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Mapping Distribution and Relative Density of Nesting Least and Crested Auklets at Segula Island, Alaska, May-June 2006

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MAPPING DISTRIBUTION AND RELATIVE DENSITY OF NESTING LEAST AND CRESTED AUKLETS AT SEGULA ISLAND, ALASKA, MAY-JUNE 2006

Heather M Renner and Joel H Reynolds[1]

Abstract

The Alaska Maritime National Wildlife Refuge was established, in part, to conserve marine bird populations. This requires the ability to detect at least large changes in their abundance. Monitoring populations of auklets and other crevice-nesting seabirds has proven problematic even though numerous methods have been attempted since the mid 1960's. Quantifying changes in geographical size of auklet colonies may be a useful alternative to directly measuring population size. Anecdotal evidence suggests several large colonies have decreased recently in both extent and abundance, simultaneous with vegetation encroachment and succession. In May-June 2006 we employed a recently developed standardized method for colony mapping, using a randomized systematic grid survey, on Segula Island. Additionally, we improved the method to support fitting patch occupancy models to account for less than perfect detection. These models simultaneously estimate detection rates and the occupancy rate, allowing for unbiased estimates of occupancy and colony area. Quantitatively mapping all large auklet colonies is logistically feasible using this method and could provide an important monitoring baseline for the status of auklet colonies through time.

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Introduction

The Alaska Maritime National Wildlife Refuge provides the majority of nesting sites for least and crested auklets (*Aethia pusilla* and *A. cristatella*), two species of colonial-nesting seabirds endemic to the Bering and Okhotsk seas. The refuge was established particularly for the conservation of marine birds and marine mammals, and a fundamental measure of whether there are conservation issues is population trend. Nevertheless, monitoring populations of auklets and other crevice-nesting seabirds has proven problematic even though numerous methods have been attempted since the mid 1960's (Jones 1993a, 1993b).

Anecdotal evidence suggests several large colonies in the refuge have declined in the past 30 years based on observations of apparently fewer birds associated with the colonies and a sense that a smaller proportion of breeding colonies is being occupied now than formerly. One of these colonies is Segula Island. During May-June 2006, we visited the island to test a newly developed monitoring technique (Renner et al. 2006) for the purpose of acquiring baseline data on the geographic extent and relative density of auklets in the colony (Renner and Reynolds 2006).

Here we report a summary of the data and how we applied the new methods. We also include an annotated list of birds seen during our field work at Segula (Appendix A).

Study Area

Segula Island (52° 02'00" N, 178° 09'00" E) is in the Rat Island group of the central Aleutian Islands. The volcanic island includes coastal block-field habitat with crevices used by least and crested auklets. The auklet nesting colony was described in 1979 (Early et al. 1980) and more thoroughly surveyed in 1995 (Thomson 1995a). However, methods for detecting auklet presence were not standardized nor were survey points georeferenced during earlier surveys. The auklet colony lies south of Gula Point (Thomson 1995) and consists of a densely overgrown lava flow that is 200-300 years old (Nelson 1959). Much of the area used by auklets is covered in tall grass tussocks where nesting crevices only occur in very low densities. It is impossible to assess precise habitat change since 1995, but the colony appears to be rapidly overgrowing. One set of three observation plots used for attendance counts in 1995 was completely overgrown by 2006 and gave no evidence of any potential habitat or attending birds.

Methods

The survey was conducted between 24 May and 6 June 2006 (early incubation period). Weather in this period was unusually dry for summer in the Aleutians, with no rain. There is no regular reference for judging this year's apparently low auklet attendance on Segula, but during our survey period attendance was reported to be extremely low on Buldir Island (approximately 10% of 'normal' until around 7 June; Ian L. Jones, pers. comm..) but not on Kasatochi Island (Brie Drummond, pers. comm.). Nesting chronology for auklets was about a week later than normal at both sites.

Survey methods, detailed below, followed Renner et al. (2006) with slight variation due to the additional objectives described ('Method 2' below). The need for multiple independent samples within each grid cell required dividing each grid cell into equal-sized *sample units* which fit evenly into a cell, e.g. partitioning the grid cell into squares or hexagons. In contrast, Renner et al. (2006) randomly selected the center of a circular observation plot within each grid cell. Our choice of hexagonal sample units led to slightly off-square grid cells formed from rectangular arrays of hexagonal sample units.

The circular *observation unit* was retained due to its simple implementation in the field. Since the largest circular observation unit that could be inscribed in a sample unit did not fully cover the hexagon sample unit (area covered = 91%) or square sample unit (78.3%), there was an added component in the probability of detection attributable to observing only a subset of each sample unit. Effectively, this is just incorporated into the overall probability of detection. The choice of hexagonal sample units was driven by the desire to minimize this added component.

Two-dimensional area and geographic extent of the Gula Point auklet colony was estimated using three different methods. Each method determined the presence or absence of nesting auklet evidence on a sample of cells from an overlain grid of cells; cells were approximately 100 m x 100 m squares.

