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Scott F. Pearson, Peter J. Hodum, Michael Schrimpf, Jane Dolliver, Thomas P. Good, and Julia K. Parrish

Washington Department of Fish and Wildlife
Wildlife Program
Wildlife Science Division

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Rhinoceros Auklet (*Cerorhinca monocerata*) Burrow Counts, Burrow Density, Occupancy Rates, and Associated Habitat Variables on Protection Island, Washington: 2008 Research Progress Report

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Scott F. Pearson[1], Peter J. Hodum[2], Michael Schrimpf[3],
Jane Dolliver[3], Thomas P. Good[4], and Julia K. Parrish[3]

[1] Wildlife Research Division, Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia, WA 98501-1091

[2] Biology Department, CMB 1088, University of Puget Sound, 1500 N. Warner St., Tacoma, WA 98416

[3] School of Aquatic and Fishery Sciences and Biology Department, Box 355020 University of Washington, Seattle WA 98195-5020

[4] NOAA Fisheries, Northwest Fisheries Science Center, 2725 Montlake Boulevard E., Seattle, WA 98112

ABSTRACT

Unlike many species of seabirds that use the Salish Sea (Puget Sound, Georgia Basin and Strait of Juan de Fuca) during migration or for over-wintering, rhinoceros auklets (*Cerorhinca monocerata*) depend on this region for reproduction. As a result, population trends are more likely to be tied to events occurring locally. In addition, as a top-level piscivorous predator, the species is particularly susceptible to fluctuations in forage fish populations. These characteristics make the rhinoceros auklet an ideal candidate for assessing the health of the Salish Sea ecosystem. An additional advantage to using this species is the availability of historic data from the 1970s for assessing population trends. Finally, greater than 95% of the North American population of the rhinoceros auklet occurs in Washington, British Columbia, and southeast Alaska. Nearly all of these birds breed on eight large colonies, of which Protection Island in Washington is one of the largest. The importance of this island to the species as a whole inspired us to assess changes in its population.

Using a stratified random sampling scheme, we estimated that there are 54,113 ± 9,390 (95% CI) burrows on Protection Island. This estimate is approximately 51% greater than any of the previous estimates. Using infra-red camera probes to assess burrow occupancy, we estimated occupancy to be 66% ± 5% (95%CI) which is very similar to previous occupancy estimates. Using these two values, we estimate that there were 71,430 ± 13,514 (95%CI) birds breeding on the island in 2008. These results make Protection Island the third largest rhinoceros auklet nesting colony in North America. In general, there was a positive correlation between burrow density and percentage of unvegetated area (bare ground) and percent slope. There is a negative correlation with perennial grasses, shrubs, and forbs. These results confirm the importance of steep, grass-dominated slopes located relatively close to the water for auklet nesting.

The concentration of such a large portion of the North American rhinoceros auklet population on Protection Island suggests that population trends and success on this island has significant implications to the species. Our results suggest that the Salish Sea rhinoceros auklet population is healthy; however apparent methodological differences with past estimates lead us to caution against directly comparing our results to those previously reported. Management actions should focus on maintaining suitable nesting habitat and address issues that inhibit successful nesting. Finally, we provide detailed information on a statistically robust and relatively inexpensive sampling scheme that will allow future and comparable estimates for assessing population trends.

Future goals include providing similar estimates and measurements of the same habitat variables on Smith Island in Puget Sound and Destruction Island on the outer Washington coast. Once these surveys are complete, we will submit to a peer-reviewed journal a manuscript examining changes in colony size between the 1970s and today for Protection and Destruction islands and will compare population changes between Sound (Salish Sea) and the outer coast. Such comparisons are critical to determining if events occurring in the Puget Sound are unique to the Sound or are part of larger-scale phenomena. Finally, the development of a relatively sophisticated habitat model will allow us to identify habitat features important to Rhinoceros Auklets when they select locations for their burrows. These types of analyses are critical to helping land managers understand how to restore and manage existing habitat, especially in the face of invasion by non-native grasses (e.g., *Ammophila spp.* and *Bromis techtorum*) and animals (e.g., European rabbit *Oryctolagus cuniculus*) that these islands have experienced.

INTRODUCTION

Marine birds have long been used as indicator species in coastal marine environments (Cairns 1988, Parrish and Zador 2003) because of their ubiquity (Davoren and Montevecchi 2003), their broad diet represented by a cross-section of species (Montevecchi and Myers 1995), and their collective vulnerability to a range of human activities (Furness and Tasker 2000). However, to use seabirds as indicators, accurate population counts and trend assessments are required. Methods used to count seabirds range from at-sea surveys to breeding colony counts. Breeding colony counts in particular provide information on numbers of adults actually attempting to breed. Colony counting techniques range from mark-recapture techniques (Sydeman et al. 1998), counts of birds in flight (Bretagnolle and Attie 1991), measuring calling rates (Monteiro et al. 1999), and counts of nests and burrows (Rayner et al. 2007). In the case of burrow-nesting seabird species, determining breeding activity can be problematic. For burrow nesting species, not all burrows are occupied during any given nesting season, so obtaining accurate occupancy data are essential for robust population estimates. Methods for obtaining occupancy information include playback response (Ryan et al., 2006), burrow scoping (Lawton et al., 2006), and burrow excavation (Cuthbert 2004).

