Herner-Thogmartin HH, So KJ, Stephensen SW, Thogmartin WE. 2026. Reduced survey intensity has minimal impact on goose status and trend estimation at a Pacific Northwest refuge. Northwest Science 99(4): *in press*.

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Reduced survey intensity has minimal impact on goose status and trend estimation at a Pacific Northwest refuge

Running footer: Reduced Survey Intensity

0 tables, 4 figures

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Abstract

Monitoring key ecological attributes helps land managers understand the current state of the resource and determine needed actions. We assessed whether reduced sampling intensity of winter goose populations at Nestucca Bay National Wildlife Refuge, Oregon, affected management-relevant inferences about species status and trend. Using sub-sampled survey data (2007–2019), we evaluated whether lower sampling frequencies maintain accurate and precise population estimates and trend detection. We analyzed five metrics: first arrival date, peak abundance date, maximum count, last departure date, and goose use days. Two alternative sampling schedules—fortnightly (every other week) and monthly—were compared to the status quo weekly sampling. Fortnightly, but not monthly, sampling produced estimates only slightly biased (≤4% lower) and similarly precise to weekly sampling. Season start and end were consistent across schedules, but peak day and maximum count varied more with reduced sampling. Detecting a 5% mean annual change in total goose use days with 80% power required 7–8 years of data, regardless of sampling intensity. Aleutian geese showed similar power, while Dusky Canada geese required over a dozen years to detect the same trend. Power increased with the mean:variance ratio, indicating more abundant species were better sampled for trend detection.

In conclusion, reducing sampling from weekly to fortnightly had minimal impact on status and trend inferences, improving efficiency without compromising data quality. Optimizing the sampling schedule for wintering waterfowl balances cost and staff time constraints without sacrificing data quality.

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Key Points:

• Winter goose patterns are hard to track due to survey cost and timing. We examined how reducing survey frequency affects results.

• Counting geese every two weeks gives trends similar to weekly surveys, while monthly counts miss important peaks and timing.

• Biweekly surveys offer accurate and efficient long-term monitoring, though detecting small changes still takes many years.

Keywords: monitoring, sampling intensity, survey design, waterfowl, white-cheeked goose

Introduction

The National Wildlife Refuge system is a national network of lands and waters for the conservation, management, and, where appropriate, restoration of biological resources for the benefit of the American people (National Wildlife Refuge System Administration Act, 16 U.S.C. §668dd). Resources devoted to these activities are limited, however, requiring refuge biologists to prioritize biological resources and subsequent management actions. Because of these limits, this prioritization often entails foregoing activities in some areas to ensure successful management in others. As a result, one management activity routinely omitted is ecological monitoring. The largest portion of an ecological monitoring program budget is usually spent on data collection, leaving other essential elements under-resourced such as sampling design, training, data management, quality assurance, analysis, and reporting (Caughlan and Oakley 2001). Thus, when opportunities arise for reducing monitoring activities with little cost to the resource, sound management dictates their consideration in hopes of increased efficiencies (Field et al. 2005).

Monitoring the status and trends of biologically relevant endpoints of management interest is an essential aspect of the National Wildlife Refuge System's Inventory and Monitoring Program (USFWS 2014). Ostensibly, this monitoring informs an adaptive management approach referred to as Strategic Habitat Conservation (National Technical Assistance Team 2008, Thogmartin et al. 2011), wherein changes to populations attributed to a management action may lead to revision of management goals. National Wildlife Refuges routinely conduct wintering period surveys of waterfowl abundance to inform habitat management programs (Aagaard et al. 2015, Kumar and Rice 2021) with the aim of improving recreational opportunities and species abundance.

A key question in designing a wildlife monitoring scheme pertains to sample size, i.e., how much sampling is enough? If sample sizes are inadequate, resulting estimates of the ecological attributes may be imprecise and therefore provide little insight into the population of interest and possibly delay detection of any changes. However, if sample sizes are too large, the information provided may be high quality but come at the expense of not being able to apply the needed resources elsewhere. Numerous studies have explored trade-offs between sampling frequency, intensity, and the precision of ecological estimates (e.g., Urquhart et al. 1998, Thogmartin et al. 2007, Weiser et al. 2019). These studies emphasize the importance of aligning sampling design with monitoring objectives, available resources, and the temporal and spatial variability of the target species. Such insights are particularly relevant for refuges like Nestucca Bay National Wildlife Refuge, where efficient monitoring is essential for informed management decisions within a constrained operational environment.

Nestucca Bay National Wildlife Refuge was established along the central Oregon, USA, coast in 1991 to protect and enhance habitat for Dusky Canada Geese (*Branta canadensis occidentalis*; hereafter Dusky Geese) and Aleutian Cackling Geese (*B. hutchinsii leucopareia;* hereafter Aleutian Geese) (USFWS 2013). Dusky Geese populations declined significantly in the mid-1980s leading to hunting restrictions and, in 2015, to an end to hunting of Dusky Geese in the Northwest Permit Zone (southwest Washington and northwest Oregon; WDFW and ODFW 2015). In 1982, due to population declines, Aleutian Goose harvest was halted in Oregon coastal areas, including the Pacific City area where the Semidi Islands segment of Aleutian Goose (Hatch and Hatch 1983) historically used refuge lands. For Nestucca Bay National Wildlife Refuge to achieve its objective of optimizing management for overwintering geese (e.g., Goal 9; USFWS 2013), understanding status and trend in species abundance while minimizing costs and staff time is essential. We examined various sampling schemes to determine whether it is possible to reduce the frequency of on-going sampling while maintaining the statistical accuracy of species abundance estimation. Kumar and Rice (2021) pursued a similar interest but examined three methods of spatial subsampling, aiming to reduce the proportion of a refuge needing to be sampled on each survey occurrence. Here, our objectives were to evaluate potential bias, changes to precision, and power to detect trend in management-relevant endpoints (overwinter state, trend, and temporal patterns in goose abundance) from reduced temporal sampling intensity.

Methods

Study area

Nestucca Bay National Wildlife Refuge is, as of 2025, a 1,253 acre (507 ha) refuge situated in Tillamook County, Oregon "where the Nestucca and Little Nestucca rivers converge and debouch into the Pacific Ocean" (USFWS n.d.; Figure 1). Nestucca Bay is a tidal marsh that has been converted in large parts to pasture through the creation of berms and tide gates, limiting the range of water levels caused by the tide (Meyer and Beatty 2006). Habitat types within the refuge include short grass pastures actively managed using cooperative agriculture (~one-third of all habitat), marsh, bog, forested wetlands, upland and coastal meadows, tidal marsh, estuarine shoreline, and tidelands. Non-refuge habitat for geese is largely adjacent pasture held in private ownership. Both the refuge and adjacent private lands provide winter forage for geese.

White-cheeked geese consist of eleven subspecies that are grouped into two *Branta* geese species, Canada Goose (*Branta canadensis*) and Cackling Goose (*Branta hutchinsii*) (Mowbray and others 2016b). Six of these subspecies winter in Nestucca Valley including Cackling Goose (*Branta hutchinsii minima*; hereafter Cackling Goose), Taverner's Cackling Goose (*B. h. taverneri;* hereafter Taverner's Goose), Aleutian Cackling Goose (hereafter Aleutian Goose), Lesser Canada Goose (*Branta canadensis parvipes*; hereafter Lesser Goose), Dusky Canada Goose (hereafter Dusky Goose), and Western Canada Goose (*B. c. moffitti;* hereafter Western Goose). Taverner's Geese are smaller than the Dusky and Western, about the same size as the Lesser, and larger than the Cackling (Taverner's is the largest of the Cackling Goose subspecies).

Survey description

Standardized surveys for geese in the non-breeding season (October-April) were conducted from winter 2007–2008 to winter 2023–2024. Sampling consisted of an intensive area-search of field units during which observers (agency staff and volunteers) recorded all geese detected to subspecies except for Taverner's Geese and Lesser Geese, which, because of morphological similarity, makes separate identification difficult; thus, these two subspecies were combined in all counts. When geese could not be identified to subspecies, they were attributed to an Unidentified Goose category.