- Method 1 - One 16 m^2 survey plot per grid cell was visited following Renner et al. (2006) to estimate colony area without correcting for lack of perfect detection, i.e., this method is biased and underestimates colony area.
- Method 2 - Five survey plots on a random sample of 80 grid cells were visited to get unbiased estimates of detection probability, patch occupancy and their associated uncertainties.
- Method 3 - Each cell's occupancy was subjectively assessed by having the field observer search the cell area exhibiting the most suitable habitat. This was done strictly for comparison to Method 2 as this approach was expected to provide the highest detection probability possible and thus highest colony area estimates, though it is impossible to standardize the method or to estimate its associated uncertainty. An additional objective was to estimate relative density by counting feathers and droppings on sampling plots visited in Method 1.

Why use patch occupancy models to estimate colony area?

Presence-absence data obtained from a single visit to a sample of sites provides biased estimates of the proportion of sites (or sampled area) occupied (*occupancy rate*) because of confounding with less than perfect detection. The *absent* sites are a mixture of sites where the item of interest was truly absent and sites where the item was present but undetected. This leads to underestimates of occupancy rates and, for long-term monitoring, confounding of changes in occupancy with changes in (the unknown) detection rate.

Less than perfect detection can occur for at least three reasons: due to only observing a subset of the full cell (spatial subsampling), observer error (deficient searching), or loss of evidence due to weather (temporal subsampling). The main approach presented here, Method 2, accounts for the first factor, which we feel is dominant in this application. It also reduces the second source by choice of observational unit (small enough for thorough searching) and standardized guidelines; the third factor may be partially controlled by field work timing.

Occupancy models (see Appendix B) overcome the lack of perfect detection by simultaneously estimating detection rates and the occupancy rate, allowing for unbiased occupancy estimates. Fitting these models, which are built from standard mark-recapture models, requires multiple independent sampling events at each site (Mackenzie 2002, 2003).

Sampling Design

The *observational unit* was a 16 m^2 circular plot (Figure 1) inscribed in the *sample unit*, a hexagon with radius 2.26 m and area 17.58 m^2 (91% of the sample unit was observed). A grid of sample units was overlain across the whole island, partitioned for logistical convenience into *subregions* (approximately 1 km x 1 km) composed of squarish *cells* (approximately either 100m x 100m or 50m x 50m) of sample units.

Final dimensions of logistically convenient collections of sample units were:
Cells: extent North - South = 108.3 m; extent East - West = 101.6 m, i.e., a 26 row x 24 column array of sample unit hexagons. Cell area was 10969.92 m^2.
Subregions: extent North - South = 1083.2 m; extent East - West = 1016.3 m, i.e., a 10 x 10 array of cells.

The counting unit for the colony area estimate was the cell. A cell was considered occupied if *any* evidence of occupancy was detected within the cell. That is, the analysis ignored the fact that some cells might not have been completely filled with potential habitat.

Stage 1. [before heading to the field] Create and overlay a grid of cells across the island.

Stage 2. [1 day] Define the initial sample frame (collection of relevant cells) by exploring the colony perimeter via auditory and visual cues of occupancy. On the first day in the field we walked the approximate perimeter of the colony. The sample frame was defined as all cells crossed by or contained within the approximate perimeter, along with a 1-2 cell thick boundary around the approximate perimeter.

Stage 3. [6 days, two people working independently] Visit an unaligned systematic sample of one sample unit per cell in the sample frame. The observational unit was centered on the center of the selected sample unit and investigated for any evidence of auklet presence: belly feathers, droppings, vocalizations, vegetation wear, or birds attending on the surface of the circular plot.

Each visited observational unit was classified into one of four categories:
- Present – (‘occupied’) evidence detected,
- Absent – (‘unoccupied’) no evidence detected,

Non-Habitat – (‘unoccupied’) the observational unit did not contain any potential habitat (i.e., was a snow field, water, grass plain with no crevices, etc.), or

X – (‘missing’) inaccessible due to occurring on a cliff face or inaccessible beach section.

Density Survey – At most observational units visited during Stage 3 counts of feathers and droppings were recorded rather than just presence or absence of evidence. Counts at few high density units were omitted due to time constraints.

Expert Search - The center of each cell was located and the whole cell assessed as either:

- Non-Habitat - cells completely composed of some combination of water, solid plain of grass with no rocks or talus offering crevice openings, or tundra / snowfields completely covered and offering no crevice openings, etc., or cells that were both composed of $< 1\%$ (surface area) of crevice-containing habitat and the rest non-habitat and (ii) that were discontiguous or isolated from the main colony; or
- Potential Habitat – cells containing crevice openings and that were not clearly Non-Habitat.

All potential habitat cells were searched for evidence of occupancy by investigating, initially, the potential habitat closest to the initial sample observational unit. The search continued until evidence was found or 5-10 minutes effort had been expended. Thus the Expert Search led to the following cell classifications:

Non-Habitat – defined above;
Present (‘occupied’) – evidence found in cell by directed search;
Absent (‘unoccupied’) – no evidence found in cell by directed search.

Sample Frame Refinement. At the end of Stage 3, all visited cells that had been classified as Non-Habitat were removed from the sample frame. Note that such cells either formed a boundary around the colony area or occurred within the colony region itself (patches). If cells containing cliffs had inaccessible initial sampling plots (e.g., on a cliff), these plots were treated as ‘missing data’ in the analysis.

