Researcher Disturbance in Colonies of Wading Birds: Effects of Frequency of Visit and Egg-Marking on Reproductive Parameters

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Abstract.—In two closely matched colonies of Tricolored Herons (*Egretta tricolor*) we found no differences in reproductive parameters of the one visited frequently (16 times) and the other visited infrequently (7 times). Visits to colonies were standardized and were initiated only after most of the herons had partially completed their clutches. These results suggest that limited colony visitations beginning after courtship and early egg-laying do not result in large disturbance effects. We caution, however, that these findings should not be applied without further testing, especially since the colonies we studied were relatively free of aerial and ground predators. We also found that letters marked on the sides of eggs were turned down by parental birds significantly more often than expected due to chance. We suggest researchers label eggs inconspicuously on the ends or not at all. *Received 13 December 1988, accepted 29 June 1989.*

Key words.— human disturbance, *Egretta tricolor*, wading birds, reproductive success, Everglades.

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Numerous studies of the effects of disturbance have been conducted in colonies of nesting birds, and show generally that reproductive responses vary greatly with species, timing, and type of disturbance. For instance, Burger (1982) found abandonment of Black Skimmer (*Rhynchops niger*) colonies to be common following visits of predators, but uncommon if colony failure was due to high tides. Southern and Southern (1979) found the reactions of Ring-billed Gulls (*Larus delawarensis*) to predators varied depending on whether the predator was nocturnal or diurnal. The effects of human disturbance are of particular interest to researchers, since activity associated with the study of nesting may introduce large artifacts into the reproductive parameters recorded.

Reproductive parameters of wading birds (Ciconiiformes) are increasingly sought as indicators of demographics and wetland health (Custer and Osborn 1977, Frederick and Collopy 1989a). However, the effects of researcher disturbance in colonies are only known within broad limits. The current state of knowledge does not allow estimation of the magnitude of effects due to specific visit protocols. Using paired control and experimental plots in the same colonies, Tremblay and Ellison (1979) showed that researcher visits to colonies of Black-crowned Night herons (*Nycticorax nycticorax*) during nest-building and early incubation led to abandonment of nests, and avoidance of the colony by renesters and courting birds. The existence of an early-nesting sensitive period has been echoed in a qualitative way for Great Blue Herons (*Ardea herodias*, Quinney 1983, Drapeau *et al.* 1984), White Ibises (*Eudocimus albus*, Frederick 1985, Shields 1985), and herons of the genus *Egretta* (Dusi and Dusi 1968, Bjork 1987). During this period, breeders may abandon the nesting attempt outright, or may not return to the nest in time to defend it from aerial predators (Shields 1985, Tremblay and Ellison 1979, Drapeau *et al.* 1984), usurpation by other species (Burger 1978), or dismantling by both conspecifics and other species (Kushlan 1973, Drapeau *et al.* 1984). This response seems specific to the early nesting period; similar initial disturbances during late incubation in Tremblay and Ellison's (1979) control sites did not lead to similar responses.

The effects of researcher visits occurring after the completion of clutches are somewhat ambiguous. Tremblay and Ellison (1979) found significantly fewer young fledged from experimental than from control nests, but attributed this to the effect of early visits to the experimental sites, rather than to continued, frequent visits in mid-to-late cycle. Thus their experimental design did not allow direct comparison of the effects of frequency of visit and timing of visits. Goering and Cherry (1971) also used paired colony sites, and found no differences in reproductive parameters of control (4 visits) and experimental (16 visits) nests, when initial visits to both were during late incubation. However, their comparisons did not control for the effect of species.

The emerging picture for ciconiiforms is that researcher disturbance during and before egg-laying will strongly affect reproductive parameters, and that visits initiated late in incubation may not. However, the end of the sensitive early period has only been crudely estimated by these studies, and the effect of frequency of visits late in the nesting cycle has not been adequately investigated.

In addition, ciconiiform eggs are often marked by researchers in order to accurately determine egg fates (Bjork 1986, Frederick and Shields 1986, Shields and Parnell 1986, Shields 1987, Frederick and Collopy 1989a). Although these marks are known to affect egg turning behavior in some passerines (Holcomb 1969, Gibb 1970), it is unknown if the same is true in ciconiiforms.