Assessing trends in Washington's rhinoceros auklet (*Cerorhinca monocerata*) population is likely to provide valuable information on a top-level piscivorous predator and, due to their susceptibility to fluctuations in prey fish populations, insights into forage fish trends (Montevecchi 1993, Roth et al. 2007). Breeding and recruitment failures as a result of food shortages have led to substantial declines in the breeding populations of seabirds (Anker-Nilssen et al. 1997). Unlike many species of seabirds that use the Salish Sea during migration or for over-wintering, rhinoceros auklets depend on this region for reproduction. As a result, population trends are more likely to be tied to events occurring locally. These characteristics make this species an ideal candidate for assessing the health of the Salish Sea ecosystem. An additional advantage to using the rhinoceros auklet is the availability of historic data for assessing population trends (e.g., Wilson 1977, Wilson and Manuwal 1986). Finally, the rhinoceros auklet is a compelling focal species because Wilson (2005) reported a 30% decline in the Protection Island rhinoceros auklet colony between the 1970s and 2000, making this species an ideal focus for management related research.

More than 95% of the North American population of rhinoceros auklets occurs in Washington, British Columbia, and southeast Alaska (Gaston and Deschesne 1996). Nearly all of these birds breed on eight large colonies (Washington = Protection and Destruction islands; British Columbia = the Moore Group, Pine, Storm, Triangle, and Lucy islands; Alaska = Forrester Island; Gaston 1996). Because of the large number of active burrows, the nesting colonies in the Salish Sea are critically important to the North American population of this seabird. In the 1950s, there was estimated to be between 6,000 – 8,000 birds on Protection Island (Richardson 1961). In the 1970s and 1980s, the population was estimated to be between 31,400 and 40,600 birds (Wilson and Manuwal 1986, Thompson et al. 1985, Gaston and Deschesne 1996). In 2000, a population estimate indicate that Island's population declined to approximately 24,000 (Wilson 2005). To provide an updated population estimate, we used a stratified random sampling design to estimate the number of rhinoceros auklet burrows and the number of occupied burrows on Protection Island in 2008. To identify habitat variables associated with auklet burrows, we measured vegetation, slope, and elevation variables.

METHODS

Study Area.—Protection Island is 143 ha in area (approx. aerial extent above mean high tide) located 3.2 km off the mouth of Discovery Bay at the eastern end of the Strait of Juan de Fuca. Located in the Olympic Mountain rain shadow, it receives only around 25-50 cm/yr of precipitation and has a maritime climate. Along its perimeter, the island contains beach and spit habitats that give way to cliffs and steep slopes while the interior of the island is flat or rolling. The majority of the island is dominated by non-native annual and perennial grasses and forbs, while small sections on the north and north east sides are dominated by native shrubs (e.g., ocean spray (*Holodiscus discolor*), snowberry (*Symphoricarpos albus*), Nootka rose (*Rosa nutkana*)) or native shrubs and trees (primarily Douglas-fir (*Pseudotsuga menziesii*), willow (*Salix spp*), Douglas maple (*Acer glabrum*)), and grand fir (*Abies grandis*). The U.S. Fish and Wildlife Service and Washington Department of Fish and Wildlife currently manage nearly the entire island as a "refuge" and as a "wildlife area", respectively.

Study Design.—We used a stratified random design to estimate the number of burrows and burrow occupancy on Protection Island in 2008. Strata were defined by both landform and burrow density (see Figure 1). The "steep slope" stratum is located primarily on steep grassy slopes on the southern side of the island and is the area with the highest burrow density. The "transitional" stratum is located on the western end of the island just above the steep slope stratum and is an area of moderate and patchy burrow density. The distribution of burrows in this stratum is patchy. The "cliff edge" stratum is located on the northern side of the island, just above a sheer vertical cliff (see definition below); this stratum is dominated by grasses and forbs the west and trees and shrubs to the east. The area has variable burrow density, and the burrows do not usually extend more than 15 m inland from the cliff edge. The "island top" stratum consists of flat to rolling terrain where there are no burrows. Much of this area is apparently too far inland and insufficiently steep for auklet nesting.

Figure 1. Orthographic photo of Protection Island from 2006 with burrow density/landform strata overlaid. The "vertical cliff" stratum is the linear feature on the vertical cliff just below the seaward edge of the "cliff edge" stratum.

The "vertical cliff edge" stratum has a single row of burrows on the upper vertical cliff edge on the north side of the island. Random points were located across the island by randomly selecting vertices of a 10m x 10 m "fishnet" grid superimposed on the entire island in ArcGIS 9.2™ (Esri Inc. 2006). We selected more random points in higher density strata to try to reduce the variance associated with the overall estimate.