Counts were conducted roughly weekly through the overwinter period aside from a couple weeks at the end of December. Counts in winter 2007–2008, the first year of the survey, were initiated late compared to subsequent years, biasing first arrival dates and goose-use-days. Surveys in winter 2019–2020 were disrupted by the pandemic. Thus, these two years were excluded from analysis. Sampling in 2020–2021 did not occur.

Aside from the first year in which surveys were conducted (winter 2007–2008), usually two and never more than three observers conducted counts of geese overwintering in Nestucca Valley. Count duration was quite variable and averaged 15–20 min/field unit but could exceed 1 h for some units depending on the number of geese present or if there were multiple collars read. As with other large-scale waterfowl monitoring programs (Kumar and Rice 2021), there was no consistent way to account for detection probability because of the variety of habitats and species surveyed. More on the study area and sampling methods is described in Herner-Thogmartin et al. (in press).

Analysis

Five metrics were calculated for each sampling schedule, including the status quo weekly sampling schedule. These annual metrics were first arrival date, peak date of abundance, maximum count, last departure date, and goose use days (Herner-Thogmartin et al., in press). Dates were the number of days since 1 October. Goose use days were calculated with the trapezoid method (using the pracma package's *trapz* function; Borchers 2024); the trapezoid method approximates the area under a curve by summing the areas of trapezoids formed between each pair of consecutive counts and in doing so provides a time-integrated measure of seasonal goose abundance. All analyses were conducted in the statistical programming language *R* (version 4.4, R Core Team 2024) and data and example scripts are publicly available (So et al. 2025, Thogmartin et al. 2025).

Sample Design Evaluation—For each metric quantifying goose wintering behavior, we evaluated sampling sufficiency under reduced survey effort by deterministically subsampling the full weekly count series. Weekly data were treated as the reference dataset. We then created two fortnightly subsamples (retaining only odd- or even-numbered survey weeks) and four monthly subsamples (retaining separately observations from the first, second, third, or fourth survey week of each month). For each subsampled dataset, all abundance and phenology metrics were recomputed directly from the observed counts using the same functions applied to the weekly data. No bootstrapping, resampling, or simulated data were used in these comparisons. We assessed the effect of reduced sampling by comparing the mean, variance, coefficient of variation, quantile ranges, and correlations of the reduced-interval metrics to those obtained under weekly sampling.

Power to Detect Trend—We also evaluated the influence of sampling interval on the power to detect a long-term change in goose-use days. Because of annual variation in goose counts, preliminary analysis confirmed it was not feasible to detect a one-year changein goose-use days with any reasonable power (analysis not shown). Thus, we calculated the number of years required to detect a 5% annual change in goose-use days with 80% power and a false-positive rate (α) of 0.10. For each sampling design (weekly, fortnightly odd and even), we used the same empirical weekly survey data applied under the Sample Design Evaluation. Goose-use days were recalculated for each time series under alternative sampling intervals. To isolate annual variability from long-term change, we first detrended each historical time series, removing systematic declines in abundance. A 5% annual decline was then imposed by setting the slope of a linear model to correspond to a 5% decrease per year, while retaining the observed residual variance. Power was estimated using simulation by repeatedly fitting a linear regression of goose-use days on year and evaluating the two-sided test of the slope at $\alpha = 0.10$. Power was defined as the proportion of simulations in which the slope was detected, and adequate power was taken as the point at which the lower bound of the simulation-based 95% confidence interval exceeded 0.80.

Species-specific Analyses—We then repeated these sample sufficiency and power analyses for the most commonly occurring five geese species, focusing on the two geese species of greatest management concern, Aleutian and Dusky Geese. Further, we examined the relationship between power and the mean:variance relationship for the five most common geese surveyed at Nestucca Bay National Wildlife Refuge to assess the extent to which more precise measures of goose-use days might improve inferential ability of the surveys.

Results

Sampling intensity

Differences among sampling schemes were relatively few (Table S1, Figure S1, S2). Mean all-goose goose use days estimates were, aside from one fortnightly sampling interval, significantly lower for alternative sampling schemes compared to the estimate based on status quo weekly sampling (by more than 100,000 goose use days or 13.7% in one instance), but the precision of the estimates as depicted by coefficient of variation and confidence interval width indicated the alternative sampling schemes were generally similarly precise to the status quo weekly sampling scheme (Figure 2, Table S1).

Weekly sampling typically began in early October and ended in late April. Reduced sampling intensity often led to a delay in identifying the first arrival date, at least when sampling was reduced to once per month (Table S1). This delay was as great as 11 days. There was little effect of sampling intensity on determining the last departure date.

The greatest discrepancies occurred with the annual maximum count and the peak date of abundance. Annual maximum counts were 11.5 to 36.1% lower, depending on the alternative (Table S1); the imprecision in the estimates as described by the coefficient of variation were generally higher (except for one fortnightly sampling alternative). Similarly, identification of the peak date of abundance was, at times, delayed nearly 50 days but with some alternatives identified as occurring significantly earlier than the status quo.

Sampling every other week as opposed to once monthly was generally more similar to the status quo weekly sampling, providing similar goose use days (albeit 1.6–3.9% lower) with similar precision and similar arrival, peak, and departure dates in at least half of the fortnightly sampling alternatives. Sampling once per month was comparatively unreliable in returning metrics of similar value to the status quo.

Power to detect trend

Given the comparatively incongruous results from monthly sampling, we compared the power to detect a trend in goose-use days for the status quo weekly and alternative fortnightly sampling intervals. Power to detect a trend in goose-use days differed little between status quo weekly and every other week (fortnightly) sampling intervals. Power to detect changes of 5% with 80% power generally required seven or eight years irrespective of sampling intensity (Figure 3).

Similar power was observed for Aleutian Geese, with eight years required to detect a 5% trend for monthly sampling and 7–9 years required for fortnightly sampling (Figure 4). We estimated less power to detect a trend for Dusky Geese; using a conservative criterion (lower 95% CI ≥ 80% power), the Weekly schedule reached adequacy at 14 years, the Even schedule at 13 years, and the Odd schedule at 16 years. When the trend to be detected was 10%, the power to detect reached 80% at approximately eight years (not shown).

Aleutian and Dusky Geese were the most evenly abundant species at the refuge, leading to high mean:variance goose-use days ratios, with ratios of ~2.5:1. Cackling and Taverner's / Lesser Geese (as a combined species group) were closer to 2:1 and Western Geese were ~1:1. Power among these species linearly scaled with this mean:variance relationship ($\beta = 0.21$, p = 0.006, adj. $R^2 = 0.92$), tripling between Western and Cacking Geese, for instance, indicating that the regularly occurring abundant geese species were better sampled for detecting trend in annual goose use.

Discussion

We assessed whether a reduction in sampling intensity at Nestucca Bay National Wildlife Refuge, from every week in winter to fortnightly or monthly, would materially change the inferences managers draw about goose status and trend. We found estimates of total goose use days were only slightly biased low (no more than 4%) and were similarly precise under fortnightly sampling. In contrast, monthly sampling proved unreliable for characterizing peak abundance and maximum counts, metrics that are sensitive to short, sharp pulses in use, and introduced delays in detecting first arrival. Similar results occurred for each species as well.

Beyond point estimates, managers often need to understand how quickly real changes become detectable. Here, the power analyses demonstrated that high interannual variability in goose abundance, not the intra-season interval between surveys, dominated the effort required to detect modest trends. Detecting a 5% annual change in total goose use days with 80% power typically required 7–8 years of data, irrespective of weekly versus fortnightly sampling. Species differences mirrored their mean:variance relationships with more abundant and regularly occurring geese achieving adequate power sooner, while less common or more variable species (e.g., Dusky Geese) generally requiring a decade or more to detect changes of similar magnitude. Alternatively, aiming to diagnose trends of 10% or more or accepting a higher rate of falsely detecting a trend when one does not occur are both likely to lead to more readily observable differences in goose-use days over time. Regardless, reducing the sampling intensity from weekly to every other week had little discernible effect on the power to detect a trend.

Thus, it appears Nestucca Bay National Wildlife Refuge could reduce the intensity of its monitoring activity from weekly to every other week while maintaining adequate inferences for management decisions. If arrival and departure timing are important refuge considerations, weekly sampling for the first and last months of the season could eliminate bias (Table S1) but still achieve cost and staff time savings from a seasonal reduction in sampling intensity during the intervening months.