Stage 4. [4 days, two people working independently] Revisit a subset of cells. A simple random sample of 80 Potential Habitat cells was selected from those defined at the end of Stage 3. A simple random sample of four more sample units was selected from each of these cells. Each of the additional plots was investigated for evidence of occupancy. The choice of 80 cells and four sample units was based on field logistics; higher values for either choice would have further improved precision of the estimates.

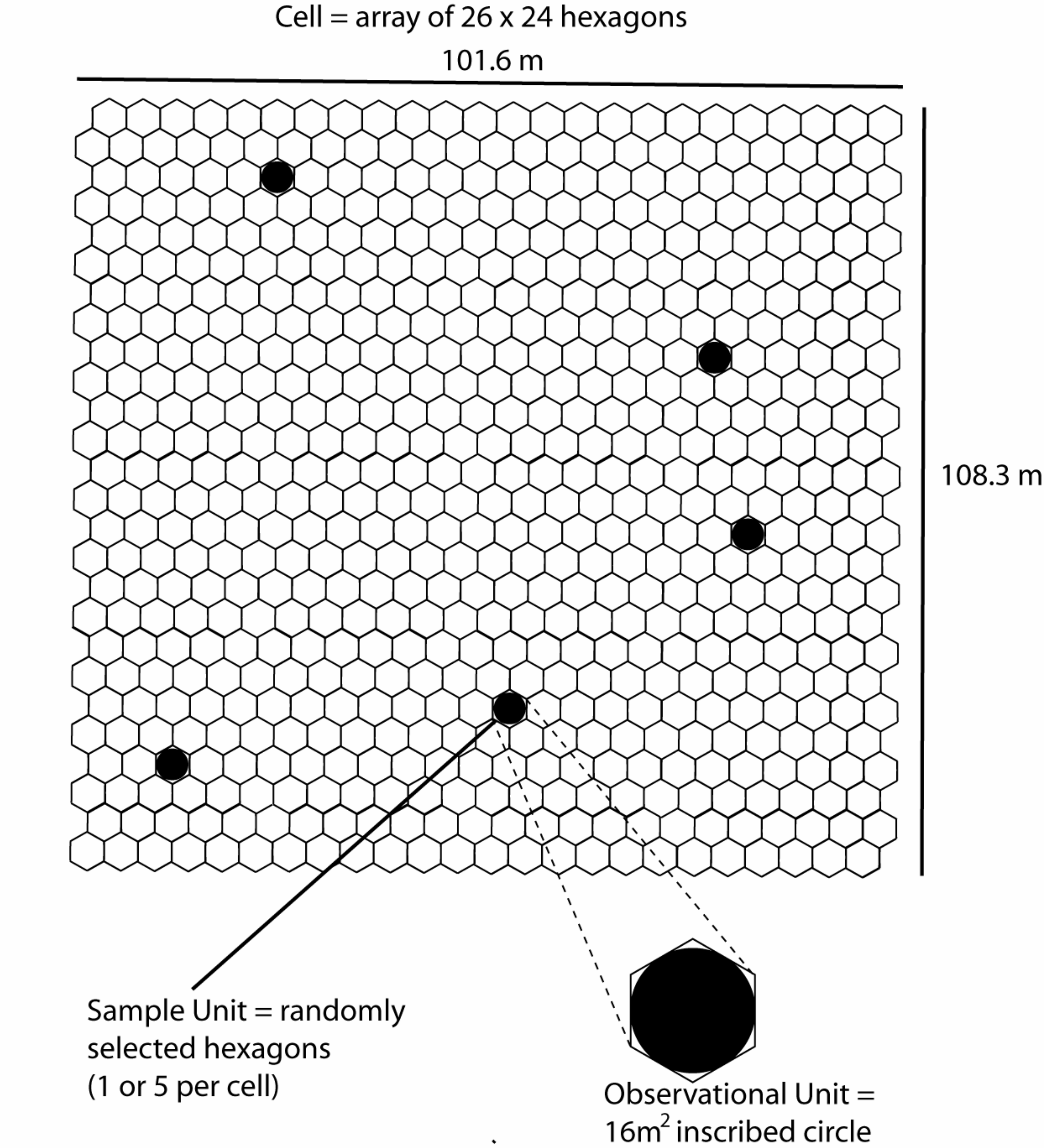

Figure 1. Diagram showing sampling design used for documenting occupancy by auklets at Segula Island, Alaska in 2006. Cells shown here were arranged in subregions - 10x10 arrays shown in Figure 2.

Patch Occupancy Analyses

The sample design satisfies all the assumptions of the patch occupancy models introduced by MacKenzie et al. (2002, 2003) with the extension that only a subset of cells were visited multiple times. In contrast to their original development (MacKenzie et al. 2002), in this application the multiple samples per cell vary in space (location within the cell) rather than in time (visitation period at the site). Each visited sample unit resulted in one of three responses: 0 (unoccupied / absent), 1 (occupied / present), or x (missing data). The standard model was simplified in this application since the order of observation of the sample units did not matter.

Three models were fit: the standard patch occupancy model that assumed all occupied cells share a common probability of detection, an extension of that model that allowed for two latent classes (strata) of occupied cells with differing probabilities of detection, and a further extension allowing for three strata (Pledger 2000). All three models were fit using maximum likelihood methods and the best fitting model selected using AIC (Burnham and Anderson 2002). Goodness of fit for the selected model was assessed using the standard Chi-square goodness of fit statistic with the null reference distribution estimated via Monte Carlo simulation (1000 simulated samples) from the fitted model (MacKenzie and Bailey 2004). Standard errors of parameters of interest were estimated from 1000 nonparametric bootstrap resamples (Lunneborg 2000). Confidence intervals were calculated as Estimate +/- 1.96 x Standard Error (Lunneborg 2000).

