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STRUCTURE OF SUCCESSFUL NESTS OF THE AMERICAN GOLDFINCH (*CARDUELIS TRISTIS*)

DORIS J. WATT AND AMY M. DIMBERIO

Department of Biology
Saint Mary's College
Notre Dame, Indiana 46556 USA

Abstract.—We measured characteristics of nests of the American Goldfinch (*Carduelis tristis*) and compared these quantitative variables to fledging success. Characters associated with a nest having successfully fledged young were presence of excrement on the nest rim, large cup diameter and circumference, presence of feather sheaths and thistle down in the nest lining, and absence of eggshell remains in the nest. We used canonical discriminant analysis to classify nests as successful or unsuccessful. Testing the accuracy of the method, we obtained 69% and 79% correct assignment in two subsets of nests with known success rates. We then used the analysis to classify nests of unknown fledging success. We feel that using this technique can aid researchers in assessing nesting success of birds whose nests cannot be located during the breeding season.

LA ESTRUCTURA DE NIDOS EXITOSOS DE *CARDUELIS TRISTIS*

Sinopsis.—Medimos características de nidos de *Carduelis tristis* y comparamos estas variables cuantitativas al éxito de anidamiento (vuelo de los pichones). Características asociadas con nidos de donde volaron pichones lo fueron la presencia de excremento en el borde del nido, un diámetro y circunsferencia amplia de la copa, presencia de capas de plumas y plumón en la cubierta interna del nido, y la ausencia de remanentes de cascarones. Utilizamos un análisis discriminativo para clasificar los nidos en exitosos o fracasados. Obtuvimos un 69% y 79% de aciertos en dos subconjuntos de nidos con éxitos ya conocidos lo que permitió verificar la utilidad del método. Luego utilizamos el mismo tipo de análisis para clasificar nidos con éxito desconocido. Creemos que utilizando esta técnica podemos ayudar a los investigadores para que determinen el éxito de anidamiento de aves cuyos nidos no puedan ser localizados durante la época de anidamiento.

The reproductive cycle of the American Goldfinch (*Carduelis tristis*) is characterized by a late summer period of nest construction and breeding (Middleton 1978, Tyler 1968). The female goldfinch builds a small, durable cup nest woven of fine vegetable fibers and lined with plant down. Four to six eggs are laid and the young fledge about 13 days after hatching. As the young grow, they expand the cup of the flexible nest, changing its shape and dimensions. Several days before fledging, the parent birds cease removing fecal sacs and the young birds excrete on the rim of the nest. In addition, several days before fledging the feathers begin to emerge from the feather sheaths and are preened and removed by the young birds. These feather sheaths fall into the nest lining. If such nests are found shortly after a successful fledging, these characteristics can be noted. However, in a particular study, a researcher may not find all the nests during the breeding season, or may not have witnessed the successful or unsuccessful outcome of a particular nest. The purpose of this paper is to demonstrate that quantitative characters associated with nest success can be measured months after the breeding season and used to estimate relative success rates among nests.

METHODS

During the summers of 1986 and 1987 we found and documented breeding success of nests of goldfinches within a kilometer of the campus of Saint Mary's College. Nests were located in maples (*Acer* sp.) within the campus habitat, walnuts (*Juglans* sp.) within the orchard habitat, and a variety of unidentified shrubs, saplings, and weeds in the old field habitat. In late autumn (19–23 Dec. 1986 and 1 Oct.–15 Nov. 1987) we collected all the nests including ones we had not found during the breeding season ($n = 21$ in 1986, $n = 36$ in 1987), and placed them in plastic zip-lock bags for storage. We then inspected the nests and measured the following characteristics (see Fig. 1) using a vernier caliper: (1) nest diameter at its widest to the nearest hundredth cm, (2) nest diameter at the narrowest, (3) inner nest depth, (4) total nest depth, (5) nest circumference at the rim, (6) nest circumference at the widest part of the cup, (7) nest rim thickness at its thickest, and (8) nest rim thickness at its thinnest. We also measured (9) cup volume (amount of water displaced by glass beads that filled the cup), and counted the (10) number of deposits of excrement on the nest, (11) number of eggshell remains knocked from the nest lining, and (12) number of insect remains knocked from the nest. We also noted (13) presence or absence of the nest's lining, and we observed the nest contents microscopically and noted the (14) number of thistle down fragments, and (15) number of feather sheath fragments. The last two variables were estimated on a scale of 0–9, with 0 = none, 1 = a few, up to 9 = many, and samples were surveyed several times to obtain a consistent estimate for each nest relative to the other nests.

