- and post-mitigation periods as 2011-2012 and 2013-2018 respectively (adapted from the DKIST HCP report, Table 7, p. 27), we then have a hypothetical data set for chicks produced of N=312, with $n_1$ = 55 in the pre-mitigation group and $n_2$ = 257 in the post-mitigation group. In the pre-mitigation group, the proportion predated was 12.7 percent (7 predated out of 55 = 0.127), while in the post-mitigation group, the proportion predated was 1.6 percent (4 predated out of 257 = 0.01556). The data are thus arranged as shown in Table 1. Note that as a descriptive observation, the percentage of chicks predated during the pre-mitigation period was much higher than during the post-mitigation period (12.7 percent compared to 1.6 percent).

Table 1. Pre- and Post-mitigation and Predation Mortality for Chicks

| | Pre-mitigation (2011-20112) | Post-mitigation (2013-2018) | TOTAL |
|---|---|---|---|
| Chicks Predated | 7 (12.7%) [a] | 4 (1.6%) [b] | 11 |
| Chicks Not Predated | 48 (87.3%) [c] | 253 (98.4%) [d] | 301 |
| TOTAL | 55 (100%) | 257 (100%) | 312 |

For the Z-test, let the null hypothesis be that the proportions for chicks predated are the same between the pre- and post-mitigation periods. The Z statistic for group proportions is the difference between these proportions divided by the standard error for group difference in proportions, as indicated in Figure 1: 0.111709/0.045598 = 2.44987. The probability of this Z value if the null hypothesis were true (assuming a two-tailed test), is p= 0.014294, making Z significant to less than alpha (α) of.05 and very close to α of .01. Thus, we can reject the null (i.e., conclude that the difference between 12.7 percent and 1.6 percent wasn't due to chance).

Figure 1. Z-test for the difference between two proportions

$$Z = \frac{p_1 - p_2}{S_{P_1 - P_2}}$$

$$S_{P_1 - P_2} = \sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}}$$

Now consider the Phi (ϕ) correlation coefficient. The data are arranged in Tables 1 and 2. Using the formula in Figure 2 for the chick predation mortality data in Table 1, we get ϕ = 0.230810, which is mathematically identical to a Pearson correlation coefficient ($r^2$) between two binary variables, and means that about twenty-three percent of the variance in predation can be statistically “explained” by mitigation period (pre- vs. post-).

Figure 2. Phi Correlation Coefficient

$$\phi = \frac{ad - bc}{\sqrt{(a+b)(c+d)(a+c)(b+d)}}$$

The significance test for ϕ uses the Chi-square ($\chi^2$) distribution, and being the same statistic as Cramer’s V when both variables are binary, can also be calculated by taking the square root of $\chi^2$ divided by the total sample size (N=312):

$$\phi = \sqrt{\frac{\chi^2}{N}}$$

In the case of chick predation mortality, $\chi^2$ is 16.621 (we can solve for $\chi^2$ using the formula above, such that [$(.230810^2)*(312)=16.621$], which is the same result as calculating $\chi^2$ using the traditional long formula with expected and observed frequencies. At $df$=1, $\chi^2$ = 16.621 and p=.000046, which far exceeds the 10.83 critical value required for an alpha (α) < .001. Thus, we can reject the null hypothesis of independence between mitigation period and predation.

The Gamma (γ) coefficient is a bivariate test of correlation/association for two ordinal variables that indicates the direction of the association, ranging from γ = 1.00 (perfect direct/positive association) to γ = -1.00 (perfect inverse/negative association), such that γ = 0.00 reflects no association at all. Gamma is calculated by the formula in Figure 3, where the difference between concordant and discordant pairs of cases is divided by the sum of concordant and discordant pairs.

