Methods for determining concealment of arboreal bird nests

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Abstract Visual estimates of vegetation concealing bird nests have typically been used to assess the importance of nest concealment to predators. We developed a new method that more accurately quantifies nest concealment. During the breeding season of 2001, we took digital pictures of 63 nests from 3 vantage points (1 m above the nest, 1 m at the level of the nest, and 1 m below the nest); we imported the pictures into Adobe Photoshop™ (Adobe Systems Incorporated, San José, Calif.) and determined percent of nest concealment by dividing the number of vegetation pixels by the number of total nest pixels. We compared this method with visual estimates for each nest by the 4 authors and another method counting squares on a transparent grid over photographs. Of 45 paired *t*-tests, 29% resulted in significant differences between individual observer estimates and between individual observer estimates and the 2 other methods. In contrast, there were no differences between trials using the Adobe Photoshop method. We also found inconsistencies among individual observer estimates and methods in evaluation of nest concealment between depredated and nondepredated nests. We suggest that the Adobe Photoshop method improves repeatability over visual estimates, thus providing a more accurate assessment of the importance of nest concealment and a more accurate basis on which to evaluate management decisions.

Key words Adobe Photoshop™, birds, Colorado, digital photographs, methods, nest concealment, nests, predators

For most bird species that build open-cup nests, predation is the leading source of nest failure (Martin 1988, 1993; Martin and Li 1992). Therefore, predation exerts a major evolutionary influence on nest-site selection and nest structure (Collias and Collias 1984, Martin and Roper 1988, Knopf and Sedgwick 1992, Kelly 1993). Most birds have several putative adaptations to predation, including nest defense (Joern and Jackson 1983, Lowther et al. 1987) and nest concealment (Collias and Collias 1984, Crabtree et al. 1989, Martin 1992). Birds may also reduce risks of predation through nest inaccessibility and complexity of nest construction (Ambedkar 1978, Collias and Collias 1984), which is particularly evident in the tropics, where predation pressures may be relatively intense (Ricklefs 1969, Skutch 1985).

Nest predation may also be affected by other ecological variables and anthropogenic changes to the bird species' habitat. In general, predation risks appear higher in fragmented forests and in edge habitat (reviewed in Paton 1994). With the rapid and significant decline of >100 species of Neotropical migrants (Rappole and McDonald 1994) has come a race to understand predation patterns and the variables that may be used to predict predation.

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This was evidenced from the plethora of experiments performed over the last 2 decades. For example, experimental studies have used Japanese quail (*Coturnix coturnix*) or domestic chicken eggs to compare patterns of predation with respect to habitat fragmentation (Andrén and Angelstam 1988, Yahner and Scott 1988, Yahner et al. 1989, Gibbs 1991, Laurance et al. 1993, Picman and Schriml 1994), habitat type (Seitz and Zegers 1993), size of forest patches (Wilcove 1985, Tellería and Santos 1992), predator density (Reitsma 1992), introduced predators (Henry 1969), and placement of nests (Martin 1987, Seitz and Zegers 1993).

While studies conflict in their results for many of these ecological and nest-site variables that may or may not affect predation, results from nest-concealment studies have been particularly enigmatic. Some studies have used visibility indices at a given distance from the nest in 4 cardinal directions (Filliater et al. 1994, Moskát and Honza 2000). Other investigators have estimated vegetation density with rod contact at given distances from the nest (Colwell 1992, Munson 1992, Norment 1993, Guyn and Clark 1997, Delany and Linda 1998). Yet other studies have attempted to determine percent of vegetation covering the nest (Martin and Roper 1988, Holway 1991, Kelly 1993, Kilgo et al. 1996, Wiebe and Martin 1998) or percent of cover along a sampling stick (Dion et al. 2000). Some of these investigators have used Nudds' (1997) method of a white cover board with a large grid (Guyn and Clark 1997, Hoover and Brittingham 1998, Purvis et al. 1999) or a mirror with a grid (Morin 1992) to aid in their nest-concealment estimations. Unlike methods of quantifying some of the other variables that may affect predation patterns, methods of quantifying percent of nest concealment have been particularly inconsistent, and most methods have been based on unreliable subjective estimates. Indeed, while some studies have revealed that well-concealed nests are more successful than less-concealed ones (Nice 1937, Nolan 1978, Crabtree et al. 1989, Martin 1992), other studies have failed to find an association between nest success and nest concealment (Holway 1991, Burhans and Thompson 1998, Ortega and Ortega 2001).