Although our evaluation focused on optimizing sampling intensity for refuge-specific management objectives, wintering goose dynamics are shaped by processes operating at larger spatial and ecological scales, including migratory connectivity, regional population trajectories, weather-driven distributional shifts, and landscape-level habitat availability across the Pacific flyway (Golas et al. 2025). Consequently, site-level patterns at Nestucca Bay reflect both local management and broader regional forces. The reliability of fortnightly sampling should therefore be interpreted as the quality of local inference given typical year-to-year variability imposed in large measure by flyway-scale drivers. Thus, continued cooperation with regional and flyway-scale monitoring and management efforts (Pacific Flyway Council 2006, 2015) remains essential for situating refuge-level monitoring within a larger management context. These findings translate into clear, practical guidance. First, adopting a fortnightly schedule is compatible with robust inference on seasonal use and overall trend for the wintering goose assemblage. Second, if precise phenology (arrival and departure timing) is a priority, weekly visits during the shoulder months (early October and late April) could eliminate timing bias while preserving efficiency in mid-season. Third, resources freed by reduced survey intensity could be invested in other critical elements; for monitoring, for instance, heightened effort in training. quality assurance/quality control, and reporting could be improved. Reduced sampling intensity affords the Refuge the opportunity to redirect effort to other priorities with minimal consequences to inferences on status and trend. Because many Refuges operate with limited staff capacity, applying this type of retrospective subsampling analysis to their own long-term datasets could similarly reveal where survey effort could be reduced while maintaining biologically meaningful estimates.

An important caution is advised. If the Refuge should want to partition status and trend according to strata, such as ownership (e.g., public versus private) or habitat categories, sampling intensity may need to be reevaluated considering these new criteria. Partitioning geese by strata is likely to reduce mean abundance and, possibly, elevate the variance in counts as geese move within the season among strata, leading to a reduced power to detect trends. Such stratification also intersects with broader landscape-level realities, as public lands often shoulder a disproportionate share of providing reliable forage during energetically demanding spring migration, when access or management on adjacent private lands may be more variable.

Regardless of sampling intensity, more than a half dozen years are required to detect modest trends in these wintering geese populations. Given disruptions to sampling incurred by the recent Covid-19 pandemic, it is natural to ask what the consequences to trend detection would be if sampling was skipped in some years. Weiser et al. (2019), studying sampling intensity for monarch butterflies (*Danaus plexippus*), found that sampling breadth (years) had a stronger effect on statistical power than sampling intensity (number of visits within years) in large part because of high inter-annual variability in species abundance. Because goose abundance exhibits substantial interannual variability, reducing survey frequency from annual to biennial intervals would likely delay detection of moderate population trends while still permitting the identification of more pronounced changes in abundance (Herbert and Weseloh 2003). However, whether such reduced sampling intensity would allow for robust attribution of observed population changes to specific causal factors remains uncertain (Carpenter et al. 1989).

In summary, reducing winter survey frequency from weekly to every other week provides a pragmatic path to greater efficiency without compromising the core inferences required for management at Nestucca Bay National Wildlife Refuge. The approach retains accurate and precise estimates of seasonal use, preserves power to detect modest trends at the time scales dictated by interannual variability, and can be tailored to protect phenological resolution where needed. Looking ahead, the most promising refinements could involve (i) testing stratified designs where management questions demand them, (ii) exploring dynamic scheduling (e.g., temporary increases around anticipated peaks), and (iii) strengthening data systems to ensure that field efficiencies translate into durable, high-quality information for decision making across the refuge and the broader Pacific Flyway.

National Wildlife Refuges are faced with many competing demands and limited resources. As such, using available resources as efficiently as possible is imperative for successfully attending to the National Wildlife Refuge System's mission. Reducing effort in one area allows for increased effort in another, a matter of conservation triage (Bottrill et al. 2008). Embedding this resource allocation decision in the context of the myriad other choices faced by refuge management is the next step for optimal allocation of wildlife management resources.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. Any use of trade, product, website, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

Data Availability Statement

The datasets used in this study can be found on the U.S. Fish and Wildlife Service's Service Catalog (ServCat): https://iris.fws.gov/APPS/ServCat/...

Author Contribution

JH-T: Conceptualization, Funding acquisition, Writing—Original Draft, Writing—Review & Editing, Visualization

KS: Data acquisition, Data Curation, Review of draft

SS: Data collection, Review of draft

WT: Methodology, Formal analysis, Software, Writing—Original Draft, Writing—Review & Editing, Visualization

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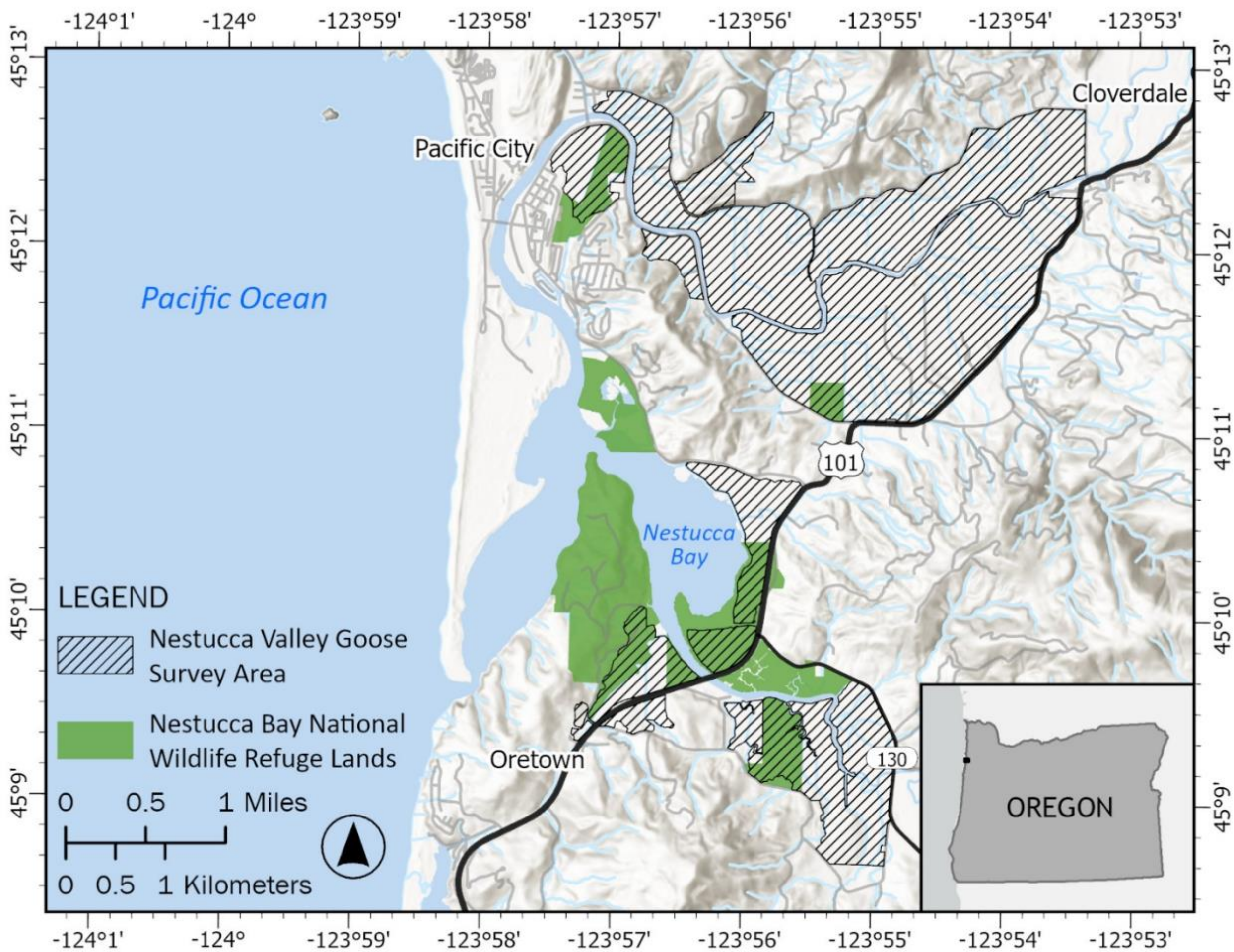
Figure Captions

Figure 1. White-cheeked geese overwinter on the U.S. Fish and Wildlife Service Nestucca Bay National Wildlife Refuge (in green) and on adjacent private land along the coast of north-central Oregon, USA

Figure 2. Mean and coefficient of variation of goose use days (with 95% confidence intervals) by sampling interval simulated from historical goose surveys at Nestucca Bay National Wildlife Refuge, Oregon, USA. Weekly sampling is the status quo (as denoted by dashed line); the remaining sampling intervals are reduced sampling intensity alternatives.