Here, we report on the effects of two types of human researcher disturbance in colonies of ciconiiform birds in the freshwater marshes of the Florida everglades. The first investigates the effects of frequency of visits in paired colonies of Tricolored Herons (*Egretta tricolor*). The second investigates the effect of marking eggs on parental egg-turning behavior in four ciconiiform species.

METHODS

All data were collected during a large-scale study of nesting success during the spring breeding seasons of 1986 and 1987 in the freshwater grassland marshes of southern Florida (Water Conservation Area 3A). A detailed description of the study site and methods can be found in Frederick and Collopy (1988). Colonies were located in tree islands (usually composed predominately of willow [*Salix caroliniana*]) surrounded by inundated wetlands, and were often used by more than one bird species. These colonies were prone to synchronous abandonments, usually following sharp increases in nearby marsh water levels, but were surprisingly well insulated from both aerial and ground predators (Frederick and Collopy 1989b).

Effects of frequency of visits in Tricolored Heron colonies

We compared the reproductive parameters of Tricolored Herons nesting in two small colonies located less than 2 km apart ("frequently visited" at 25°52.89′N, 80°47.75′W, "infrequently visited" at 25°51.81′N, 80°48.40′W) in similar habitat on the western side of the study area in April/May of 1987. Both colonies were composed predominantly of willow, both contained a single Great Blue Heron nest in the tallest central tree, and both contained an alligator (*Alligator mississippiensis*) pond in the north end. Both colonies were accessible only by airboat; the absence of airboat tracks other than our own confirmed that no additional human disturbance occurred at either colony during our study.

Both colonies were first visited on 11 April and both contained Tricolored Heron nests with complete or partially complete clutches. The experimental colony was visited thereafter once every 4 days (a total of 16 visits), and the control colony visited once every eight days (a total of seven visits). Protocol of visits was the same in both colonies. Visits occurred between 0600 and 0830 h at both colonies. During visits, colonies were approached to within 50 m by airboat, and one hour was spent by two persons in the colony marking nests with numbered strips of orange surveyor's flagging, and recording nest contents. Eggs were marked with indelible laundry marking pens, and were measured. Young were not handled, and nests were not checked if young were older than 14 days of age.

The nesting period was divided into egglaying (first egg to six d), incubation (next 16 d) and nestling (hatching to 14 d) periods. Nests were considered successful if they produced one young of 14 d of age or older. Overall nesting success was compared using Mayfield's (1961, 1975) method, with statistics derived according to Hensler and Nichols (1981) and Hensler (1985). The infrequently-visited colony contained 26 Little Blue Heron nests (22% of the 117 nests in the colony), while the frequently-visited colony contained only Tricolored Heron nests (104 nests). Because nests of these two species are indistinguishable prior to hatching (McVaugh 1972, Hancock and Kushlan 1984), failure during incubation was difficult to assign to species. Because of this difficulty, we lumped nesting success of both species in the infrequently-visited colony during the incubation period, and combined this figure with success of Tricolored Heron nests there during the nestling period (Hensler 1985).

Date of nest initiation (laying of first egg) was determined only for nests at which we could derive a first egg date through egg-laying sequence, or by back-dating from hatching dates. Clutch size data were taken only from those nests which could be accurately dated through laying sequence alone. The number of nestlings fledging was determined only for those nests which were visited within two days of the 14-d fledging definition date. After this date, young became mobile, and finding the entire brood became unreliable.

The entire study area was classified into 150 categories of vegetation using SPOT satellite imagery; multispectral and panchromatic images were overlaid to give an effective resolution of approximately 10 m (see Bennetts *et al.* 1988 for further details). Vegetative composition and areal size of control and experimental colonies were compared using this classification scheme.