In this paper we 1) compare 3 methods of determining nest concealment and 2) present a novel approach to the problem of quantifying nest concealment. The first method was a visual estimate of percent concealment over nests, by far the most common method reported in the literature. The 2 other methods used photographs taken 1 m from the nest at 3 angles. For 1 of these methods, we used a transparent grid over photocopies of the photographs to count squares (Ortega and Ortega 2001), and for the other, we used Adobe Photoshop™ (Adobe Systems Incorporated, San José, Calif.) to count pixels. We also applied these different methods to test the null hypothesis that there was no difference in nest concealment between depredated and nondepredated nests.

Study area and methods

From mid-May through July 2001, we searched for nests at Colorado State University's San Juan Basin Research Center, 8 km south of Hesperus, La Plata County, Colorado (37°14′N, 108°2′W). The Research Center, located along the La Plata River, consisted of pastures grazed by cattle at various intensities. The riparian pastures were dominated by narrow-leaf cottonwoods (*Populus angustifolia*) and to a lesser degree by riverbirch (*Betula fontinalis*). The riparian zone varied from approximately 5–200 m on either side of the river; shrubs and other heavy understory vegetation were scarce. The upland pastures were dominated by Gambel oak (*Quercus gambelii*) and grasses.

We visited nests every 1–3 days and recorded the contents of each nest until all birds fledged or until the nest failed through predation or abandonment. We considered predation of nestlings to have occurred if all nestlings disappeared from the nest before they were old enough to fledge.

We quantified nest concealment using 2 methods. As soon as possible after finding each active nest, we took digital photographs with a Nikon CoolPix880™ (Nikon Corporation, Tokyo, Japan) digital camera 1 m from the nest at 3 vantage points: directly below the nest, directly above the nest, and at the level of the nest (on a horizontal plane) toward the center of the nest plant with the nest between the camera and the center of the plant. For 1 method we imported the photographs into Microsoft Word, adjusted the brightness and contrast as needed, and printed the photographs in black and white. We drew circles around nests with a highlighter pen and highlighted all vegetation covering the nests. We placed a transparent grid with 6-mm squares over the highlighted photocopy and counted the total number of squares the nest covered and the number of squares with vegetation covering the nest. We included all squares with

≥50% coverage and defined nest concealment as percent coverage (number of squares with vegetation over the nest divided by the total number of squares occupied by the nest).

For the second method, we imported the pictures into Adobe Photoshop. We determined the number of pixels the nest covered by selecting the area of the nest and choosing "histogram" under the "image" menu. We then deselected the areas of visible nest (leaving only the area of vegetation covering the nest) and determined the number of pixels of vegetative cover. To arrive at percent concealment, we divided the number of vegetation pixels by the number of total nest pixels. We repeated this method approximately 2 months later for all nests to determine consistency.

We also estimated the percent of vegetation covering a nest by visually examining each picture on the screen in Adobe Photoshop. This was done independently by all four authors without discussion among ourselves.

We could not take photographs from all 3 vantage points for all nests. All photographs from above the nest and most photographs at nest level required using a ladder. Some nests were too high to take photographs from either above or level with the nest; for these nests we were able to take photographs from 1 m below by standing on a ladder. Furthermore, some nests were 0% or 95–100% concealed from ≥1 angle, so either there was no point in taking a photograph or it would have been useless because the nest boundaries would have been impossible to determine. These values were referred to as field-determined values. Therefore, the sample size varied among vantage points, and the total number of nests was greater than the number of photographs from any 1 vantage point. Vantage points with field-determined values of 0% and 95–100% and no corresponding photograph were not included in the analyses of paired sample *t*-tests, although we did include them in the analysis of depredated versus nondepredated nests.