Figure 3. Power to detect a trend in all-goose goose-use days from overwinter sampling conducted at Nestucca Bay National Wildlife Refuge, Oregon, USA, at weekly or fortnightly (every two weeks) intervals. The values in parentheses are the proportional magnitude of change (5% or 10%) in goose-use days to be detected.

Figure 4. Species-specific power to detect a change in goose-use days of 5% for the weekly and fortnightly sampling intervals for Aleutian and Dusky geese at Nestucca Bay National Wildlife Refuge, Oregon, USA.



Base modified from U.S. Geological Survey, U.S. Fish and Wildlife Service, and other Federal and State digital data, various scales
Shaded relief from Esri and its licensors, copyright 2026
Universal Transverse Mercator, zone 10 north
472 North American Datum of 1983

473 Figure 1. White-cheeked geese overwinter on the U.S. Fish and Wildlife Service Nestucca Bay

474 National Wildlife Refuge (in green) and on adjacent private land along the coast of north-central

475 Oregon, USA

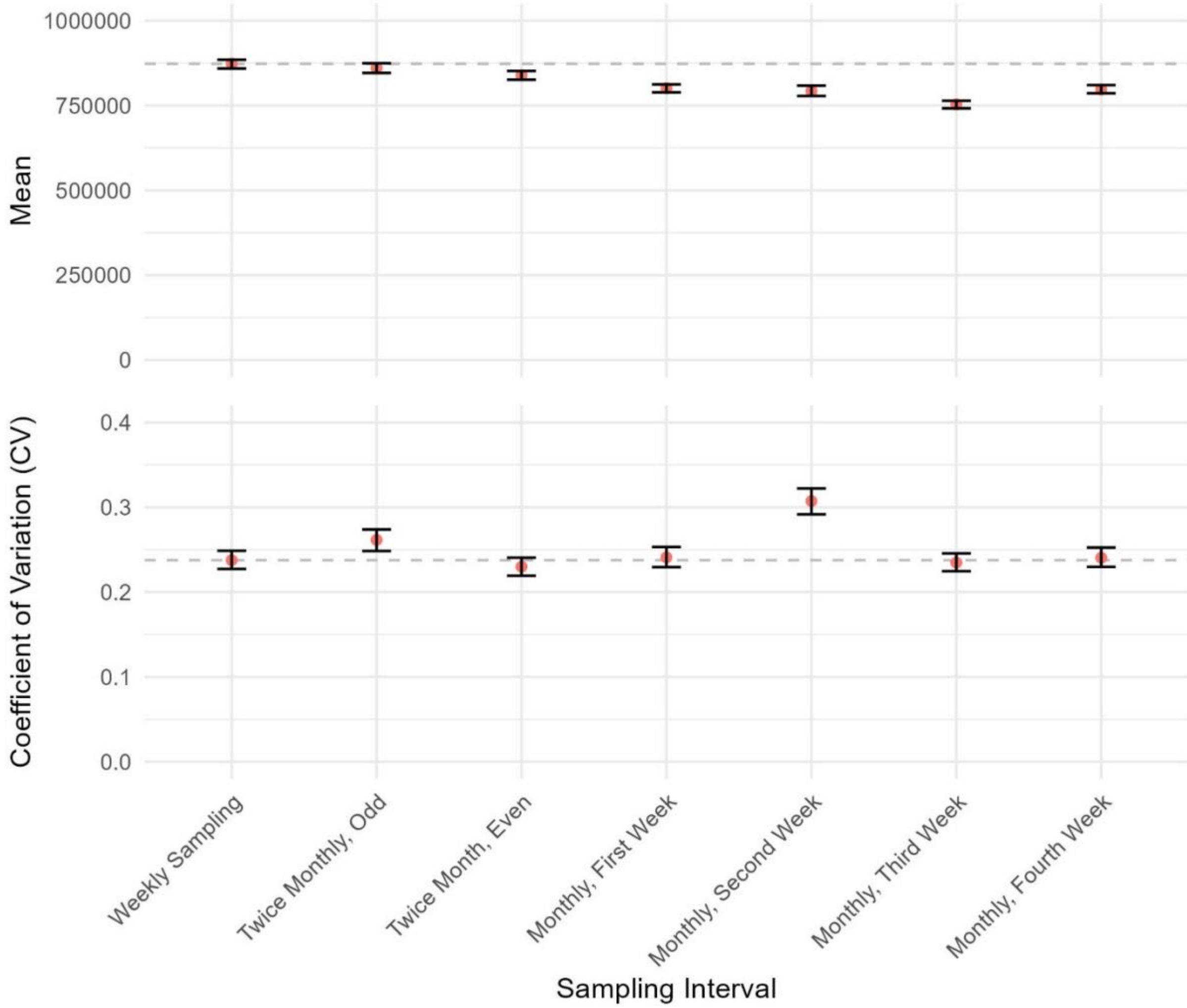


Figure 2. Mean and coefficient of variation of goose use days (with 95% confidence intervals) by sampling interval simulated from historical goose surveys at Nestucca Bay National Wildlife Refuge, Oregon, USA. Weekly sampling is the status quo (as denoted by dashed line); the remaining sampling intervals are reduced sampling intensity alternatives.