Definition of a burrow. —We defined a burrow based on characteristics that we could determine either by using an infra-red camera probe (Sandpiper Technologies Peep-A-Roo Video Probe ®) or by direct manual inspection. When using the camera probe, we could visually assess the structure of a burrow, defining it as an entrance that led to both a tunnel and at least one nesting chamber. For those entrances that we did not probe to identify nesting chambers, we inserted our arm into the entrance to determine length; we considered any burrow that extended beyond our reach to be a burrow. In our experience, all or nearly all burrows of this length have at least one nesting chamber, and this method excludes burrow starts, which tend to be very short (<0.5 m). Burrows with more than one entrance were considered a single burrow unless there were two separate tunnels and two nest chambers. Collapsed burrows were not counted as burrows.

Field methods.—We loaded the randomly selected points into a Trimble GeoXT® unit and intended to use the location information to navigate to each point. However, because of projection issues in the field, navigating to the random points was not possible. Instead, we used high-resolution color orthographic photos printed with the randomly selected sampling points overlaid to navigate to the points using landforms. In all cases, we felt that we were successfully able to navigate to within 30m of the actual point using this process. To reduce bias associated with this approach, we then selected a random azimuth and distance within 20 m from the point to select the point where we measured burrows, occupancy and vegetation. We recorded the loction of each plot sampled using the Trimble GPS unit. At each point, we counted the total number of burrows within a 2.5 m radius of the point using a stake placed in the center and 2.5 m attached cords to measure the perimeter of the plot. For burrows on the edge of the plot, we considered only those for which the 2.5 m touched at least one entrance to fall within the plot.

To estimate the number of occupied burrows for plots containing ≤6 burrows, we probed all burrows with an infra-red camera probe. For plots containing >6 burrows, only the 6 burrow entrances nearest the center stake were probed. A burrow with an adult, egg or chick was considered occupied. If we could not determine the contents of a burrow in a plot with > 6 burrows, we indicated this on our datasheet and moved on to the next nearest burrow until we had a total of 6 burrows of known status for a given plot. Within each 2.5 m radius plot, we measured the following habitat variables at the plot center: slope angle at the plot center using a clinometer; aspect measured in degrees using a compass at the plot center; and elevation using the Trimble unit at the plot center. We used the following vegetation classes to estimate percent cover and height: bare ground, annual grasses, perennial grasses, annual and perennial forbs, shrubs, and trees. We estimated percent cover and height per vegetation class using the following categories: <1%, 1-5%, 6-25%, 26-50%, 51-75%, and 76-100% for cover, and 0-1.5m, 1.6m-3m, 3+m for height.

Defining strata and strata surface area.—We delineated the four strata by walking the lower and upper extent of the burrows in the steep slope strata with a Trimble GeoXT® unit. The data from the unit were post-processed to approximately 1 m accuracy (in over 90% of the cases, this resulted in < 1m accuracy and all points were within 2 m). We then used these lines to create the steep slope polygon. However, a portion of the lower line, approximately 400 m, could not be walked because the slope was too steep and unstable. This portion of the line was hand digitized in Arc GIS 9.2 using a color orthographic photo with 18" resolution. We determined the location of this portion of the line by: (1) identifying areas without burrows on the ortho photo (areas of slope failure that were unvegetated) and (2) using our prior field knowledge of the lower extent of burrows on this slope. The cliff edge polygon was created by digitizing the cliff edge to determine its length; the width of the polygon was 15 m or the area actually sampled (the center of the cliff edge plots were 2.5 m from the cliff edge, the inner plots were 10 m from the center of the edge plots, and the radius of all plots was 2.5 m). Both ends of the cliff edge polygon were connected to the steep slope polygon. The transitional stratum polygon was created prior to our field sampling based on our field knowledge of the extent of burrows on the upper slopes. This upper extent was hand digitized using the orthographic photo as a base image and reference and it was connected to the cliff edge polygon and the steep slope polygon. The island top polygon was the remaining interior portion of the island.

To provide an estimate of surface area for each stratum polygon, a 10 m altitude raster coverage ("Digital Elevation Model, 10M" Washington Department of Natural Resources, Olympia) was converted in ArcGIS 9.2 to a triangulated irregular network using the Three-Dimensional Analyst extension package, with the Z tolerance level set to 0.2 (0.1 setting did not improve the resolution) to maximize accuracy. The Z tolerance controls the vertical accuracy of the resulting triangulated irregular network with greater accuracy at settings closer to zero. A higher resolution raster coverage would have been preferable but, is currently not available. We then used the triangular irregular network polygon volume tool in ArcGIS to calculate the surface area for each strata polygon.