Statistical analyses

Our data were normally distributed (all *P* values >0.05, Kolmogorov-Smirnoff tests of normality). To compare methods of nest concealment and consistency between individual observer estimates on a case-wise basis, we used two-tailed paired sample *t*-tests (SPSS 1999) to test the null hypothesis that there was no difference between methods and between individual observer estimates in evaluation of each nest. Each individual observer's estimates were compared with those of the 3 other individual observers and with the values obtained from the 2 other methods (5 pair-wise comparisons); therefore, to correct for multiple comparisons, we applied the Bonferoni inequality to decrease the probability of Type I errors (Hays 1981) and considered a *P* value of ≤0.05/5 (i.e., $P \leq 0.01$) to be significant. For all pair-wise comparisons, we excluded nests with field-determined values of 0% and 95–100% concealment because their inclusion would have inflated consistency (i.e., the values would have been the same for all methods and individual observer estimates).

We also compared mean values of nest concealment among individuals and methods with one-way ANOVA tests (SPSS 1999). To determine whether methods or individual observer estimates affected the application of data to analysis of predation patterns, we used unpaired *t*-tests (SPSS 1999) to determine differences in mean concealment between depredated and nondepredated nests for each individual and both methods of quantifying nest concealment. For these nests, we included field-determined values of 0% and 95–100% concealment because these values would likely be used in application of the methods to determine differences between depredated and nondepredated nests. For this set of data we did not correct for multiple comparisons, because in an application of the methods, only 1 method or 1 individual observer's set of estimates would be used to determine differences in nest concealment between depredated and nondepredated nests. Therefore, we considered $P \leq 0.05$ to be significant.

Results

We conducted 2 trials of the Adobe Photoshop method approximately 2 months apart for all nests to determine consistency. Means within each of the 3 angles did not differ >1.0 % between the first and second trials, and there were no differences in paired *t*-tests (above: $t=0.624$, $P=0.54$; level: $t=1.007$, $P=0.32$; below: $t=0.021$, $P=0.983$). Therefore, to compare these methods with the 2 other methods, we used the average of the 2 trials.

We included 63 nests in the analysis of paired *t*-tests (without field-determined 0% and 95–100% values): 24 western wood-pewees (*Contopus sordidulus*), 1 plumbeous vireo (*Vireo plumbeus*), 8 warbling vireos (*V. gilvus*), 5 yellow warblers (*Dendroica* *petechia*), and 25 chipping sparrows (*Spizella passerina*). Out of 45 paired *t*-tests between individual observer estimates, between individual observer estimates and the other two methods, and between the Adobe Photoshop and transparent grid methods, 29% resulted in significant differences (Table 1). Among the 18 paired *t*-tests between individual observer estimates, 22.2% resulted in significant differences, whereas among the 12 *t*-tests between individual observer estimates and Adobe Photoshop, 50% resulted in significant differences (Table 1). Two of the 3 paired *t*-tests comparing the Adobe Photoshop and transparent grid methods resulted in significant differences (Table 1).

For analysis of depredation (with field-determined values of 0% and 95-100%) we included 75 nests: 26 western wood-pewees, 1 plumbeous vireo, 8 warbling vireos, 6 yellow warblers, and 34 chipping sparrows. Although 29% of the 45 total paired *t*-tests resulted in significant differences, results of unpaired *t*-tests comparing mean nest concealment of depredated and nondepredated nests were more consistent (Table 2). However, this included nests with field-determined values (0% and 95-100% concealment), which increased consistency among investigators and methods. In fact, when comparing total mean nest concealment values among investigators and methods, P values were consistently lower in the data set without field-determined values (above: $P=0.90$; level: $P=0.42$; below: $P=0.03$, one-way ANOVA, df=5) than in the data set with field-determined values (above: $P=1.0$; level: $P=0.85$; below: $P=0.48$, one-way ANOVA, df=5).

There were no significant differences in mean percent concealment above the nest between depredated and nondepredated nests. At the level of the nest, all methods and all investigators determined that nondepredated nests were consistently more concealed than depredated nests, and the differences were significantly different for Adobe Photoshop and 2 individual observer estimates (Table 2). Differences in mean nest concealment between depredated and nondepredated nests below the nest were more inconsistent, but the average difference (of all investigators and methods) between depredated and nondepredated nests was only 6.1 % below the nest, whereas the average difference in mean nest concealment between depredated and nondepredated nests at the level of the nest was 19.8 %.