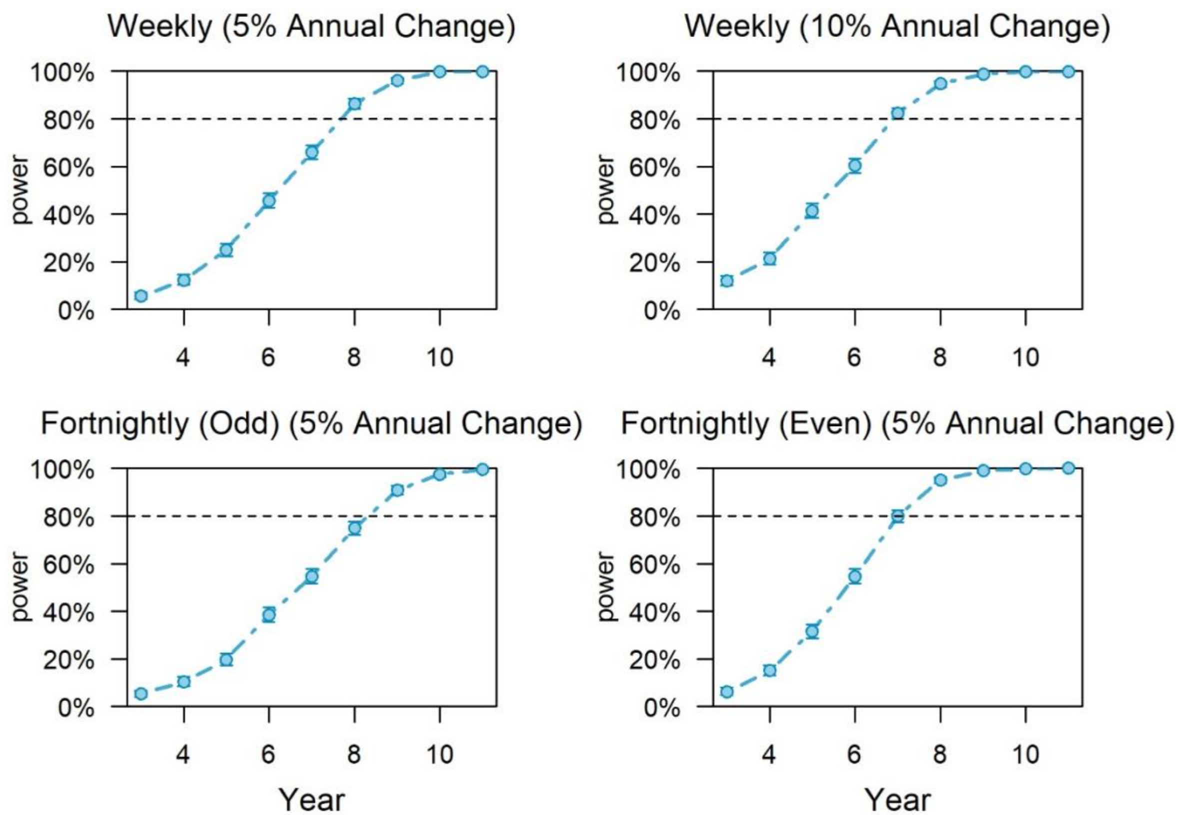


Figure 3. Power to detect a trend in all-goose goose-use days from overwinter sampling conducted at Nestucca Bay National Wildlife Refuge, Oregon, USA, at weekly or fortnightly (every two weeks) intervals. The values in parentheses are the proportional magnitude of change (5% or 10%) in goose-use days to be detected.

Herner-Thogmartin HH, So KJ, Stephensen SW, Thogmartin WE. 2026. Reduced survey intensity has minimal impact on goose status and trend estimation at a Pacific Northwest refuge. Northwest Science 99(4): *in press*.

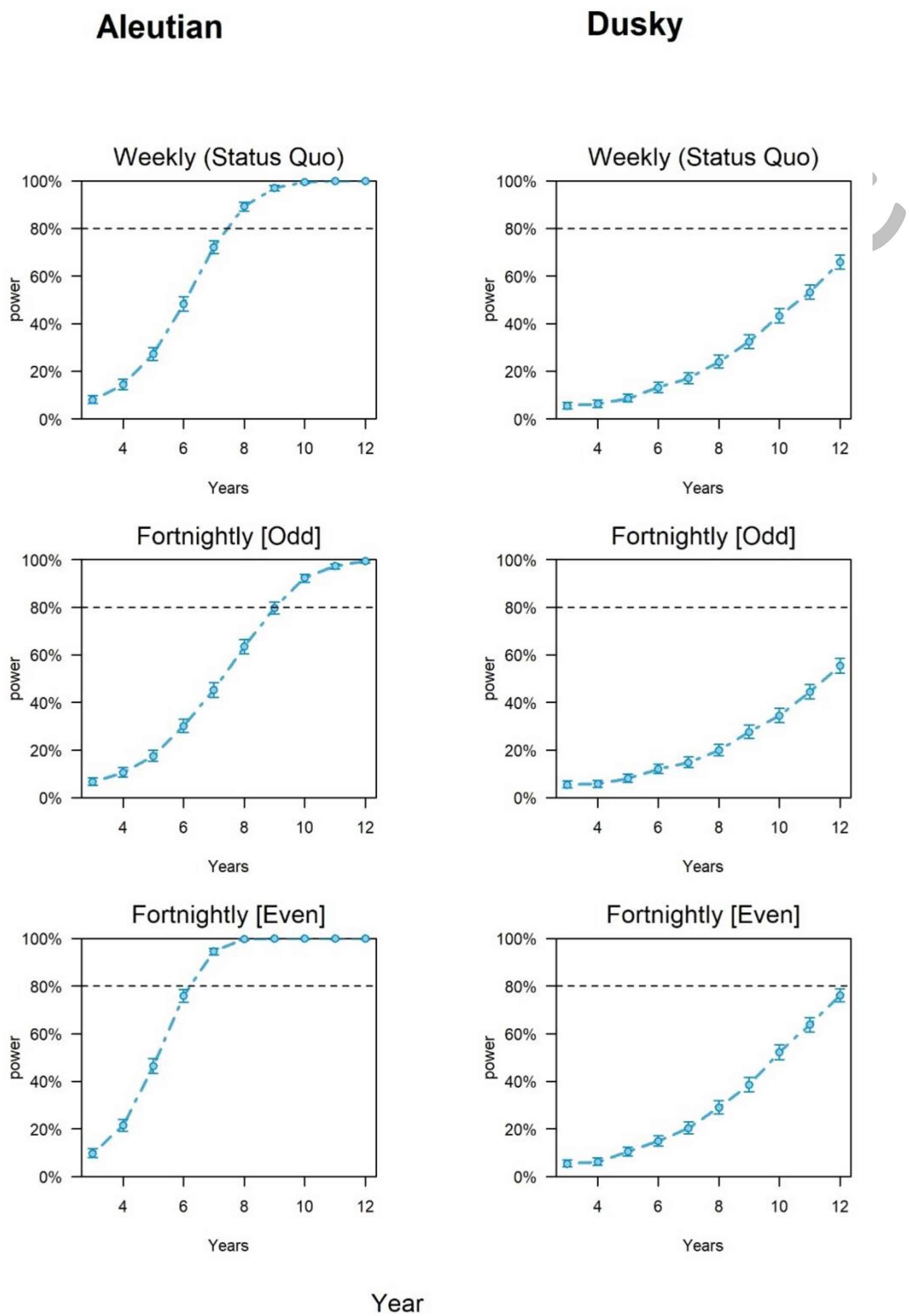


Figure 4. Species-specific power to detect a change in goose-use days of 5% for the weekly and fortnightly sampling intervals for Aleutian and Dusky Geese at Nestucca Bay National Wildlife Refuge, Oregon, USA.

Supplemental Table 1. Summary statistics for five metrics describing wintering geese abundance and phenology in Nestucca Valley, Oregon, 2007-2019, under varying scenarios of sampling intensity. Dates are measured in days since 1 October. SD = standard deviation; CV = coefficient of variation; Interval width is the span between the upper (97.5%) and lower (2.5% CL) confidence limits.

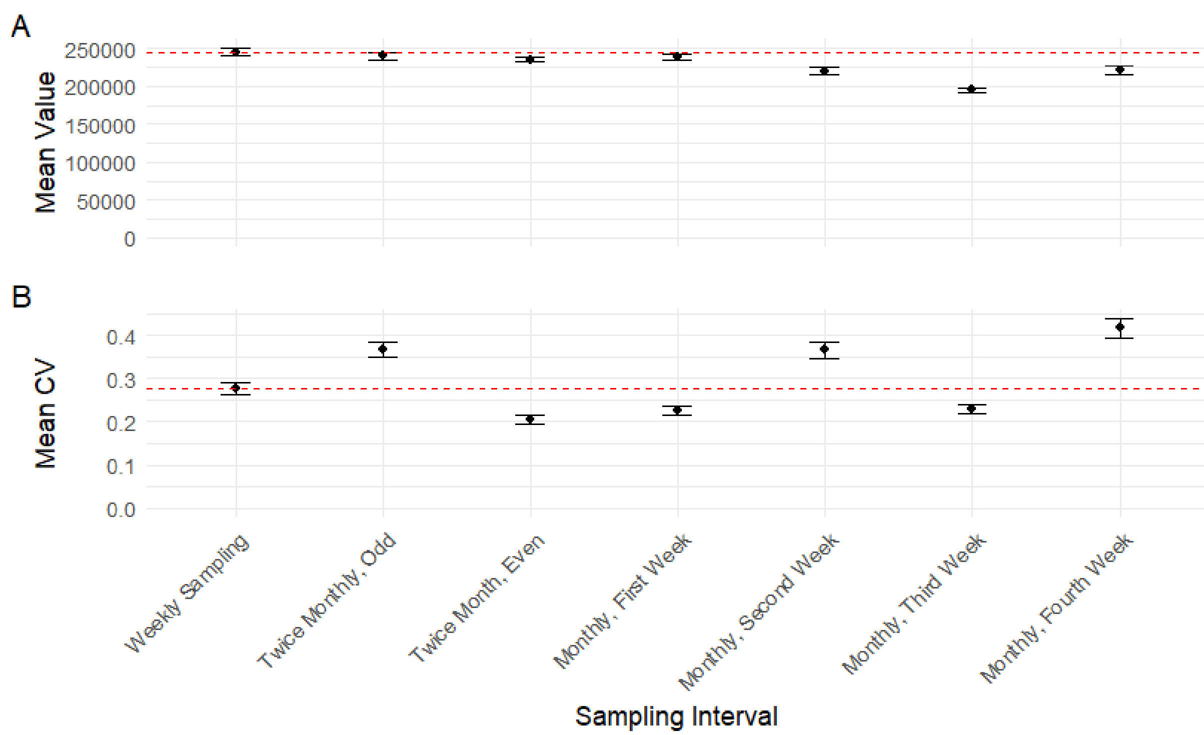
Metric	Sampling Interval	Mean	SD	CV	2.5% CL	97.5% CL	Interval Width
Goose Use Days	Weekly Sampling	873,256	207,277	0.237	585,260	1,245,326	660,067
	Twice Monthly, Odd	859,980	224,927	0.262	566,706	1,268,306	701,600
	Twice Month, Even	839,128	192,912	0.230	529,984	1,165,244	635,260
	Monthly, First Week	800,709	192,957	0.241	480,997	1,093,810	612,813
	Monthly, Second Week	793,602	244,049	0.308	489,970	1,240,578	750,609
	Monthly, Third Week	753,673	177,098	0.235	452,899	1,054,060	601,161
	Monthly, Fourth Week	797,137	191,747	0.241	533,023	1,155,194	622,171