Statistical analyses.— A mean burrows estimate for the entire island was derived by multiplying the estimated mean number of burrows per plot by the strata weight (N_h/N) and then summing these weighted means, following Cochran (1977):

$$\bar{Y} = \sum_{h=1}^{L} W_h \bar{Y}_h$$

where suffix h denotes the stratum, $\bar{Y}$ = population mean, W_h = stratum weight, and $\bar{Y}_h$=stratum mean. We then multiplied this island mean by the potential number of plots within the three occupied polygons (cliff edge, steep slope, and transitional). Overall variance was derived using equation 5.6 in Cochran (1977).

$$V(\bar{y}_{st}) = \sum_{h=1}^{L} W_h^2 \frac{S_h^2}{n_h} (1 - f_h)$$

where suffix h denotes the stratum, $V(\bar{y}_{st})$= variance of estimate, W_h = stratum weight, S_h^2 = true variance, f_h = sampling fraction in the stratum, and n_h = number of units in the sample. The number of burrows on the outer cliff edge was a complete count rather than an estimate and was added to the polygon-derived estimate to derive an overall island estimate. Because the "island top" polygon contained no burrows, we eliminated this polygon from all estimates. To estimate the number of occupied burrows on the island we multiplied the overall average burrow occupancy rate by the number of burrows using Goodman's (1960) formula on the exact variance of products.

RESULTS

Burrow and occupancy estimates.-- In June and July of 2008, we counted the number of burrows and estimated burrow occupancy in 166 randomly selected plots distributed among four strata (Table 1). In addition, we directly counted the number of burrows along the vertical cliff face from a 22' powerboat under extremely calm conditions. Using these data, we estimate a total of 54,113 ± 9,390 (95% CI) rhinoceros auklet burrows on Protection Island. Burrow density varied from 0.11 to 0.26 per m^2 among strata (Table 1) and from 0 to 0.92 per m^2 among plots.

Table 1. Surface area, number of plots, burrow counts and density and associated variance by strata in June 2008.

Strata	Surface area (m^2)	Number of plots[1]	Total burrow count	Average number of burrows/plot	Sample variance	Est. Total number of Burrows	Burrow density/ m^2
Steep slope	156,251	79	406	5.1	16.33	40,907	0.26
Cliff edge	31,560	44	165	3.8	21.68	6,029	0.19
Transitional	68,168	15	31	2.1	10.92	7,177	0.11
Island top	836,194	28	0	0.0	0.00	0	0.00
Vertical cliff	Linear feature		681			681	

[1]Plots were 2.5 m in radius or $19.6m^2$ in area

On June 15-17, 2008, we probed 435 burrows in which we were able to assess occupancy (able to check all tunnels and chambers of the burrow with an infra-red camera probe). We were unable to assess occupancy status of only one burrow. Of these 435 burrows, 287 were occupied. Of the occupied burrows, we observed chicks in only 22 (≅8%) and adults and/or eggs in all remaining burrows, indicating that our assessment was conducted at the very end of the incubation period. We surveyed the island top stratum random plots later than all the other strata (between 17 and 29 July), and none of these plots contained burrows. Because none of the plots in this stratum contained burrows, there was no temporal occupancy bias associated with sampling them later in the season. The number of occupied burrows did not differ among strata with an overall average of 66% ± 5% (95% CI; Figure 2). Using these occupancy rate and burrow count estimates and their associated variances, we estimate that there were 35,715 ± 6,757 (95% CI) occupied burrows on Protection Island in 2008. If each occupied burrow represents a pair of auklets, then we can double this estimate to derive an estimate of the number of auklets nesting on the island in 2008 (71,430 ± 13,514).

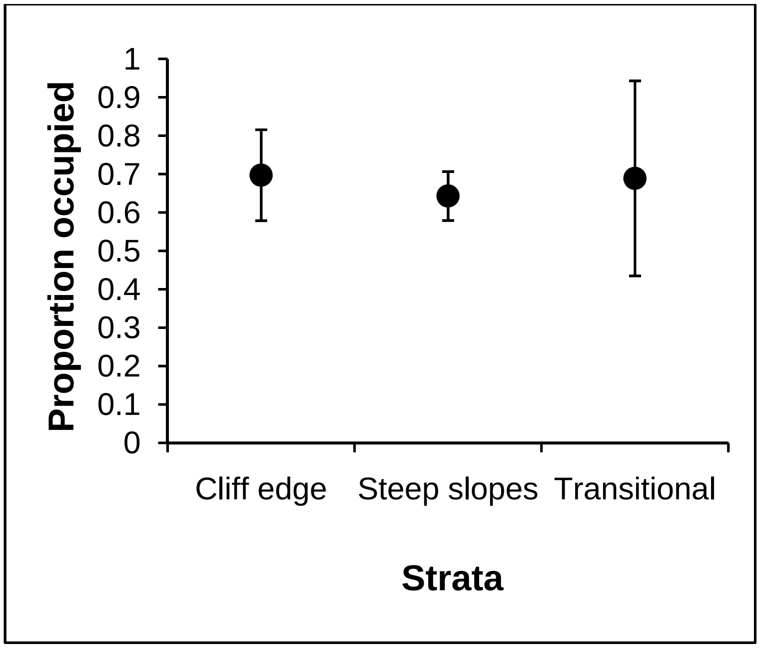

Figure 2. Mean proportion of occupied rhinoceros auklet burrows (±95% CI) by stratum on Protection Island in June 2008.