Classification of revisited cells to stratum

Fitting a patch occupancy model that allows for strata differing in their probability of detection does not directly assign each sampled cell to a specific stratum (e.g., unoccupied, occupied - low density, occupied – high density). However, a classification rule for assigning cells to stratum can be developed from the parameter estimates. The essential step is to decide, before viewing the data or parameter estimates, how much more likely a cell's observations must be, assuming the cell belongs to stratum A compared to stratum B, in order to assign the cell to stratum A. We required a classification likelihood level of 10, e.g.

$$\text{Prob(cell results }|\text{stratum A)} \geq 10 \times \text{Prob(cell results } | \text{ stratum B)}$$

to assign a cell to stratum A rather than stratum B.

Software

The survey grid of cells and observation unit samples were generated using programs written by the second author for the statistical data analysis package and environment R (R Development Core Team 2005), as were the summaries and figures. The code is available upon request. Occupancy models were fit using the freeware program PRESENCE (MacKenzie and Hines 2002, http://www.mbr-pwrc.usgs.gov/software/presence.html). Maps were prepared using ArcGIS version 9.1, and all occupancy and density data are archived in a FileMaker Pro version 7 database.

Results

Sample Frame Development

Stage 2 identified a contiguous set of 308 cells for visitation as potential habitat. Of these, the Expert Search of Stage 3 identified 92 cells as Non-Habitat (Figure 2), leaving a revised colony sample frame of 216 cells. Six cells had inaccessible initial sampling plots on seaside cliffs; these plots were treated as 'missing data' in the analysis.

Based on available field effort, a random sample of 80 cells from the 216 was selected for revisiting in Stage 4. Four (additional) sample units were randomly selected from each of these 80 cells. Initially, we had planned to stratify the cells by cover type – bare rock, moss, vegetation. This intention was dropped in the field during Stage 3 as there was one predominant cover type for all cells – thick vegetation.

The sampling design provides for three naïve colony area estimates as well as that from the occupancy model estimation (Table 1), where an estimate is *naïve* if it ignores the bias caused by lack of perfect detection. Figure 2 shows occupied cells as designated by each of the three naïve estimate methods. The occupancy model does not assign status to specific cells, so we cannot generate a map using this method (but see below – Classification of revisited cells to stratum).