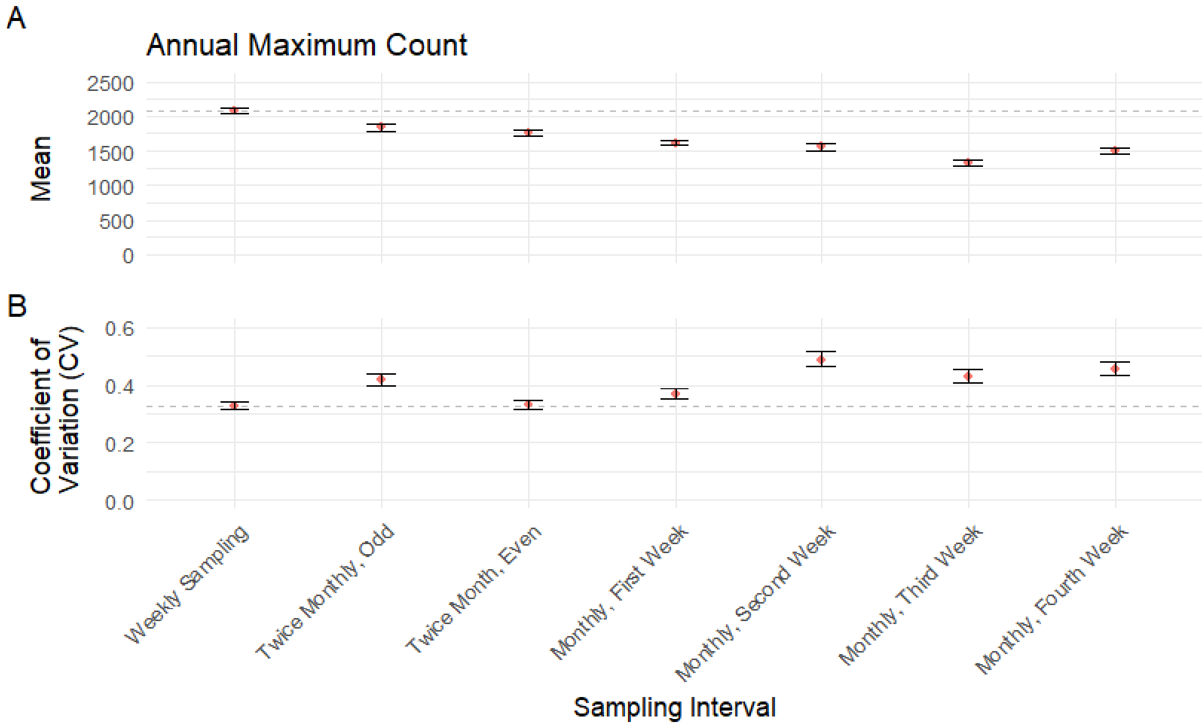
Annual Maximum Count	Weekly Sampling	2077	681	0.328	1073	2924	1851
	Twice Monthly, Odd	1836	769	0.419	813	2924	2111
	Twice Month, Even	1763	586	0.332	923	2809	1886
	Monthly, First Week	1618	593	0.366	742	2696	1954
	Monthly, Second Week	1562	765	0.489	740	2924	2184
	Monthly, Third Week	1328	574	0.432	832	2547	1715
	Monthly, Fourth Week	1504	683	0.454	709	2646	1937
Arrival Date	Weekly Sampling	24.9	20.1	0.808	4	77.5	73.5
	Twice Monthly, Odd	24.1	10.8	0.447	13	52	39
	Twice Month, Even	19.3	8.85	0.458	4	32	28

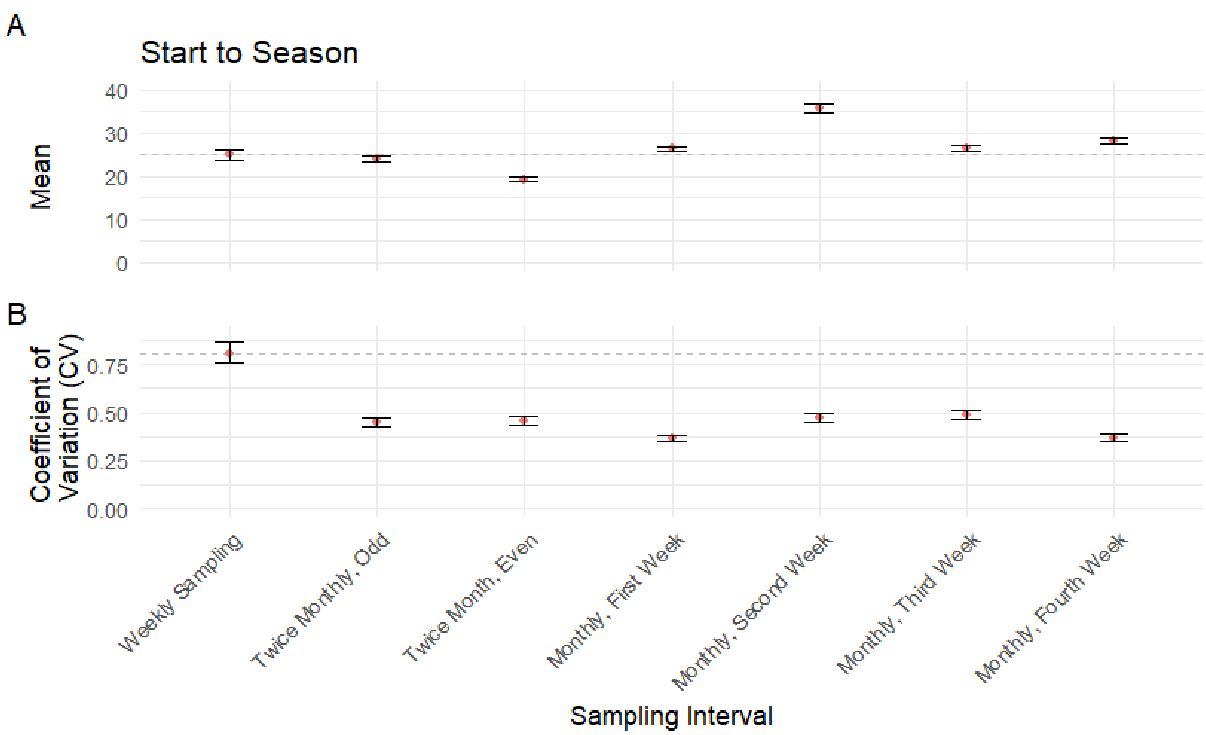
	Monthly, First Week	26.3	9.57	0.363	4	34	30
	Monthly, Second Week	35.8	17	0.475	13	67	54
	Monthly, Third Week	26.4	12.9	0.488	14	46	32
	Monthly, Fourth Week	28.1	10.3	0.365	21	52	31
Peak Date	Weekly Sampling	98.6	49.8	0.505	23.4	191	167
	Twice Monthly, Odd	102	62.5	0.612	22	193	171
	Twice Month, Even	135	44.9	0.333	32	200	168
	Monthly, First Week	147	43.5	0.296	32	200	168
	Monthly, Second Week	96.7	53.7	0.556	37	183	146
	Monthly, Third Week	92.5	47.6	0.514	43	160	117
	Monthly, Fourth Week	120	64.4	0.538	22	193	171