For the cliff edge stratum, the ideal sampling approach would have been to define the landward edge of this stratum by following the outer extent of burrows with a GPS unit and then measuring the number of burrows and occupancy at random points within the area bounded by the cliff edge and this line. Because we did not do this prior to our sampling, we instead selected 22 random points at the cliff edge and then 22 plots 10 m inland and perpendicular to the cliff edge from each edge plot center. Of the 22 inland plots, 13 did not contain burrows. In contrast, all but 3 of the edge plots contained burrows. These results suggests that we successfully captured the average width of the burrow extent for this stratum. The number of burrows per plot also changed dramatically as we moved away from the edge in this stratum (edge plots = 6.2 ± 2.4, interior plots = 1.3 ± 0.8), suggesting that we equally sampled the high and low burrow density portions of this stratum.

Habitat variables associated with burrows.-- In general there was a positive correlation between the number of burrows and (1) proportion of unvegetated area or bare ground in a plot, and (2) percent slope, and there is a negative correlation with perennial grasses, shrubs, and forbs (Table 2).

Table 2. Spearman correlation matrix of the number of rhinoceros auklet burrows and associated habitat variables measured within randomly selected 2.5m radius plots

	Number of Burrows	Elevation	Slope	Aspect	Un-vegetated	Annual Grass	Perennial Grass	Forbs	Shrubs	Trees
Number of Burrows	1	.	.	.	.	.	.	.	.	.
Elevation	0.010	1	.	.	.	.	.	.	.	.
Slope	0.239	-0.429	1	.	.	.	.	.	.	.
Aspect	0.105	0.156	-0.052	1	.	.	.	.	.	.
Un-vegetated	0.530	-0.132	0.393	0.196	1	.	.	.	.	.
Annual Grass	0.147	0.009	0.076	-0.048	-0.286	1	.	.	.	.
Perennial Grass	-0.367	0.073	-0.296	-0.084	-0.385	-0.463	1	.	.	.
Forbs	-0.227	0.052	-0.255	0.037	-0.142	-0.075	-0.103	1	.	.
Shrubs	-0.230	0.099	-0.423	0.083	-0.098	-0.351	0.130	0.186	1	.
Trees	-0.114	0.086	-0.310	-0.038	-0.054	-0.367	0.124	0.201	0.774	1

The vegetation form was important for these associations; the negative correlation was increasingly pronounced going from trees, shrubs, forbs, and perennial grasses.

Description of the strata.—The steep slope stratum plots averaged 32m in elevation (range: 16-56m), and 44° in slope (range: 2-102°) and had vegetation dominated by grasses (primarily annuals) with few forbs. In cliff edge stratum plots, elevation averaged 46m (range: 35-57m) and slope averaged 17° (range: 0-60°), with plots dominated by one of two basic vegational assembledges: (1) annual and perennial grasses and forbs and (2) shrubs and trees (Douglas-fir, western hemlock, grand fir, Douglas maple, ocean spray, and snow berry). The elevation of the transitional stratum averaged 39m (range:28-

56 m), its slope averaged 20° (range:2-32°) and was dominated by grasses (perennial and annual) and forbs. The elevation of the island top stratum plots averaged 28 m (range: 25-55m), it's slope averaged 9° (range: 0-19°) and was generally dominated by grasses and forbs, while a few plots included Douglas-fir, Nootka rose, ocean spray, and snowberry.

DISCUSSION

Our estimate of 54,113 ± 9,390 (95% CI) rhinoceros auklet burrows on Protection Island is approximately 51% greater than any of the previous estimates (Table 1). If accurate, this burrow estimate and our estimate of the number of birds breeding on the island in 2008 (71,430 ± 13,514) would make Protection Island the third largest nesting colony in North America.

It is interesting to consider why our count is so much higher than previous estimates (see Table 3). It is possible that the population on the island has grown considerably since the 2000 estimate, but it seems unlikely that the population would have grown from 24,000 to 71,430 in only eight years (4.2% annual growth rate). There may be methodological reasons for this apparent discrepancy. Previous estimates by Wilson and Manuwal (1986) and Thompson et al. (1985) employed a combination of sub-sampling within high density areas and complete counts along cliff faces and lower density areas. Even though sub-sampling was used to derive estimates, no associated variance was reported. As a result, we cannot compare the lower bounds of our estimate to the upper bounds of previous estimates. Similar to our work, Wilson and Manuwal (1986) used both their estimated burrow occupancy estimate and burrow count estimate to derive an estimate of the number of breeding birds on the island. Again, they did not report the variances associated with each estimate or attempt to combine these variances when reporting the overall population estimate for the island.