Figure 3. The Gamma (γ) Coefficient

$$\gamma = \frac{n_c - n_d}{n_c + n_d}$$

For the two-category ordinal variables mitigation period and predation in Table 1, the calculations are much simpler than for cross-tabular data with more than two categories: $n_c$ = (7 x 253) = 1,771 and $n_d$ = (48 x 4) = 192. Thus, γ = (1,771-192) / (1,771+192) = 1,579 / 1,963 = 0.80, which indicates a strong relationship between mitigation and predation, with the direct/positive correlation in the direction of pre-mitigation being associated with greater predation, and post-mitigation being more associated with lower predation. The significance test for γ uses the *t* distribution:

$$t = \gamma\sqrt{\frac{n_c + n_d}{N\,(1-\gamma^2)}} = \left(0.80\sqrt{\frac{1{,}771 + 192}{312\,(1-0.64703)}}\right) = 3.39$$

The resulting *z* value of 3.40 has a two-tailed probability of 0.000699, which is far below any commonly used α level (e.g., a conservative α of 0.01 has a critical value of only 2.58), and thus we can reject the null hypothesis and conclude not only that are mitigation period and predation correlated, but strongly and in the specific direction of post-mitigation being associated with lower predation.

**Bivariate Tests for Adult Predation**

For adult predation, using the data in Table 2 below (adapted from the DKIST HCP report, Table 7, p. 27), results are summarized succinctly for the three measures of association without the extended mathematical exposition in the previous section on chick predation. The Z test for proportions is quite a bit weaker, but still significant with the maximum α used in any social, behavioral, or biomedical research ($\alpha < .05$). We have $n_1$ = 110 adults in the pre-mitigation group and $n_2$ = 514 in the post-mitigation group, for a total N=624. The pre- and post-mitigation predation proportions were 0.03636 (4/110) and 0.005836 (3/514), respectively. Z is 1.681, with p=0.0465, which is just under the maximum α threshold of .05 needed to reject the null hypothesis and conclude that mitigation is significantly related to predation for adult birds.

Table 2. Pre- and Post-mitigation and Predation Mortality for Adult Birds

| | Pre-mitigation (2011-20112) | Post-mitigation (2013-2018) | TOTAL |
|---|---|---|---|
| Adults Predated | 4 (3.6%) [a] | 3 (0.6%) [b] | 7 |
| Adults Not Predated | 106 (96.4%) [c] | 511 (99.4%) [d] | 617 |
| TOTAL | 110 (100%) | 514 (100%) | 624 |

Using the same formulas as in the previous section on chick predation, the Phi coefficient for adult predation is ϕ = 0.110451 between mitigation period and adult predation, and $\chi^2$ = 7.612, p=.005798 at *df*=1, which exceeds the 6.635 critical value required for an alpha (α) < .01. Thus, we can likewise reject the null hypothesis.

The Gamma (γ) coefficient is $n_c$ = (4 x 511) = 2,044 and $n_d$ = (106 x 3) = 318. Thus, γ = (2,044 - 318) / (2,044 + 318) = 1,726 / 2,362 = 0.73, a similarly strong positive association as with chick predation. The *t*-test for significance is

$$t = \left(0.73\sqrt{\frac{2{,}044 + 318}{624\,(1-0.5340)}}\right) = 2.85$$

The probability of $t$ = 2.85 in a two-tailed test is p=0.004372, which is below an alpha ($\alpha$) < .01 (critical value would have been $t$ = 2.58). We can reject the null hypothesis and conclude that mitigation period and predation are strongly correlated in the direction of post-mitigation being associated with lower predation.

**Fledgling Success**

The data for Fledgling Success are arranged somewhat differently from predation. The numbers of successful and nonproductive burrows in Table 3 (below) were adapted from the DKIST HCP final report. Total successful and nonproductive burrows per year are the sum of both old and new successful and nonproductive burrows.

