

DISCUSSION AND RECOMMENDATIONS

The purpose of this study was to provide baseline data about procellariiform seabird species at HAVO by summarizing the results of previously published as well as unpublished surveys and by surveying procellariiform seabird diversity and identifying flight corridors and colony sites within park boundaries. Our observations establish that NESH and BSTP still occur inside the park and indicate general areas that are likely nesting habitats. Although we failed to locate exact nesting sites, the data we gathered may aid future searches for NESH and BSTP nesting colonies.

Though we did not find NESH nesting sites during our surveys, this is likely due to insufficient survey effort and the fact that part of our search effort was conducted in coastal areas. However, our first search priority was to confirm incidental reports of NESH calls in order to document NESH occurrence within HAVO. Therefore, some of the coastal areas we visited were suboptimal habitat judging from the habitats of documented colonies outside HAVO and on other Hawaiian islands. Numerous incidental auditory detections by park staff suggest that NESH still occur in the park and may be prospecting for nest sites at low to mid elevations. Cat scat has been found at many locations in the park (HAVO RM unpub. data) from low to high elevations; it is likely that in addition to mongooses, these predators are preventing successful nesting. It may be possible for NESH to re-colonize lowland areas in the park if measures such as predator control and restoration of native vegetation were implemented. Incidental observations by park staff suggest that NESH do nest in the forest of the Kīlauea East Rift Zone, at 700 to 900 m. However, finding them in the uluhe fern thickets would require a more concerted and sustained effort than was possible in this inventory. Helicopter transport would facilitate access to the area and trained search dogs might allow finding nest sites within this densely vegetated habitat. One must consider, however, that trampling uluhe fern cover may pose a threat to nesting seabirds by facilitating access for predators such as cats. Colonies should first be located using less invasive means such as radar, night vision, and auditory surveys. Predator control should be conducted during and following such efforts. As a further precaution, searches with dogs should not occur until after the breeding season.

Repeated consecutive nighttime radar, night vision, or auditory surveys will be required to pinpoint nesting by this rare seabird. During surveys in the Puna District adjacent to HAVO, Reynolds and Ritchotte (1997) visited one site 11 times for 275 survey hours in 1993, with a mean detection rate of one detection per hour in order to document nesting. Nest attendance data from surveys at other islands may provide some information on the timing of the most regular and frequent travel to the nests and thus may improve the chances of detecting birds at very small colonies. Such data are available for the Kīlauea Point National Wildlife Refuge on Kauai (H. Freifeld, US Fish and Wildlife Service, pers.comm.). However, timing of bird travel has been found to vary between colonies on different islands (D. Ainley, H.T. Harvey & Associates, pers.comm.) and a wide window should be applied in future observations to allow for these differences. Given the time and cost involved in prolonged monitoring, it would be worthwhile to investigate the use of remote auditory recording equipment at promising sites to find out more about seasonal detection probabilities.

We were able to identify potential nesting sites for BSTP in the park that could be confirmed with future monitoring. The numerous detections of transiting BSTP and possible nest sites

suggest that they do breed on Mauna Loa. The two potential nests are in the vicinity of the nest reported by Banko et al. (1991). It is surprising that BSTP nests have not been found at this location and in other areas of Mauna Loa. It is possible that nesting birds have retreated to higher elevations in recent decades due to increasing pressure from introduced predators, such as mongooses whose upper elevation limit is around 2,100 m (HAVO RM unpubl. data). Alternatively, observers may have overlooked nests or did not search in inaccessible areas where nests may be located. This is possible since BSTP nest site selection preferences have not yet been described. In addition, nests of BSTP may be more inconspicuous, and therefore more difficult to find, than nests of the larger HAPE. Additionally, it is possible that BSTP have better nest hygiene, leave less guano outside of nests, or are otherwise less disruptive to the substrate because of their smaller size. Based on records of BSTP carcasses found among HAPE colonies, we previously thought that they were nesting among HAPE, though we were unable to confirm this through photographs or by measuring footprints at nest entrances.

The maps of flightlines will be useful for future efforts in locating BSTP colonies. The data show that most BSTP detected were flying either up- or downslope, indicating that their colonies are at higher elevations than our survey areas. Before mapping flightlines in the future, the accuracy of the two methods of data collection for flightlines should be investigated. In the first method, each detection was mapped as a point, then the points were connected to determine the average direction of flight. In the second technique, observers estimated the overall direction of travel of each bird, resulting in the mapping of a vector rather than a series of points. We suggest that this second method depicts the line of travel more accurately, because error in distance measurements are compounded when more than one distance is estimated.