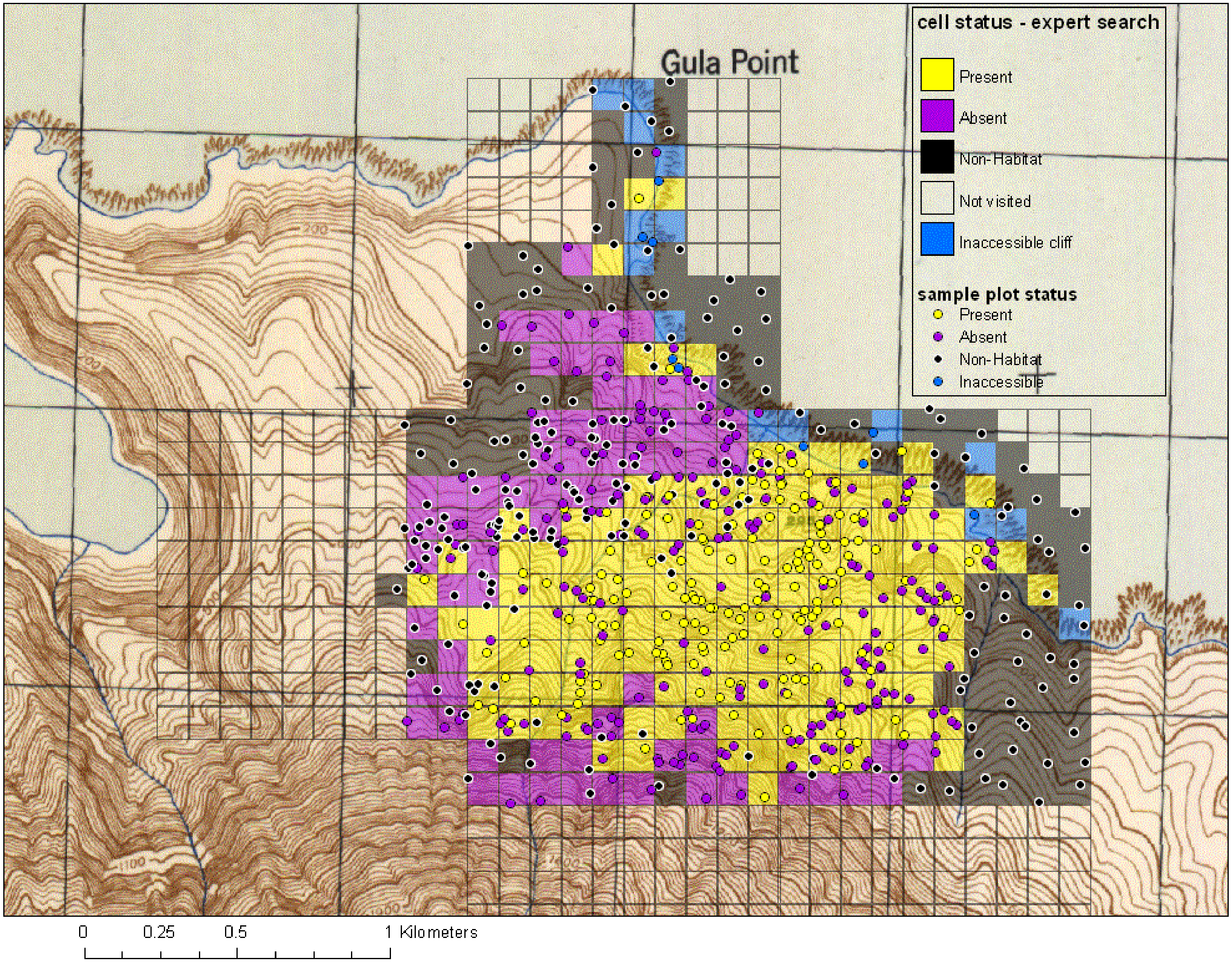

Figure 2. Map of Gula Point auklet colony, Segula Island, Alaska in 2006. Cells are color coded by occupancy status as determined by the Expert Search, and status of individual sample plots within cells is shown as well.

Table 1. Survey summaries and associated colony area estimates from different methods for sampling the auklet colony for evidence of occupancy. See text for survey methods. Only the occupancy model accounts for less than perfect detection to give an unbiased colony area estimate; the area estimates from the first three methods are all biased low by different amounts. In the first two methods Area Estimate = Number of Occupied Cells * Cell Area, in the last two methods Area Estimate = Occupancy Estimate * Total Number of Cells * Cell Area. Relative Bias was estimated as (Area Estimate / Occupancy Model Area Estimate – 100%).

	Non-Habitat	Sample Inaccessible	Unoccupied	Occupied	Total Cells	Occupancy Estimate	Area Estimate (km^2)	Relative Bias
Expert Search of cell	90		75	141	308	141/216 = 0.653	1.55	-21%
Stage 3 (1 sample unit / cell)	36	6	98	76	216	76/(216-6) = 0.362	0.83	-58%
Stage 4[1] (5 sample units / cell)			28	52	80	52/80 = 0.65	1.54	-21%
Occupancy Model					216	0.828	1.96	

[1] Treats all visited cells whose five sample units failed to detect any evidence as absent rather than simply undetected.

Patch Occupancy Model Selection

The data clearly supported the model allowing for two cell strata differing in their probability of detection (Table 2, Delta AIC and Model Likelihood columns). The goodness of fit assessment failed to detect any significant departure of the observations from the selected model (Table 2, Goodness of Fit).

The patch occupancy model, by accounting for the less than perfect detection of evidence in a sample unit, estimated colony area at 1.96 km^2 (95% bootstrap CI: 1.47, 2.50 km^2) (Table 3). The identified strata greatly differed in their probability of detection, 0.20 versus 0.78 (Table 3), with the majority of the occupied colony being attributed to the lower density strata (π_{Low} = 64% of occupied colony, Table 3; Figure 1). Collecting five samples from each of the 80 cells provided fairly precise estimates of detection probabilities; multiple samples would have had to be collected from more than 80 cells to improve precision of the probability of occupancy estimate (Table 3).

Table 2. Model selection results from fitting models differing in the number of latent cell strata to data from all potential habitat cells (216 cells) and treating inaccessible plots as missing data. The model with the smallest AIC is considered the best from among those under consideration (Burnham and Anderson 2002). Delta AIC = AIC – smallest AIC across models and provides a relative measure of model performance among the models under consideration. Model Likelihood is a measure of the observations' weight of evidence for a specific model relative to the others. The Goodness of Fit P values are from a Monte Carlo test of each model's adequacy as a description of the underlying data. The data clearly are best described by the model allowing for two strata differing in their detection probabilities.

Model: Number of Detection Strata	AIC	Delta AIC	Model Likelihood	Goodness of Fit
1	624.03	23.2	0.00	0.00
2	600.83	0.0	0.88	0.22
3	604.83	4.0	0.12	0.03

Table 3. Parameter and Colony Area estimates from the occupancy model with two detection strata ('Model 2' Table 2). Bootstrap standard errors ('SE') and confidence intervals ('CI') are described in the text. Prob(Occupied) is the probability that a randomly selected cell in the sample frame is occupied . π_{Low} is the probability a randomly selected occupied cell has low density of evidence (formally, has low detection probability).

Prob(Occupied) (SE)	Area km^2 (95 CI%)	π_{Low} (SE)	Prob(Detect | Low Density) (SE)	Prob(Detect| High Density) (SE)
0.83 (0.110)	1.96 (1.47, 2.50)	0.64 (0.13)	0.20 (0.08)	0.78 (0.8)

Classification of revisited cells to stratum

Requiring a classification likelihood level of 10 to assign a sampled cell to a particular stratum based on the parameter estimates from Model 2 (Table 3) assigned cells exhibiting 4 or 5 sample units with evidence to the high density stratum and those with 1 sample unit with evidence to the low density stratum (Table 4). A specific cell exhibiting no evidence on any of 5 sample units could not be specifically assigned to the Unoccupied versus Occupied-but-low-density stratum.