Table 3. Summary of burrow count and occupancy estimates for Protection Island between 1961 and 2008.

Year	Burrow estimate	Occupancy estimate	Occupied burrows[1]	Source
1961	1,500 – 2,000	-	-	Richardson (1961)
1977	27,549	62.1%	17,108	Wilson (1977), Wilson and Manuwal (1986)
1983	27,059	-	-	Thompson et al. (1985)
2000			12,000	Unpublished data cited in Wilson 2005
2008[2]	54,113 ± 9,390	66% ± 5%	35,715 ± 6,757	This paper

[1]This variable has also been described as the number of rhinoceros auklet pairs on the island.
[2]All values in this row are ± 95% confidence interval

These statistical differences are unlikely to explain the very large differences in burrow and bird population estimates. More likely explanations for this difference are that: (1) we found burrows in locations not previously included in estimates or not previously occupied by burrows; and/or (2) we used different methods for calculating the area occupied by burrows. Because no methods are provided for determining the area occupied by burrows in previous publications, we cannot comment on this possibility. However, it is likely that previous estimates used aerial extent while we used ground area. In addition, we found burrows outside the areas surveyed by Wilson (1977, Figure 3) and Thompson et al. (1985, Figure 1), which are the only studies providing rough maps of burrow and sampling locations. Specifically, Wilson (1977) and Thompson et al. (1985) indicate that burrows were located on the slope above the cliff edge only in the area relatively close to Kanem Spit. In contrast, we found burrows along the entire cliff edge and vertical cliff stratum on the northwest and northeast side of the island including burrows in the shrub and forest-dominated portions of this strip. More importantly, we found the high density areas on the southeasterly side of the island (sampled by quadrats previously) to be considerably larger and much more continuous between Kanem and Violet spits than pictured in Thompson et al. (1985) and slightly larger than that pictured by Wilson (1977). From the published literature, we cannot determine if previous researchers looked outside the areas where burrows were counted or estimated to determine if burrows occurred elsewhere on the island. In contrast, our estimate includes the entire island above the lowest burrows. Because of these methodological differences between our estimate and previous estimates we don't recommend direct comparisons.

The occupancy rates did not differ among strata, but the variance surrounding the transitional stratum was higher than the other strata suggesting greater variability in occupancy. This stratum was farther from the water than the other strata and did not have the consistently steep slopes of the steep slope stratum. As a result, portions of this polygon may be less desirable than others resulting in higher variability in occupancy rates.

We also measured occupancy along a transect used as a reproductive index site for the island in 2006, 2007 and 2008 and found occupancy rates to be similar to those reported here. Finally, occupancy rates found in our different strata all overlap with the occupancy rate reported by Wilson (1977). These data suggest that occupancy rates do not differ dramatically among years or locations on the island.

The concentration of such a large portion of the North American rhinoceros auklet population on Protection Island means that this island has significant implications to the species as a whole. As a result, management actions should focus on maintaining suitable nesting habitat and address issues that inhibit successful nesting.

The positive correlation between burrow densities and steep, grass dominated areas is likely attributed to several factors, including selection by auklets of steep conditions relatively close to the water and avoidance of areas either farther away from the water or dominated by trees and shrubs . The high percentage of bare ground and annual grasses in areas used most heavily by birds is very probably the result of digging activity and probably not associated with habitat selection. Birds depositing the soil outside their burrows and their regular trampling associated with excavation and burrow visits creates and maintains the extensive areas of bare ground on the steep slopes. The considerable black-tailed deer (*Odocoileus hemionus columbianus*) activity on these slopes likely also contributes to soil erosion and the bare open condition of these slopes. This constant disturbance results in ideal conditions for the establishment of annual grasses [primarily cheatgrass (*Bromus techtorum*)] which are well adapted to this type of disturbance.

NEXT STEPS

Our goal is to provide similar estimates and measure the same habitat variables on Smith and Destruction islands. If funds are available we will complete both estimates in 2009. If not, we will only undertake work on Destruction Island in 2009. Once all three islands have been completed, we will submit a manuscript to a peer-reviewed journal that will allow us to examine changes in colony size between the 1970s and today for Protection and Destruction islands and assess changes in the Sound (Salish Sea) and on the outer coast. Such comparisons are critical to determining if events occurring in the Sound are unique to Puget Sound or are part of a larger scale phenomenon. Finally, we develop a relatively sophisticated habitat model that will allow us to identify the habitat features important to rhinoceros auklets when selecting locations for their burrows. This type of analysis is critical to helping land managers understand how to restore and to manage existing habitat.

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LITERATURE CITED

Bretagnolle, V., and C. Attie. 1991. Status of Barau's petrel Pterodroma baraui colony sites breeding population and taxonomic affinities. Colonial Waterbirds 14:25-33.