No previous radar surveys have been conducted specifically for BSTP. Therefore, the exact signature this species leaves on the radar screen is not known. Though speed and behavior are well established for HAPE and NESH transiting to colonies, it is possible that the smaller BSTP, which have more erratic flight and fly slower, may not leave as clear a signature as the other two species. There is a need to distinguish BSTP from HAPE where both occur together. Using the 48 km/h flight speed cutoff established for the larger seabirds may have resulted in a failure to count BSTP. In addition, HAPE at high elevations may act differently than those transiting to colonies at low elevations, where standards of speed, behavior, and timing were developed. Within colonies, pre-breeding HAPE follow curved flight paths while conducting aerial breeding displays (personal observation). Displaying birds may fly slower than the 48 km/h cutoff established for transiting birds. In addition, petrels fly much lower to the ground at higher elevations within the breeding colony and therefore may disappear periodically behind high points on the landscape. For example, HAPE have been observed flying lower than one meter above ground level (personal observation) while banking around bushes in their path. Because of these different flight patterns at high elevations, it may be difficult to distinguish displaying HAPE and BSTP from bats or Barn Owls, both of which occur at higher elevations (personal observation). In addition, it is difficult to find the perfect radar placement when the radar unit must be flown in. Using truck-mounted radar, the operator is able to review ground clutter patterns (landscape features that prevent the radar from detecting the birds) before making a final site selection. When the radar unit is placed by helicopter, it can be placed only once, and the operator does not have the opportunity to minimize ground clutter. Because of these

incongruities between bird biology and logistics, radar may not be an appropriate tool at higher elevations, at least where displaying birds confound flight patterns.

When interpreting the previous radar survey data, it appears that Reynolds et al. (1997) detected significantly more seabird targets at their coastal location at Pali Uli (3.8 targets/hour) as compared to observations by Day et al. (2003) at Hōlei Sea Arch (1.2 targets/hour). Day et al. (2003) did not detect any change in population size from 1995 to 2002 that would explain this difference between these two surveys. One explanation may be that the survey by Reynolds et al. lasted only 30 minutes as compared to the three hours of surveys conducted by Day et al. If this 30-minute survey were conducted during the peak of flight, estimates would be higher compared to the rate observed by Day et al., which would span more time when fewer birds are present. Other factors could also account for this difference; counts can be highly variable between nights because the detection probability of nocturnal petrel species varies seasonally, diurnally and with moon phase (Telfer et al. 1987). Day et al. saw birds flying towards the ocean in the evening, suggesting that these were adult birds returning to sea to forage after darkness. Reynolds et al. noted birds flying northeast in the evening, a path that might take these birds into the East Rift Zone of Mauna Loa, outside park boundaries.

For future radar surveys, extending the radar survey hours beyond 22:00 hrs should be considered. While the results of the HAVO-RM radar surveys reported here show a significant drop-off in bird detections after 21:30 hrs, the two nights of surveying were likely not sufficient to determine that these pulses and timing weren't anomalous. Radar surveys along the roads at Kahuku might be a valuable tool for detecting flight corridors and locating BSTP colonies if located outside HAPE display areas. In conjunction with radar surveys, observers should confirm BSTP radar detections using night vision goggles in order to establish guidelines for flight speeds and patterns. Additionally, the TrailMaster® camera could be used to document BSTP at suspected nest sites. We recommend that those looking for BSTP also search at higher elevations than we did for this survey, above 2,400 m, and along the Southwest Rift Zone of Mauna Loa.

Though we did not specifically target WTSH while surveying for nocturnal Procellariiformes, we believe that we would have detected this species during coastal surveys were they present. It is possible that seabird guano seen near Kalue during shoreline bird surveys in March 2005 was deposited there by prospecting Wedge-tailed Shearwaters. Nesting WTSH would undoubtedly have been detected after more than a decade of constant presence of HAVO sea turtle crews at coastal sites from summer to fall. The distinctive and repeated calls would make them easy to identify. It is probable that WTSH do not nest at HAVO because the young lava substrate makes it impossible for this species to dig its nest burrows. If WTSH did attempt to nest, it is likely that they would be quickly killed by mongooses and feral cats which are especially common at low elevation sites. It appears that WTSH are still attempting to nest on the western side of the island; burrows were detected at Kaloko- Honokōhau National Historical Park in November of 2001 by Ducks Unlimited staff. The burrows were unoccupied and appeared disturbed by rats or mongooses (K. Uyehara, pers. comm.). The burrows were later destroyed by a storm surge and no new burrows have been documented in the park since.

To encourage incidental sightings of seabirds by HAVO field staff working on various projects, employees should receive training on identification of seabird vocalizations. Additionally, all

Hawksbill Turtle Project volunteers should receive the training as they enter the project. A training module and field data forms for future seabird sightings or auditory observations were developed and archived with HAVO RM staff as part of this inventory project.

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