Table 4. Probability distributions for number of sample plots with evidence for each possible cell stratum, based on parameter estimates from Model 2 (Table 3). The final column assigns a cell to a stratum based on the requirement of a likelihood ratio ≥ 10.

Samples with Evidence (out of 5)	Probability | Unoccupied	Probability | Low Density	Probability | High Density	Detection Strata Classification
0	1	0.3277	0.0005	Unoccupied or Low
1	0	0.4096	0.0091	Low
2	0	0.2048	0.0648	Occupied
3	0	0.0512	0.2297	Occupied
4	0	0.0064	0.4072	High
5	0	0.0003	0.2887	High

Discussion

Colony area estimates

The Segula auklet colony is currently estimated to have an area of 1.96 km^2 (Table 3) after accounting for less than perfect detection due to spatial subsampling of each cell. Treating this unbiased estimate as the true colony area resulted in estimated relative biases of -20% to – 50% for the methods that did not account for the lack of perfect detection (Table 1). It is important to note that compared to the occupancy model even the Expert Search underestimated colony area by 21% (Table 1) as some areas identified as 'Absent' during the Expert Search were likely occupied.

Comparisons with earlier area estimates

In the late 1970s the Segula colony area was estimated to be 0.78 km^2 (Early et al. 1980), with 60% of that being unused habitat, based on walking the perimeter in one day and using a polar planimeter to measure the mapped area. In the early 1990s the colony area was estimated to be 1.28 km^2 (Thomson 1995a). This estimate was based on more extensive and intensive surveys but exact detection methods were not described. Both estimates are much smaller than even the lower bound of the 95% confidence interval estimate for our current colony area estimate (1.47 – 2.50 km^2, Table 3).

Unfortunately, the differences in colony area estimates cannot be clearly attributed to temporal changes in actual colony area, because they are confounded with changes in survey methods across the years. Due to issues described in Renner et al. (2006), none of the earlier surveys can be reproduced nor their uncertainties or biases estimated. Even so, it is apparent from the current study that ignoring the lack perfect detection severely biases the colony area estimates (Table 1). Relative to former surveys, the current effort was quite rigorous, intensive, standardized, and reproducible, yet ignoring the problem of imperfect detection was seen to cause colony area underestimates by as much as 50% (Table 1). The biases associated with the earlier surveys are plausibly much higher. Thus differences in survey methods are undoubtedly the dominant factor underlying the apparent increase in colony area through time, such as differences in the probability of detecting evidence of occupancy, differences in the underlying definitions of occupancy, and differences in the treatment of enclosed but uninhabited habitat. Additionally, colony area estimates depend on the measurement scale or counting unit (Renner et al. 2006): the current survey used units approximately 100 m x 100 m, the earlier surveys have no associated scale. The differences in scale further undermine the ability to compare area estimates.

Actually, non-quantitative field evidence leads us to strongly believe the colony area has decreased through time. Specific evidence includes: 1) dense overgrowth of the colony and occurrence of large unoccupied areas – though described by Early et al. (1980), the trend in vegetation colonization and success is only expected to have continued since their survey, not reversed; 2) except for a few subsections, the majority of currently occupied locations were restricted to the steeper side-slopes of the ridges and seldom found in the now heavily vegetated gully and valley bottoms; 3) low auklet attendance relative to the descriptions from earlier visits, though this comparison is confounded by observed low attendance at the Buldir colony during our 2006 survey period, presumably due to a late spring; 4) at least one area used for attendance counts in 1995 was completely unoccupied in 2006; and 5) consideration of the potential relative biases in earlier survey methods as described above.

The absence of a standardized survey method and, in earlier surveys, of adjustment for lack of perfect detection, prevents any quantification of changes in colony area through time. This is not to cast aspersions on the earlier efforts but rather highlights the importance of employing a standardized survey method as argued by Renner et al. (2006). In particular, the current results clearly demonstrate the importance of using a standardized method that can account for lack of perfect detection of occupancy and provide for associated estimates of uncertainty.

Methods assessment

Especially in low density colonies, the methods described in Renner et al. (2006) result in an underestimate of the true number of occupied cells. In this project, we tried to achieve a balance between reproducibility and accuracy. For example, the “Expert Search” technique may be considered the most accurate colony survey method as it incorporates the biological and field experience of the auklet researcher in identifying occupied cells. However, it suffers from three deficiencies: 1) it is least reproducible as there is no standardized method for identifying good habitat and searching a known area, 2) it does not support estimates of uncertainty such as standard errors or confidence intervals, and 3) it is still subject to potentially severe bias in low density colonies (Table 1). Expert Searches are thus probably the least useful method for monitoring trends through time.

The patch occupancy model and associated survey method produced the least biased colony area estimate as it accounts for lack of detection due to spatial sub-sampling (but not temporal subsampling). However, the occupancy model does not directly classify each cell’s occupancy. While the Expert Search misses some occupied cells, it is able to define the occupancy of some cells that the patch occupancy model is unable to differentiate between unoccupied and occupied-but-low-density (Figure 1). A combination of both approaches, as implemented here, appears to provide the most useful information in terms of both unbiased colony area estimates and standard errors as well as explicit georeferenced maps of known occupied cells.