Cairns, D.K. 1988. Seabirds as indicators of marine food supplies. Biol. Oceanogr. 5(4): 261-271.

Cochran, W.G. 1977. Sampling Techniques, 3rd edition. John Wiley and Sons, New York.

Davoren, G.K., Montevecchi, W.A. 2003. Signals from seabirds indicate changing biology of capelin stocks. Marine Ecology Progress Series 258: 253-261.

Furness, R.W., Tasker, M.L. 2000. Seabird-fishery interactions: quantifying the sensitivity of seabirds to reductions in sandeel abundance, and identification of key areas for sensitive seabirds in the North Sea. Marine Ecology Progress Series 202: 253-264.

Gaston, A.J., and S.B.C. Deschesne. 1996. Rhinoceros auklet (*Cerorhinca monocerata*). In The Birds of North America, No. 212 (A. Poole and F. Gill, eds.) The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708–713.

Monteiro, L.R., J.A. Ramos, J.C. Pereira, P.R. Monteiro, R.S. Feio, D.R. Thompson, S. Bearhop, R.W. Furness, M. Laranjo, G. Hilton, V.C. Neves, M.P. Groz, and K.R. Thompson. 1999. Status and distribution of Fea's petrel, Bulwer's petrel, manx shearwater, little shearwater and rand-rumped storm-petrel in the Azores archipelago. Waterbirds 22:358-366.

Montevecchi, W.A. 1993. Birds as indicators of changes in marine prey stocks. In: Furness R.W., Greenwood, D.J.(eds) Birds as monitors of environmental change. Chapman and Hall, London, pp. 217-266.

Montevecchi, W.A., Myers, R.A. 1995. Prey harvests of seabirds reflect pelagic fish and squid abundance on multiple spatial and temporal scales. Mar. Ecol. Prog. Ser. 117(1-3): 1-9.

Parrish, J.K., Zador, S.G. 2003. Seabirds as indicators: an exploratory analysis of physical forcing in the Pacific Northwest Coastal Environment. Estuaries 26(4b): 1045-1058.

Rayner, M. J., M.N. Clout, R.K. Stamp, M.J. Imber, D.H. Brunton, and M.E. Hauber. Predictive habitat modeling for the population census of a burrowing seabird: A study of the endangered Cook's petrel. Biological Conservation 138:235-247

Roth, J.E., K.L. Mills, and W.J. Sydeman. 2007. Chinook salmon – seabird co-variation off central California: possible forecasting applications. Canadian Journal of Fisheries and Aquatic Sciences 64:1080-1090.

Speich, S.M., and T.R. Wahl. 1989. Catalog of Washington seabird colonies. U.S. Department of Interior, Fish and Wildlife Service, Biological Report 88(6).

Sydeman, W.J., N. Nur, E.B. Mclaren, and G.J. Mcchesney. 1998. Status and trends of the ashy storm-petrel on Southeast Farallon Island, California, based on capture-recapture analyses. Condor 100:438-447.

Thompson, S.P., D.K. McDermond, U.W. Wilson, and K. Montgomery. 1985. Rhinoceros auklet burrow count on Protection Island, Washington. The Murrelet 66:62-65.

Wilson, U.W. 1977. A study of the biology of the Rhinoceros Auklet on Protection Island, Washington. M.S. Thesis, University of Washington, Seattle, Washington.

Wilson, U.W., and D.A. Manuwal. 1986. Breeding biology of the rhinoceros auklet in Washington. Condor 88:143-155.

Rayner, M.T., M.N. Clout, R.K. Stamp, M.J. Imber, D.H. Brunton, and M.E. Hauber. 2007. Predictive habitat modeling for the population census of a burrowing seabird: A study of the endangered Cook's petrel. Biological Conservation 138:235-247.

Ryan, P.G., C. Dorse, and G.M. Hilton. 2006. The conservation status of the spectacled petrel *Procellaria conspicillata*. Biological Conservation 131:575-583.

Lawton, K., G. Robertson, R. Kirkwood, J. Valencia, R. Schlatter, and D. Smith. 2006. An estimate of population sizes of burrowing seabirds at the Diego Ramirez archipelago, Chile, using distance sampling and burrow-scoping. Polar Biology 29:229-238.

Cuthbert, R. 2004. Breeding biology of the Atlantic petrel, *Pterodroma incerta*, and a population estimate of this and other burrowing petrels on Gough Island, South Atlantic Ocean. Emu 104:221-228.