Nine nests of the 57 collected had no nest lining; all nine of these nests were of unknown success. Because the absence of a lining might affect the measurement of other characteristics, and because this character would not be useful in discriminating successful and unsuccessful nests, both the variable and the nests without linings were eliminated from further analysis. Remaining values were standardized (mean = 0, variance = 1.0) and canonical discriminant analysis was performed using SPSSX (Release 2.1+) on a PRIME computer at Saint Mary's College. Non-parametric statistics were applied using StatView 512+ on a MacIntosh II.

The fates of 27 of the 48 nests used in the analysis were known (19 successful and 8 unsuccessful). Most of the unsuccessful nests were deserted during egg-laying or before hatching. The remaining 21 nests were located after breeding was completed or were positioned in such a way that fledging success had not been observed.

RESULTS AND DISCUSSION

Means and standard deviations for the measured characteristics are given in Table 1. Correlations of variables with the discriminant function scores indicated that the most important variables for separating successful and unsuccessful nests were presence of excrement on the nest rim, cup diameters and circumferences, and presence of feather sheaths, thistles

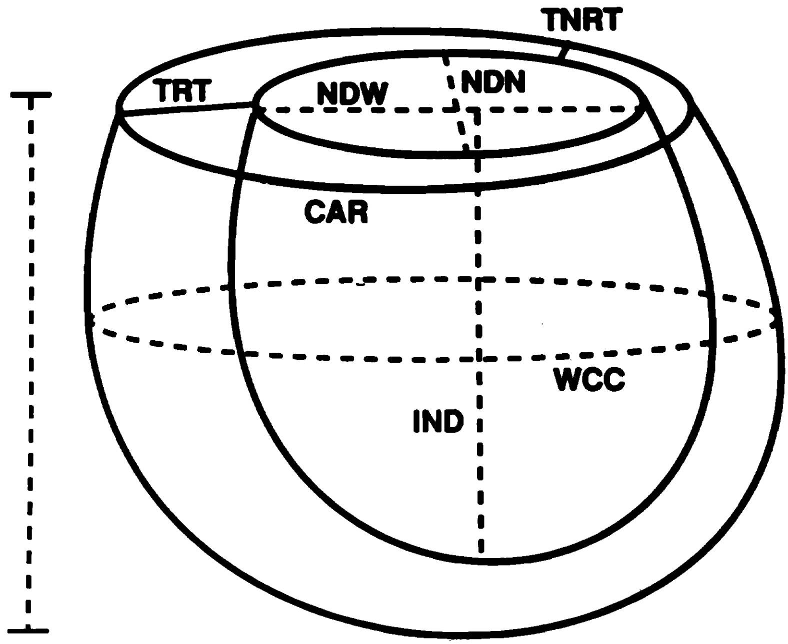

FIGURE 1. Quantitative characters measured on nests. Abbreviations are defined in Table 1.

and eggshell remains in the lining. These measurements were all significantly different between successful and unsuccessful nests (univariate *F*-ratio; Table 1). The presence of excrement and feather sheaths would be expected in nests that contained relatively old nestlings, nest cup dimensions changed due to the presence of the nestlings, and the presence of eggshell remnants probably indicated a nest that was preyed upon and thus unsuccessful (eggshell presence correlated negatively with nest success). The relationship between higher numbers of thistle down fragments and relatively more successful nests is obscure.

It also appeared as the number of young birds increased per nest, several measurements differed. For example, widest nest diameters (NDW) were 5.63, 6.48, 6.56, and 6.95 and mean cup volumes (CV) were 23.3, 32.0, 28.9 and 26.0 for 0, 3, 4, and 5 young, respectively. These values suggest that nests are more expanded and at the same time more trampled down with larger numbers of young in the nest. Statistically, however, the values for nests containing 3 young ($n = 3$), 4 young ($n = 8$) and 5 young ($n = 3$) were not significantly different (Kruskal-Wallis $H = 1.04$ for nest diameter comparison and $H = 0.23$ for cup volumes, df = 2, $P > 0.05$), perhaps due to small sample sizes. It would be useful to develop such an application, especially for use in studies where comparisons of numbers of young are needed.