Effects of egg marking on parental egg-turning behavior

We marked eggs on one side with letters between 1 and 2 cm tall using indelible laundry marking pens in a total of 53 clutches of Tricolored Herons, 36 clutches of Little Blue Herons, 15 clutches of Great Egrets, and 34 clutches of White Ibises. All eggs in each clutch were marked with different letters. On subsequent visits, the position of the mark on each egg was categorized into one of four equal sectors of the shortest circumference of the egg (up, down, or one of two sides). Because turning behavior results in less egg movement late in incubation (Lind 96, Drent 1970), we limited our sample of positions to those recorded within the first 12 days of incubation. To control for the nonindependence of egg positions within nests, each nest was only sampled once (the first visit following marking), and one egg position only was selected from each nest, using a random numbers table. The distribution of egg positions observed within each species was compared with an expected even distribution (25:25:50 - up:down:side) using Chi^2 goodness-of-fit-tests.

RESULTS

Effects of frequency of visits on reproductive success

Frequently- and infrequently-visited colonies of Tricolored Herons showed no significant differences in date of nest initiation, clutch size, probability of nest success, hatching rate, or numbers of 14-day old young per successful nest (Table 1).

All nests which failed at both colonies did so during egglaying or incubation periods. Of 29 failures at the frequently-visited colony, one could have been attributed to a snake visit, two lost single eggs due to researcher handling, and one lost an egg due to eggshell thinning. The remaining cases were found simply as empty nests. Of 15 failures at the infrequently-visited colony, one could have been attributed to the loss of a single egg due to researcher handling, and three showed evidence of addling or infertility of eggs. Again, the remaining cases were found as empty nests. The cause of failure at the empty nests could not be assigned to predation, since the primary cause of failure could have been abandonment followed by scavenging of the nest contents (Frederick and Collopy 1989b). Neither colony showed evidence of predation by mammals, crows, or owls (evidence described by Rearden 1951, Nisbet 1975, Pratt and Winkler 1985, Rodgers 1987). No obvious differences, then, were found in cause of nest failure.

The infrequently-visited colony was found to be 0.77 ha in size, and the fre-

Table 1. Comparison of reproductive parameters measured at frequently and infrequently visited colonies of Tricolored Herons.

Reproductive Parameters		Visitation Frequency: Infrequent	Frequent	Statistical Comparison
Clutch size	$\overline{X}$	3.05	3.21	Z = 1.44[1]
	SD	0.517	0.529	P > 0.077
	n	37	89	
Date of nest initiation (Julian)	$\overline{X}$	104.6	110.4	t = –0.959
	SD	15.11	9.27	P > 0.50
	n	69	104	
Overall nest success[2]	P	0.720	0.668	Z = 0.129[3]
	SD	0.0671	0.0510	P = 0.55
Hatching success	$\overline{X}$	0.9802	0.9481	t = 1.50[4]
	SD	8.725	15.677	P > 0.10
Young fledged per successful nest	$\overline{X}$	2.72	2.78	Z = –1.42[1]
	SD	0.502	0.819	P > 0.079

[1]Mann-Whitney U Test (Siegel 1956)
[2]Probability of a nesting attempt producing at least one young to an age of 14 days
[3]See Hensler (1985)
[4]Data arcsine transformed prior to t-test (Sokal and Rohlf 1969)

quent visited colony was 0.80 ha in size. The entire vegetated area of both was classified as the same category of willow dominated vegetation.

Effects of egg marking on parental egg-turning behavior

The observed distribution of positions of marks on eggs was significantly different from an expected even distribution for Tricolored Herons, Little Blue Herons, and White Ibises (Table 2). For these three species, the number of recorded "up" positions were not far from expected, while the number of "down" positions were much larger than expected. The sample size of Great Egret clutches proved too small for analysis by χ^2 tests; the number of recorded "up" positions were not significantly different from an expected 25% proportion using a binomial test.

Whether this tendency to orient marks away from vertical results in abnormal hatching rates is unknown. We marked eggs in nearly every nest we studied during the two years of study and so could not compare hatching rate with a control group of eggs.

DISCUSSION

Effect of frequency of visits on reproductive parameters

Because the conditions in the two colonies of Tricolored Herons were so closely matched, we do not think that timing of the initiation of breeding, location, size and vegetative composition of colony sites, foraging opportunities, weather during breeding, surface water conditions, predation, and numbers of breeders were potential factors explaining any differences in breeding success.