Protection Island Burrow Count Field Protocol

Last updated: 20 March 2009

Equipment needed (for 2 teams working concurrently)

2 Trimble GPS units

2 clinometers

2 compasses

4 long plastic stakes

4 stake flags (thin metal stakes with plastic flag attached)

4+ pieces of cord in 2.5m lengths

2 clipboards

data sheets

mechanical pencils

bull clips/rubber bands (for holding bottom of data sheets to clipboards)

2 infra-red camera probes (and a third for backup)

Protocol

Stratification of island

The island has been divided into 4 strata (or polygons) and the linear row of burrows on the northern side of the island (vertical cliff):

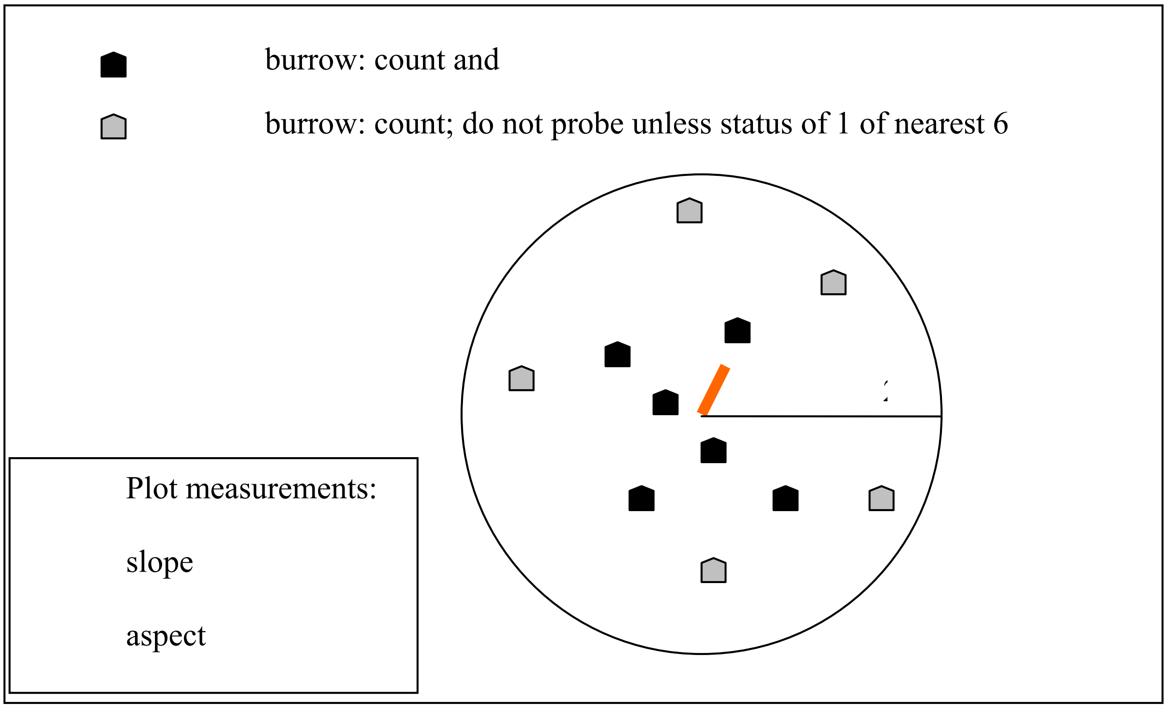
1) Cliff Edge (northern side of island)
2) Steep Slopes where most burrows are located (southern side of island)
3) Transitional area at the top of the slopes
4) Interior

Sampling points in each stratum will be randomly determined and entered into the Trimble GPS units, thereby enabling us to navigate to the center of each sampling plot

Dimensions of sampling plots: each sampling plot will be a **2.5m** radius circular plot, centered on the sampling point

Measurements to be made in each plot

1) Number of burrows in the plot
    a. *method*: count the number of burrow entrances within the 2.5m radius, using a cord attached to the central stake to determine the boundary of the plot
2) Number of occupied burrows in the plot
    a. *method*: for plots which contain ≤6 burrows, all burrows will be probed to determine occupancy. for plots which contain >6 burrows, the 6 burrow entrances nearest to the center stake will be probed. for plots with >6 burrows, if you cannot determine the contents of a burrow mark it on the data sheet and add the next nearest burrow until you have a total of 6 burrows of known status for the plot.
3) Slope within the plot
    a. *method*: use a clinometer to record representative slope angle (in °) for the plot
4) Aspect of the plot
    a. *method*: use a compass to record the direction (in degrees) that the plot is facing (aspect)
5) Elevation of the plot
    a. *method*: use the Trimble GPS unit to record elevation (in m) at the level of the central stake in the plot
6) Percent vegetation cover in the plot
    a. *method*: use ocular estimates of all % cover variables in the following cover categories: <1%, 1-5%, 6-25%, 26-50%, 51-75%, 76-100%.use the following cover variables: bare ground, annual grasses, perennial grasses, annual and perennial forbs, shrubs (list predominant species), trees (list predominant species).record height categories of vegetation in the plot: 0-1.5m, 1.6m-3m, 3+m
7) GPS location of plot using Trimble unit (provides elevation and exact location)
8) At conclusion of plot ensure that all data have been recorded for current sample plot. Determine next plot location using Trimble GPS unit and navigate to it.


burrow: count and
burrow: count; do not probe unless status of 1 of nearest 6
Plot measurements:
slope
aspect