Departure Date	Weekly Sampling	190	11.9	0.062	178	204	26
	Twice Monthly, Odd	198	9.78	0.050	179	207	27.6
	Twice Month, Even	198	8.37	0.042	179	203	24.6
	Monthly, First Week	198	8.37	0.042	179	203	24.6
	Monthly, Second Week	193	13.4	0.069	177	207	30.4
	Monthly, Third Week	184	8.16	0.044	166	189	23.9
	Monthly, Fourth Week	189	10.8	0.057	166	197	31.2

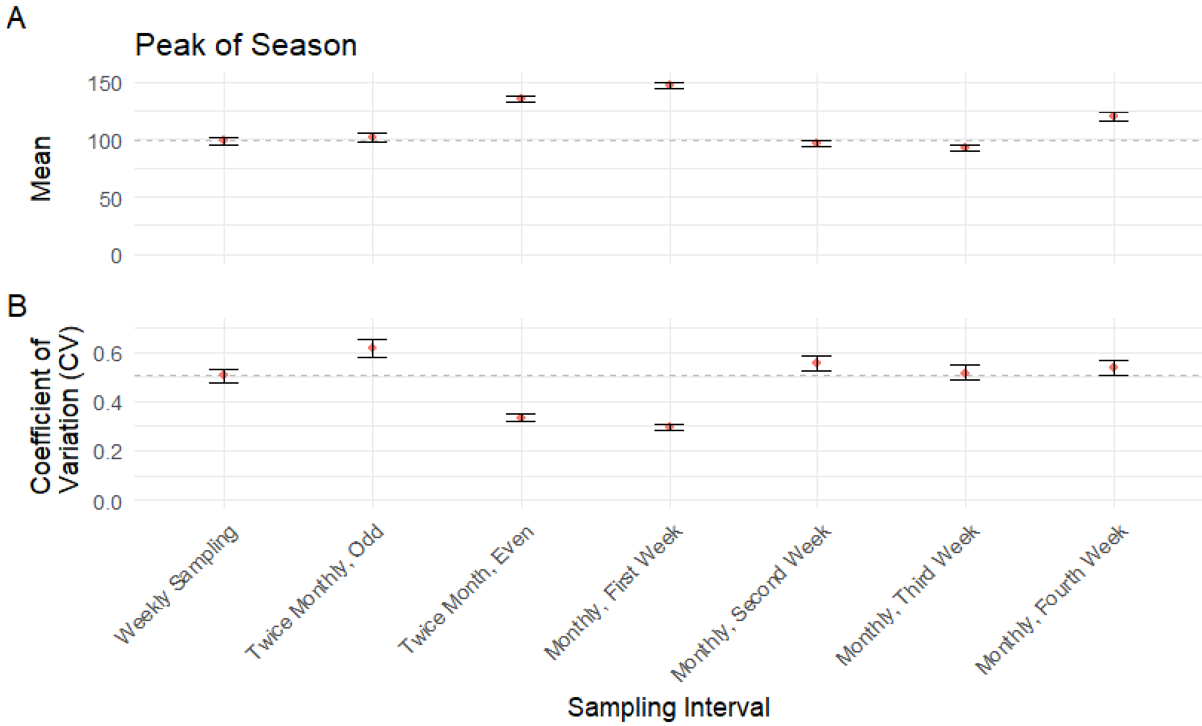
Figure S1. Mean (A) and coefficient of variation (B) of goose abundance and phenological behavior by sampling interval simulated from historical goose surveys at Nestucca Bay National Wildlife Refuge, Oregon, USA. Weekly sampling is the status quo (as denoted by dashed line); the remaining sampling intervals are reduced sampling intensity alternatives. Error bars represent 95% Confidence Intervals for both the means and coefficients of variation.







Note: This article has been peer reviewed and accepted for publication in *Northwest Science*. Copy-editing may lead to differences between this version and the final published version.