Table 3. Active Burrows – Selected Raw Data from DKIST HCP final report (Table 5, p. 21)

| | | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| OLD | Successful | 24 | 16 | 26 | 42 | 29 | 48 | 50 | 49 |
| | Nonproductive | 49 | 124 | 96 | 116 | 125 | 58 | 113 | 138 |
| NEW | Successful | 8 | 0 | 1 | 2 | 0 | 1 | 3 | 1 |
| | Nonproductive | 78 | 13 | 2 | 5 | 14 | 12 | 23 | 12 |
| | Total Successful | 32 | 16 | 27 | 44 | 29 | 49 | 53 | 50 |
| | Total Nonproductive | 127 | 137 | 98 | 121 | 139 | 70 | 136 | 150 |
| | GRAND TOTAL | 159 | 153 | 125 | 165 | 168 | 119 | 189 | 200 |
| | Fledgling Success % [1] | 20.1 % | 10.5 % | 21.6 % | 26.7 % | 17.3 % | 41.2 % | 28.0 % | 25.0 % |

[1] Fledgling Success is the Total Successful as a percentage of the Grand Total.

Using the definition of pre- and post-construction periods 2011-2012 and 2014-2018 (omitting 2013), the Fledgling Success frequencies summarize as indicated in Table 4. A descriptive observation of these data, prior to conducting any significance tests, reveals that in the pre-construction period, 15.4 percent (48/312) burrows were successful (48/312), while in the post-construction period 26.8 percent (225/841) of burrows were successful.

Table 4. Active Burrow Data Condensed to Pre- and Post-Construction periods

| | Pre-construction (2011-2012) | Post-construction (2014-2018) | TOTAL |
|---|---|---|---|
| Successful Burrows | 48 (15.4%) [a] | 225 (26.8%) [b] | 273 |
| Nonproductive Burrows | 264 (84.6%) [c] | 616 (73.2%) [d] | 880 |
| TOTAL | 312 (100%) | 841 (100%) | 1,153 |

For the two-proportion $z$ test, we have $n_1 = 312$ burrows in the pre-construction group and $n_2 = 841$ in the post-construction group, for a total N=1,153. The pre- and post-construction burrow success proportions were 0.154 and 0.268, respectively. Z is 4.460, with p<0.00001, which is well under even the most conservative α thresholds for statistical significance. Thus, we can reject the null hypothesis and conclude that construction period is significantly related to burrow Fledgling Success.

Using the same formulas as in the section on chick predation, the Phi coefficient for association between construction period and burrow success and is $\phi = 0.118819$, $\chi^2 = 16.28$, p=.000055 at $df$=1, which exceeds the 6.635 critical value required for an alpha (α) < .01. Thus, we can likewise reject the null hypothesis. Note that the Fledgling Success data produced a substantially greater $\chi^2$ than adult predation despite having about the same ϕ coefficient; the seemingly counterintuitive result is due to the latter analysis having a much greater sample size ($N$), 1,153 vs. 624.

The Gamma (γ) coefficient is $n_c = (48 \times 616)$ and $n_d = (264 \times 225)$. Thus, γ = (29,568 – 59,400) / (29,568 + 59,400) = - 29,832 / 88,968 = - 0.34, a moderately strong inverse/negative association between pre-construction and burrow success. The negative coefficient and interpretation of an inverse correlation is simply a matter of the directionality of categories in the Table 4 above. Concordance is calculated by the cells for pre-construction and successful burrows, while discordance is calculated by the cells for post-construction and nonproductive burrows, which is the inverse of the research hypothesis that Fledgling Success is greater in the post-construction period. The $t$-test for significance of γ is

$$t = \left(0.34\sqrt{\frac{29{,}568 + 59{,}400}{1{,}153\ (1 - 0.1124)}}\right) = 3.17$$

The probability of $t = 3.17$ in a two-tailed test is p=0.001565, which is below an alpha (α) < .01 (critical value would have been $t = 2.58$). We can reject the null hypothesis and conclude that construction period and burrow success are correlated in the direction of post-construction being associated with higher success. While the actual strength of the association was lower for burrow success than for either chick or adult predation (.34 compared to .75 and .73), the significance level was similarly high due to the larger number of observations.