Species composition was not the same in both colonies. The effect of this difference however, only predisposes the analysis towards a significant finding, as follows. In other colonies in the study area where species identification was not a problem, Little Blue Herons had consistently higher overall reproductive success than did Tricolored Herons in both years of study (Mayfield overall success was 72.8% and 46.1%, respectively in 1986, 71.6% and 66.1% in 1987, see Frederick and Collopy 1989a). This suggests that the inclusion of Little Blue Heron nest success data with that of Tricolored Herons in the infrequently-visited colony would bias the nest success estimate for Tricolored upwards. Because this bias occurred in the infrequently-visited but not the frequently-visited colony, this should have artificially accentuated the measurement of nest success differences in the direction predicted by an hypothesis of increasing disturbance with frequency of visit. Our finding of no significant difference, therefore, is all the more robust.

This result implies that reproductive success in Tricolored Heron colonies does not vary strongly with frequency of researcher disturbance when visits occur after most egg laying is complete. The relatively high reproductive success achieved in both colonies suggests that the frequency, timing, and protocols we used did not result in large losses in reproduction. The fact that many nests were initiated after we had begun our visits to both colonies suggests that the visits did not substantially decrease the recruitment of breeders to either location.

The striking differences between our results and those of Tremblay and Ellison (1979) were most likely due to our entering the colonies only following courtship,

Table 2. Position of marks on eggs relative to vertical on subsequent visits to nests.

	Orientation				
Species	Up	Down	Side	X^2	P
Tricolored Herons	10	32	11	552.9	<<0.001
Little Blue Herons	8	21	7	22.8	<<0.001
White Ibises	11	15	8	10.47	<0.001
Great Egrets	3	8	4	**	0.215

**Binomial probability of 3 "ups" @ expected probability of 0.25

nestbuilding, and partial completion of clutches. The lack of abandonment we found suggests that visitations during late egglaying stages fall outside of the sensitive period observed in other studies.

This interpretation should be treated with caution. First, although the sample sizes in our comparisons were robust, the results supported the null hypothesis, and one or more replications are necessary prior to strict conclusions. Second, these results apply to Tricolored Herons only; while we did not observe obviously detrimental effects in other species and locations we visited using the same protocols, we were unable to achieve the same controls in the other locations. Third, the study site where we worked was peculiar in having few or no aerial predators, and little mammalian predator activity (Frederick and Collopy 1989b). Other studies of breeding success have found that human disturbance often greatly enhances opportunities for egg predation, either while parental birds are off their nests or by leaving scent trails to nests (Milstein *et al.* 1970, Shields and Parnell 1986). The fact that our study site had very few nest predators (particularly crows *Corvus sp.* and raccoons *Procyon lotor*) may have contributed to our finding few disturbance effects, and we caution that these results should be applied with extreme care to sites having these predators. Finally, while our protocols did not result in dramatic disturbance effects, the results do not necessarily imply that the visits (at any frequency) do not have detrimental effects on reproduction. The effect of visits must be investigated using paired sites, one of which is monitored remotely and the other visited. Such an investigation be accomplished through the use of established towers or blinds (Pratt 1974), though such structures may themselves have confounding disturbance effects (Quinney 1983).

Effect of egg marking on parental egg-turning behavior

The tendency of parental birds to turn marks on their eggs down was strong and consistent across species. The only exception to this rule might be Great Egrets, though the sample size was probably too small for conclusive determination. This tendency has been noted in passerines (Holcomb 1969, Gibb 1970) and is apparently also strong among ciconiiforms. The behavior was especially remarkable in White Ibises, on whose strongly mottled eggs we sometimes had trouble finding our own marks. The apparent recognition of marks is also noteworthy because ibises will tolerate the addition of foreign conspecific eggs to their clutches during the second week of incubation, suggesting a lack of egg recognition (Frederick 1985).

Deviations from normal egg-turning behavior have resulted in significantly reduced hatching success in domestic fowl (Robertson 1961a, b). We therefore strongly recommend that researchers not mark eggs, or do so with marks that are small and cannot be consistently oriented. The latter could be achieved by marking eggs on their ends with small characters, or by drawing a continuous line around the short circumference of the egg.

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