Monitoring changes

Colony area change could not be quantitatively assessed due to the differences among survey methods described above, especially the lack, in earlier surveys, of a sampling method providing unbiased estimates of colony area by accounting for lack of perfect detection. If the current survey methods had been applied in the late 1970s and early 1990s, two assessments of change in colony area could be applied.

Trends in total colony area could be assessed using weighted regression, where each estimate would have an associated weight equal to $1/(SE^2)$. Either linear or nonlinear models could be used as warranted by the observed trends.

Changes in spatial pattern of occupancy, i.e., changes in occupancy status of georeferenced cells, might be investigated assuming each survey used a similar method of classifying cell occupancy – perhaps through a combination of the patch occupancy survey and the Expert Search survey described above. The most informative summary would be visual through mapping of change in cell occupancy status. Changes between any two surveys could be summarized quantitatively via a sign test (Conover 1999). Changes from high to low density occupancy would be interpretable. However, the assessments are limited by the inability, during each survey, to distinguish between unoccupied and occupied but low density cells.

Sample unit choice

The requirement for visiting multiple sample units randomly selected from a grid cell necessitated a choice between hexagonal or square sample units. We chose to use hexagonal sample units to maximize the spatial correspondence between sample unit (hexagon) and observational unit (circle), and thus minimize this component of spatial subsampling in the probability of detection. Given that use of a patch occupancy model simply incorporates this component into the overall probability of detection, we recommend that future surveys use square sample units to simplify the survey design and its description.

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Appendix A. Annotated list of birds observed at the north end of Segula Island, 23 May – 9 June 2006.

Cackling Goose *Branta hutchinsii leucopareia* – Aleutian Cackling geese were observed in small groups (2-10 birds) most days throughout the duration of our stay. Typically they were seen or heard on the ridge above camp, although numerous droppings were present in the auklet colony.

Green-winged Teal *Anas crecca nimia* – Two males were frequently observed in the cove near camp.

Harlequin Duck *Histrionicus histrionicus* – Groups of up to 15 were frequently observed around the mouth of Camp Cove.

White-winged Scoter *Melanitta fusca* – One was observed in Camp Cove on 24 and 26 May.

Rock Ptarmigan *Lagopus muta* – Very abundant on higher parts of the island, with numerous dropping piles in upper areas of the auklet colony.

Fork-tailed Storm-Petrel *Oceanodroma furcata* – Vocalizations were heard nightly in Camp Cove, indicating a few hundred birds in the cove. A few nested in the auklet colony as well but we did not spend time there during the night. No Leach's storm-petrels (*Oceanodroma leucorhoa*) were detected, in contrast to Thomson's (1995b) findings.

Red-faced Cormorant *Phalacrocorax urile* – Two or three individuals were occasionally observed flying in groups of pelagic cormorants near Gula Point, and near the mouth of Camp Cove.

Pelagic Cormorant *Phalacrocorax pelagicus* – Small groups (up to 10 birds) were regularly observed flying near the auklet colony cliffs, where nests were documented in 1979 and 1995 (Thomson 1995b). Because we didn't have a boat, we were unable to see the cliffs to look for nests.

Bald Eagle *Haliaeetus leucocephalus* – Several pairs probably nested on Segula in 2006. At least one nest was located in the auklet colony at the southeast edge of Gula Point – it contained two chicks on 3 June. Up to 5 birds (3 adults, 2 immature) were observed flying simultaneously near Camp Cove in late May.

Peregrine Falcon *Falco peregrinus* – At least three nests were present on the north end of the island (one above camp, one atop a sea cliff in the auklet colony, and another high up in the auklet colony.

Black Oystercatcher *Haematopus bachmani* – Two pairs nested in Camp Cove. A nest with three eggs was observed on 28 May.

Wandering Tattler *Tringa incana* – A single bird was observed in Camp Cove on 28 May.

Rock Sandpiper *Calidris ptilocnemis* – Several birds were routinely observed on the ridge east of Camp Cove. No nests were found, but birds were both displaying and chasing each other.

Glaucous-winged Gull *Larus glaucescens* – Up to 20 were observed in Camp Cove, with only one abandoned nest found. Gulls were also observed in small numbers in the auklet colony, although apparently in much lower numbers than described by Thomson (1995b).

Pigeon Guillemot *Cepphus columba* – A few birds nested in camp cove and were seen / heard daily.

Parakeet Auklet *Aethia psittacula* – Nested in and around Camp Cove and were seen / heard regularly nearshore in all areas we visited.

Least Auklet *Aethia pusilla* – On this short trip we were unable to make it to Chugul Point, where Thomson (1995b) recorded a small number of nesting auklets. We only observed auklets in the Gula Point colony area described in this report.

Crested Auklet *Aethia cristatella* – We estimated that crested auklets represent 20% of the birds nesting in the Gula Point colony but did not conduct quantitative attendance counts.

Horned Puffin *Fratercula corniculata* – Observed daily in Camp Cove throughout our stay. Up to 10 birds were often observed flying to cliffs on the west side of the cove, indicating probable nesting.

Tufted Puffin *Fratercula cirrhata* – Small numbers (<5) were observed offshore on most days.