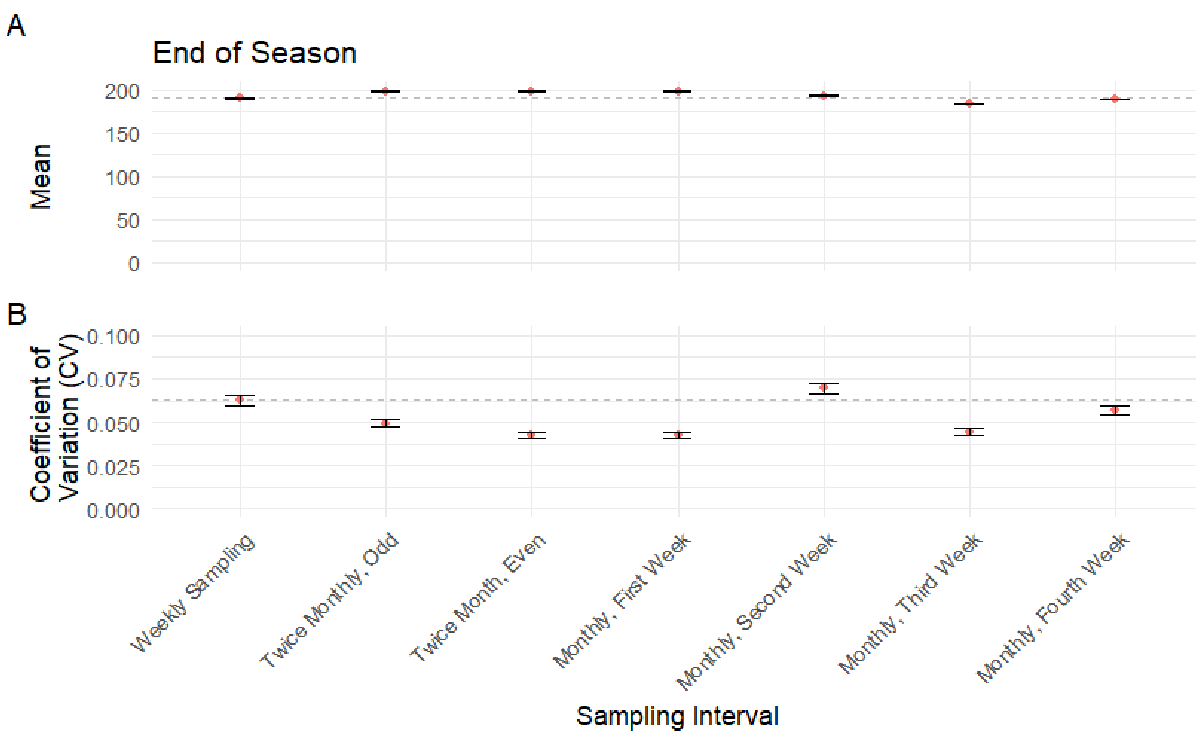


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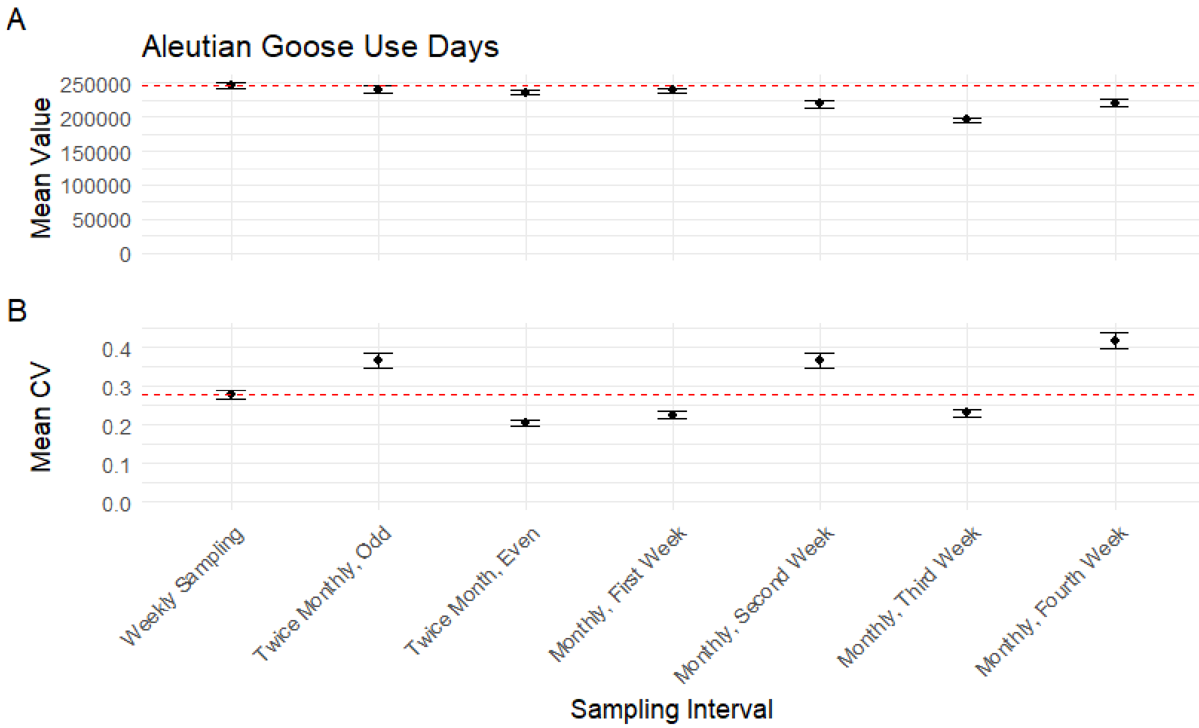
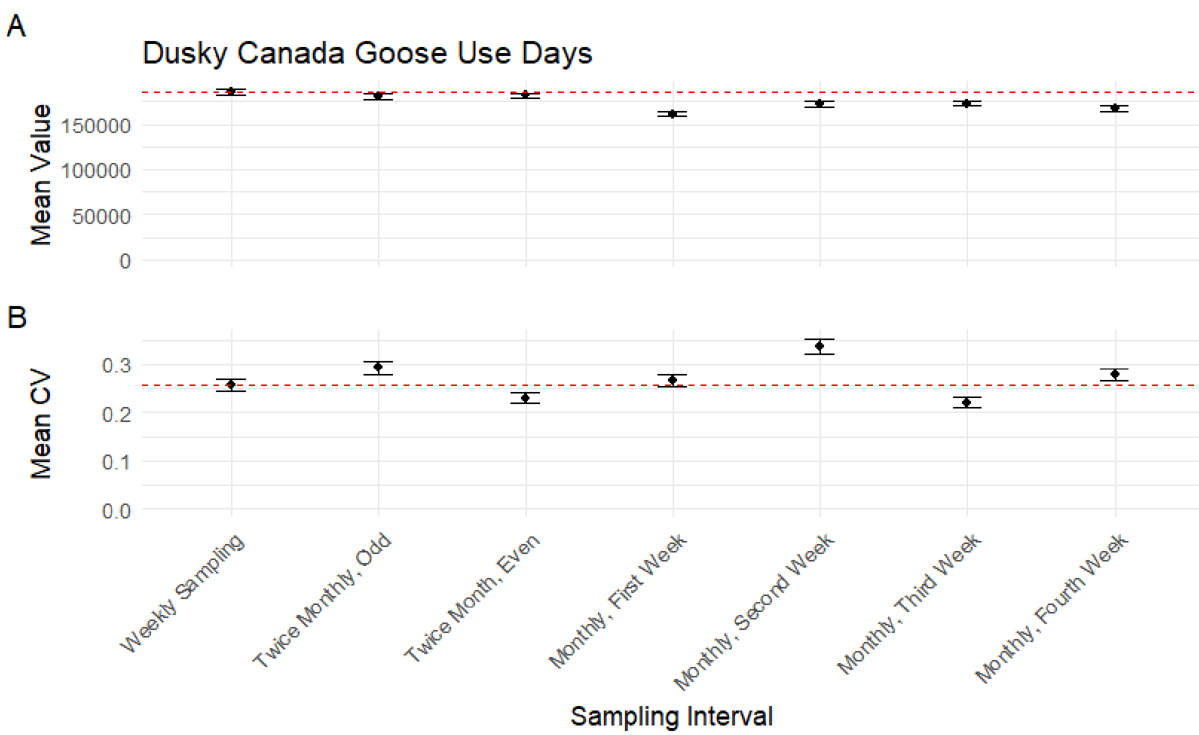
Figure S2. Mean (A) and coefficient of variation (B) of Aleutian and Dusky goose abundance and phenological behavior by sampling interval simulated from historical goose surveys at Nestucca Bay National Wildlife Refuge, Oregon, USA. Weekly sampling is the status quo (as denoted by dashed line); the remaining sampling intervals are reduced sampling intensity alternatives.





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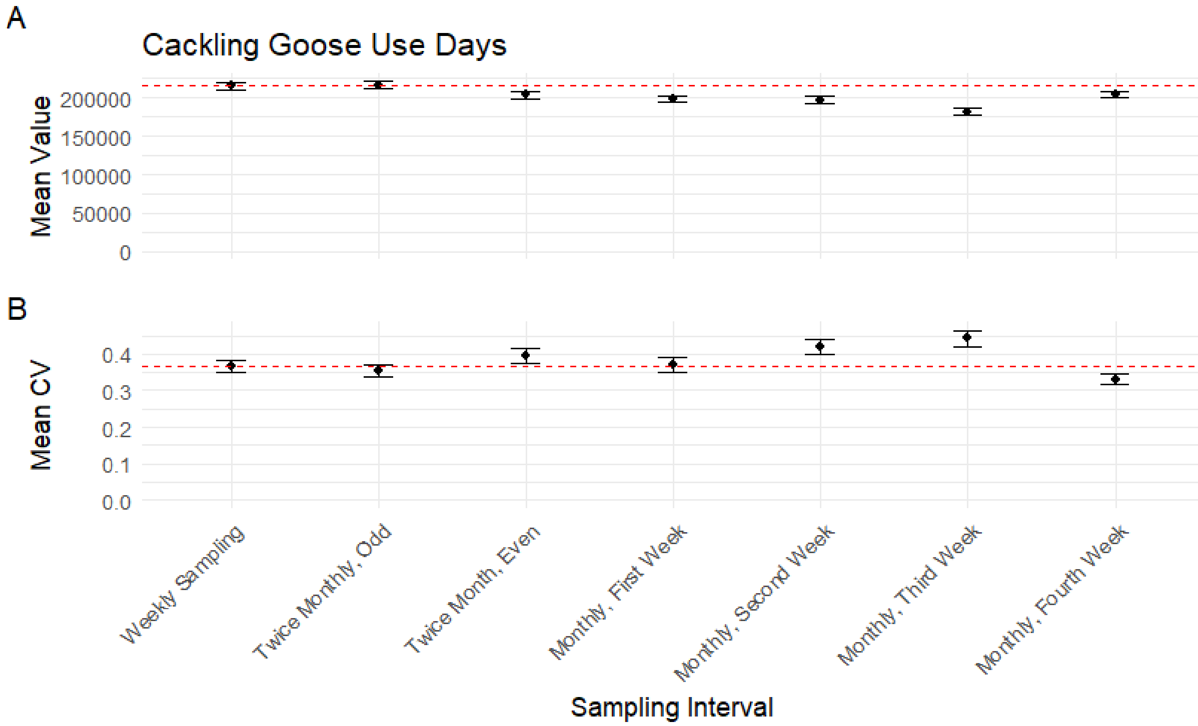
A
Cackling Goose Use Days
Mean Value
200000
150000
100000
50000
0
B
Mean CV
0.4
0.3
0.2
0.1
0.0
Weekly Sampling
Twice Monthly, Odd
Twice Month, Even
Monthly, First Week
Monthly, Second Week
Monthly, Third Week
Monthly, Fourth Week
Sampling Interval