Table 1. Mean differences of percent nest concealment (between each investigator, Adobe Photoshop™, transparent grid, and other investigators) and results of pair-wise comparisons. Pictures were taken 1 m above the nest, 1 m away from the nest at nest level (same height as the nest toward the center of the tree), and 1 m below the nest in La Plata County, Colorado, 2001.

	Above (n = 19)		Level (n = 44)		Below (n = 52)	
	Mean difference	P[a]	Mean difference	P[a]	Mean difference	P[a]
Investigator 1						
Adobe Photoshop	6.8	0.032	4.5	0.012	6.0	0.001
Transparent grid	4.1	0.304	2.5	0.286	1.6	0.490
Investigator 2	2.2	0.572	4.4	0.030	0.3	0.895
Investigator 3	2.0	0.605	4.2	0.152	2.0	0.426
Investigator 4	3.0	0.460	7.8	0.005	7.8	0.001
Investigator 2						
Adobe Photoshop	4.6	0.191	8.6	0.000	5.3	0.017
Transparent grid	4.8	0.198	2.5	0.211	0.6	0.771
Investigator 3	4.2	0.081	0.2	0.934	2.3	0.347
Investigator 4	0.8	0.818	3.4	0.108	8.1	0.002
Investigator 3						
Adobe Photoshop	8.8	0.027	8.8	0.000	8.0	0.004
Transparent grid	9.4	0.015	2.9	0.261	3.7	0.239
Investigator 4	5.0	0.039	3.6	0.137	5.8	0.008
Investigator 4						
Adobe Photoshop	3.8	0.279	12.1	0.000	13.4	0.000
Transparent grid	3.4	0.331	6.9	0.013	9.3	0.001
Adobe Photoshop						
Transparent grid	3.5	0.161	6.6	0.000	4.5	0.002

[a] Paired sample *t*-tests (alpha level set at $P \leq 0.01$ to correct for multiple comparisons).

Discussion

Our hypothesis that there were no differences among methods or individual observer estimates was not entirely supported. In paired *t*-tests, the data were inconsistent between individual observer estimates and between individuals and both the transparent grid and Adobe Photoshop methods. We also found a few inconsistencies in evaluation of nest concealment between depredated and nondepredated nests. At the level of the nest, we found significant

Table 2. Comparison of mean (± SD) percent nest concealment between depredated nests and nests that did not fail due to predation obtained from 3 methods using pictures taken 1 m above the nest, 1 m away from the nest at nest level (same height as the nest toward the center of the tree), and 1 m below the nest in La Plata County, Colorado, 2001.

	Depredated	Not depredated	P[a]	t
Above the nest	(n = 12)	(n = 35)		
Adobe Photoshop	80.4 ± 27.3	75.8 ± 34.3	0.692	0.399
Transparent grid	78.4 ± 32.7	74.1 ± 35.3	0.718	0.363
Investigator 1	82.1 ± 27.3	72.2 ± 36.9	0.403	0.845
Investigator 2	79.6 ± 28.0	73.1 ± 36.3	0.591	0.541
Investigator 3	78.6 ± 33.0	71.1 ± 37.3	0.552	0.599
Investigator 4	80.4 ± 30.1	73.3 ± 37.3	0.568	0.575
Nest level	(n = 17)	(n = 40)		
Adobe Photoshop	43.4 ± 33.1	64.6 ± 34.7	0.038	2.124
Transparent grid	41.3 ± 33.7	58.6 ± 36.2	0.103	1.659
Investigator 1	41.2 ± 35.3	61.6 ± 36.2	0.060	1.958
Investigator 2	37.0 ± 36.2	59.3 ± 37.5	0.044	2.067
Investigator 3	35.9 ± 39.1	60.5 ± 40.1	0.039	2.119
Investigator 4	35.6 ± 39.3	56.4 ± 40.5	0.080	1.786
Below the nest	(n = 19)	(n = 44)		
Adobe Photoshop	66.8 ± 26.5	67.7 ± 25.2	0.892	0.136
Transparent grid	65.8 ± 27.9	64.9 ± 26.2	0.901	0.125
Investigator 1	61.0 ± 31.9	64.3 ± 28.4	0.689	0.402
Investigator 2	66.6 ± 28.1	63.4 ± 29.8	0.686	0.406
Investigator 3	61.1 ± 33.0	62.3 ± 33.2	0.896	0.132
Investigator 4	53.9 ± 33.7	60.4 ± 33.3	0.478	0.713