Common Raven *Corvus corax* – Two were observed in the auklet colony on 26 May and again on 3 June.

Winter Wren *Troglodytes troglodytes* – Observed daily both in and around camp, and in the auklet colony.

Song Sparrow *Melospiza melodia* – Observed daily both in and around camp, and in the auklet colony. One nest was located in camp, with an adult observed carrying food on 8 June.

Lapland Longspur *Calcarius lapponicus* – Observed daily both in and around camp, and in the auklet colony.

Snow Bunting *Plectrophenax nivalis* – Observed daily at higher elevations, both above camp and in the auklet colony.

Gray-crowned Rosy-Finch *Leucosticte tephrocotis* - Observed daily both in and around camp, and in the auklet colony.

Appendix B. Simple Random Sampling Patch Occupancy Models

The standard patch occupancy model assumes that an identical number of sample units are randomly selected from each cell and visited (MacKenzie et al. 2002, 2003). That model is presented below, then extended to account for cells only visited once, then further extended to allow for occupied cells to be partitioned into a low detection and a high detection strata.

The presentation below is cast in terms of multiple independently selected sample units within each cell. Each visited sample unit results in a response of either 0 (absent), 1 (present), or x (missing data) response. In this application, the order of the sample units doesn't matter, thus simplifying the standard model.

Basic model
Assumptions:
1. A cell's occupancy status doesn't change during the period of sampling.
2. Detection probability is constant across all cells (though see below for extensions).
3. Detection of evidence at a cell is independent of detection at any other cell.
4. Detection of evidence in a sample unit is independent of detection at any other sample unit within the cell.
5. Probability of occupancy is constant across the cells.
6. T randomly selected sample units are observed in each cell.

Notation

ψ	Prob(species present at a randomly chosen cell);
$p_.$	Prob(detect evidence in a sample unit | given the cell is occupied);
N	total number of surveyed cells;
T	maximum number of independently randomly selected sample units observed from each cell;
n_i	total number of sample units in cell i in which evidence was detected (n_i = 0, 1, …, T)
$n_.$	total number of cells at which evidence was detected at least once.

For sites where the species was never detected, the probability of detection is a mixture of the probability the species is present but never detected and the probability the species is absent (site unoccupied). For example, if T = 5 and no evidence was detected in five sample units:

$$\psi(1-p)(1-p)(1-p)(1-p)(1-p)+(1-\psi)=\psi(1-p)^T+(1-\psi)\,.$$

Since sites are sampled independently, the full model likelihood is:

$$L(\psi,p\,|\,\{n_{i.}\})=\left[\prod_{\text{sites i with detects}}\psi\binom{T}{n_i}p^{n_i}(1-p)^{T-n_i}\right]\times\left[\prod_{\text{sites } j \text{ with no detects}}\left(\psi(1-p)^T+(1-\psi)\right)\right]$$

$$=\left[\psi^{n_.}\prod_{\text{sites i with detects}}\binom{T}{n_i}p^{n_i}(1-p)^{T-n_{i.}}\right]\times\left(\psi(1-p)^T+(1-\psi)\right)^{N-n_.}\,. \qquad \text{(Eq A1-1)}$$

Note that this model requires T sample units per site.

Basic model + cells with only one sample unit observed

Since multiple sample units were observed on only a subset of cells, the basic model likelihood has to be extended to account for the cells in which only a single sample unit was observed.

$$L(\psi, p \mid \{n_{i.}\}) = \psi^{S_p} p^{S_p} (\psi(1-p)+1-\psi)^{S_A} \times$$
$$\left[\psi^{n_{.}} \prod_{\text{sites i with detects}} \binom{T}{n_{i.}} p^{n_{i.}} (1-p)^{T-n_{i.}}\right] \times \left(\psi(1-p)^T + (1-\psi)\right)^{N-n_{.}}$$

$$= \psi^{S_p} p^{S_p} (1-p\psi)^{S_A} \times \left[\psi^{n_{.}} \prod_{\text{sites i with detects}} \binom{T}{n_{i.}} p^{n_{i.}} (1-p)^{T-n_{i.}}\right] \times \left(\psi(1-p)^T + (1-\psi)\right)^{N-n_{.}}$$

(Eq A1-2)

where, of the S_p + S_A cells from which only a single sample unit was visited, evidence was observed in S_p and no evidence was detected in the other S_A cells.

Basic model extended to two detection strata (unknown cell status)

The basic model can be extended to allow for two (or more) strata in detection rates following Pledger (2000):

$$L(\psi, p_1, p_2, \pi_1 \mid \{n_{i.}\}) = \left[\psi^{n_{.}} \prod_{\text{sites i with detects}} \binom{T}{n_{i.}} \left(\pi_1 p^{n_{i.}}{}_1 (1-p_1)^{T-n_{i.}} + (1-\pi_1) p^{n_{i.}}{}_2 (1-p_2)^{T-n_{i.}}\right)\right]$$
$$\times \left(\psi\left(\pi_1(1-p_1)^T + (1-\pi_1)(1-p_2)^T\right) + (1-\psi)\right)^{N-n_{.}}$$

(Eq A1-3)

While Equation 3 assumes T sample units were visited in each cell, it is easily extended to allow for multiple sample units in only a subset of cells (not shown).