TABLE 1. Summary of nest characteristics with unstandardized means and standard deviations of 48 nests, and comparison of standardized means for 19 successful and 8 unsuccessful nests with univariate *F*-ratio (df = 25).

Variable	Abbreviation	Unstandardized mean	SD	Standardized succ. nest mean	Standardized unsucc. nest mean	*F*
Widest nest diameter	NDW	6.379	0.704	0.386	−0.772	11.650**
Narrowest nest diameter	NDN	5.204	0.642	0.107	−0.880	8.875**
Inner nest depth	IND	2.415	0.744	−0.182	0.383	2.429
Total nest depth	TND	4.831	1.072	0.040	0.024	0.002
Rim circumference	CAR	21.316	2.146	0.186	−0.995	9.343**
Widest cup circumference	WCC	24.904	1.503	0.358	−0.718	10.790**
Thickest rim thickness	TRT	1.590	0.490	−0.274	0.305	1.564
Thinnest rim thickness	TNRT	0.841	0.265	−0.353	0.125	1.462
Cup volume	CV	27.146	6.672	0.089	−0.584	2.328
Excrement deposits	EX	2.542	2.672	0.706	−0.883	27.840***
Feather sheaths	FS	4.667	3.392	0.362	−0.860	11.230**
Eggshell remains	EG	1.042	2.492	−0.207	0.635	5.140*
Insect remains	IN	1.833	2.495	0.299	−0.284	1.889
Thistle down	TH	6.292	2.744	0.373	−0.516	5.628*

* = $P < 0.05$.
** = $P < 0.01$.
*** = $P < 0.001$.

We tested the discriminating ability of the analysis by dividing the 27 nests of known success, assigning every other one the status of "unknown" so that in the first test 13 of the 27 were the unknowns and in the second test 14 of them were the unknowns. In the first test the analysis correctly assigned 9 of the 13 and incorrectly assigned 4 (69% correct). In the second test 11 out of 14 were correct and 3 were wrong (79% correct). We then used discriminant function analysis to classify nests of unknown success ($n = 21$) as successful or unsuccessful based on their discriminant function coefficients. We assume that the determinations are at least 70% correct for scores that fall within the range of the "known" group. Thus, of the 21 unknowns we classified 7 as unsuccessful and 14 as successful (67%). This is comparable to the success rate of 70% among the known nests (19 out of 27).

Even after being exposed to weather conditions for up to four months it was still sometimes possible to discern excrement deposits on the nests. This proved to be the best indicator of successful nests. Measurements of nest expansion from increased nestling growth were also good indicators. Such expansion has also been documented in hummingbirds (Calder 1973), tits (O'Connor 1975), and sparrows (Kern 1984). Nest diameter should be more useful as an indicator of successful nests when the numbers of young in the nest are greater (4 or 5 rather than 1 or 2) since more young expand the nest to a greater extent. Theoretically, it is possible for a nest to contain only a single nestling which might not expand the nest a significant amount relative to an unsuccessful nest. In that case, the presence of feather sheaths becomes an added important characteristic to distinguish unsuccessful nests from ones containing one or two young in the nest. Thus, the combination of several nest characteristics provides the most powerful discrimination between successful and unsuccessful nests.

While it is possible for a predator to remove the young birds during the last few days in the nest, this technique is still an aid for researchers measuring the abilities of adults to rear young at least to fledging stage, or for ecological studies of relative habitat productivity. To demonstrate, we compared nesting success rate over three habitat types. We used all of the nests, including those with success rate assigned by the discriminant function analysis, to calculate percentage success in three habitats: orchard ($n = 31$), campus ($n = 12$), and old field ($n = 5$). Campus had the highest success rate (83%), while orchard and old field were lower (64.5% and 60%, respectively). Our results are similar to those reported for analogous habitats by Middleton (1979) who found city habitat to be the most successful (79%) and nursery and natural habitats less successful (44% and 57%, respectively). (These values were recalculated from Middleton's Table 8 after substracting nests he studied that were deserted during construction. In our study, nests so deserted were often torn down by the female and used in constructing a second nest and so were not available for us to measure.) In conclusion, we suggest that techniques using discriminant function analysis on nests found after breeding season has ended may be helpful in studying relative nesting success. This technique might also be particularly helpful in studies of species that are highly sensitive to observer disturbance.

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