[a] Independent sample t-tests, equal variances assumed ($P > 0.05$ for all tests of equal variances).

differences for the Adobe Photoshop method and 2 individual observer estimates but no significant differences for the transparent grid method and 2 individual observer estimates. This suggested that inconsistencies of nest concealment data in the literature also may be due in part to inconsistencies in methods or to unreliable methods. Additionally, variability in field estimates may be even greater than what we found because no 2 investigators are apt to view the nest from exactly the same point.

In fact, many studies have failed to find differences in nest concealment between depredated and nondepredated or successful nests. Holway (1991) found that concealment indices did not differ between depredated and successful nests of black-throated blue warblers (*Dendroica caerulescens*), and Murphy et al. (1997) found no difference in nest concealment between successful and unsuccessful cedar waxwing (*Bombycilla cedrorum*) and eastern kingbird (*Tyrannus tyrannus*) nests. Similarly, Burhans and Thompson (1998) found that concealment did not differ between depredated and successful nests. Even when they experimentally removed vegetation from the vicinity of the nest, Howlett and Stutchbury (1996) failed to find a difference in concealment between depredated and successful hooded warbler (*Wilsonia citrina*) nests.

In addition to inconsistencies among methods and the obvious problems of using unreliable methods, interpretation of nest concealment data may be complicated by predator assemblage; for example, Rangen et al. (1999) found that nest concealment varied according to the predator type. Indeed, correlations between nest concealment and nest success might be less enigmatic among ground-nesting birds that may have different predator assemblages than among arboreal nesting birds. For example, Purvis et al. (1999) found that successful ring-necked pheasants (*Phasianus colchicus*) had significantly greater overhead cover, and Wiebe and Martin (1998) found that well-concealed white-tailed ptarmigan (*Lagopus leucurus*) nests were less depredated. Guyn and Clark (1997) found that overhead concealment was greater among successful duck nests, but lateral vegetation density scores were not. Additionally, vegetation surrounding the nest site may be more important than vegetation concealing the nest at a closer range (e.g., within 1 m [Martin and Roper 1988]). Therefore, it might be useful to use visibility indices at longer distances from the nest (e.g., Filliater et al. 1994) in addition to concealment close to the nest.

Although the Adobe Photoshop method has some associated problems, it probably was more accurate than the transparent grid method, for several reasons: 1) the resolution was finer, with far more pixels than number of squares in the transparent grid, 2) it was easier to determine nest boundaries and vegetation boundaries in color than in black and white, and 3) it was more time-efficient. Furthermore, it was repeatable between trials. The main drawback with the Adobe Photoshop method was shared with all methods; determining nest boundaries that are hidden by vegetation is a problem that increases inaccuracy with increased concealed boundaries. However, with the assumption that nests (from above and below) were basically round, if at least some boundary was unconcealed, the boundaries could be approximated using the elliptical tool and following the curvature of the unconcealed boundary. We assume any method that quantifies nest concealment is more desirable and accurate than visual estimates, particularly when estimates vary significantly among individuals. We therefore recommend the Adobe Photoshop method. After the initial investment of a digital camera and Adobe Photoshop software, this method was efficient in terms of both money and time. The average time invested in each view, not including taking the photograph in the field, was approximately 3 minutes.

Our method increases repeatability and reduces observer biases in nest-concealment estimates, providing a more accurate basis for management decisions regarding habitat needs for birds. More accurate methods for quantifying nest concealment are particularly important when the main objective of the study is to determine the importance of nest concealment. This method has distinct advantages over field estimates: 1) it reduced observer bias, 2) it was repeatable, and 3) it provided a permanent record. Thus, the application of these methods could provide useful and more accurate information to wildlife and land managers.

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