

Nest remains are insufficient to identify predators of waterfowl nests

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ABSTRACT

Context. Nest predation is a leading cause of nest failure for most ground-nesting birds. Methods that allow for accurate classification of fate and identification of predators are important for understanding productivity and conservation strategies. Past studies have used a visual inspection of nest remains to determine nest fate and predict predator identity. Most formal assessments of these methods have addressed small-bodied birds nesting in trees or shrubs, and have revealed that use of evidence at nests can be relatively accurate for determining nest fate but may lead to incorrect conclusions regarding predator identity. However, few have tested the latter hypothesis for larger ground-nesting birds with precocial young. **Aim.** We aimed to evaluate a classification system developed for determining nest fate and identifying predators of waterfowl nests, at both the scale of individual nests and across the study area. **Methods.** From 2016 to 2020, we located 989 blue-winged teal (*Spatula discors*), mallard (*Anas platyrhynchos*) and gadwall (*Mareca strepera*) nests in central North Dakota. We placed cameras at a subset of 249 nests and recorded evidence of nest remains at depredated nests. **Key results.** The most common predators were American badgers (*Taxidea taxus*), followed by striped skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*) and red foxes (*Vulpes vulpes*). Using evidence of nest remains, we determined nest fates with high accuracy (98.0%). However, evidence of nest remains was only sufficient for identifying predators at 50% of nests, and the classification system was correct only 69.7% of the time. The predicted proportion of predators across the study area differed between the classification system and our video evidence as well. **Conclusions.** The accuracy of predator identifications based upon the classification system that we evaluated was not supported at any scale. **Implications.** Our results suggest that evidence of nest remains can be used to determine nest fate for large-bodied precocial, ground-nesting birds, but accurate identification of nest predators will require alternative methods such as nest cameras.

Keywords: badger, conservation, grassland, nest camera, Prairie Pothole Region, predation, waterfowl, wetland.

Introduction

Nest cameras revolutionised the study of nesting behaviour and success in birds (Thompson *et al.* 1999; Pietz and Granfors 2000; Ellis-Felege and Carroll 2012; Ribic *et al.* 2012), allowing more accurate descriptions of nesting phenology (Burnam 2008), success (Ellis *et al.* 2018), and causes of failure (Burr *et al.* 2017). However, the cost (both financial and temporal) of using nest cameras may be prohibitive for many investigators (Cox *et al.* 2012; Prinz *et al.* 2016) and may also bias nest fate (Ellis-Felege and Carroll 2012; Ribic *et al.* 2012). Thus, alternative methods for assessing the causes of nest failures could be useful, especially for studies focusing on identifying nest predators and for mitigating factors influencing the risk of predation (Weidinger 2008).

One possible way to identify nest predators is to use physical signs left behind (Williams and Wood 2002; Anthony *et al.* 2004; Staller *et al.* 2005). Methods for categorising sign at

nests for ground-nesting birds like waterfowl were based on extensive research of predators (Sargeant *et al.* 1998), but assignment of fates at other nests was less empirical and based largely on assumptions (Pietz *et al.* 2012). As a result, use of physical sign to identify predators at failed nests has been criticised, with noted weaknesses such as the potential for secondary predation, parental activity or disturbance of nest remains, and observer experience [reviewed by Lariviere (1999); also see Staller *et al.* 2005; Andes *et al.* 2019].

Despite critiques of more traditional predator identification techniques, assessments of their efficacy are sparse and have focused primarily on small birds with altricial young such as passerines (Thompson *et al.* 1999; Pietz and Granfors 2000; Williams and Wood 2002). Some investigators concluded after their assessment that traditional methods were sufficient for discerning nest success from failure, but not for identifying predators (Williams and Wood 2002; Andes *et al.* 2019). However, others have recommended against using physical sign for any level of nest fate determination. For example, Thompson *et al.* (1999) identified predation events at apparently undisturbed nests, so advised against using physical sign at nests to identify predators. Similarly, Pietz and Granfors (2000) concluded that evidence at nests was an unreliable method for identifying predators of passerine nests because the same predators left sign at both successful and unsuccessful nests.

Although deemed unreliable for passerines and recommended against for predator determination in all bird species, physical sign is still used due to logistical and financial benefits over predator identification devices like cameras (Lariviere 1999). Further, the use of physical sign to determine nest fates and identify nest predators has not been tested for accuracy for larger ground-nesting birds with precocial young, where nest remains might be easier to detect due to their larger egg and clutch sizes. Sargeant *et al.* (1998) developed a hierarchical process of classifying physical sign at depredated waterfowl nests that could potentially be used to identify nest predators at the landscape scale. Lariviere (1999) subsequently published a commentary that included a list of factors that could preclude the accurate identification of nest predators using Sargeant *et al.*'s (1998) method, including overlapping predator behaviours, multi-predator visits, and parental activity at failed nests. However, Lariviere (1999) did not conduct any empirical assessment of the method, and the Sargeant *et al.* (1998) classification system is still referenced by some investigators studying waterfowl nest success and predation (e.g. Opermanis *et al.* 2001; Sherfy *et al.* 2018; Blythe and Boyce 2020).

We tested the accuracy of the Sargeant *et al.* (1998) hierarchical classification system using evidence collected from video-monitored waterfowl nests. We focused our study on three species of ducks, including mallards (*Anas platyrhynchos*), blue-winged teal (*Spatula discors*), and gadwall (*Mareca strepera*). Using data from successful and

failed nests, our objectives were to determine if the hierarchical system accurately identified nest fate and predators at the nest and study area scales. Here, we define study area as the plots specifically searched for nests during our 5-year monitoring period.

Methods

Study area

We located and monitored mallard, blue-winged teal, and gadwall nests at two field sites in the Prairie Pothole Region of North Dakota, USA, from 2016 to 2020. Ducks Unlimited's Coteau Ranch (1214 ha), and The Nature Conservancy's Davis Ranch (2832 ha) are adjacent to each other (47.383336°N, 100.278731°W) near Denoff in Sheridan County, North Dakota (Fig. 1). Both sites are composed of mixed grass prairie with numerous wetlands. Rotational cattle grazing occurs at both study areas, and the latter site incorporates prescribed burning in its management. We selected four plots for nest searching on each study site. Individual plots were ~65 ha in size. Because the study sites were being actively managed, we selected plots that would facilitate continuity in our nest searching from year to year (Fig. 1).

Nest monitoring

We searched for nests between 0800 and 1400 hours using the standard chain drag technique (Klett *et al.* 1986). Plots were searched at least every other week, and nesting females were flushed with a 35-m long chain advancing over the vegetation between two all-terrain vehicles at a speed of 6–11 kph. Once found, we recorded the species of female flushed, number of eggs, vegetation heights or visual obstruction readings (VOR) at all four cardinal directions using a Robel pole (Robel *et al.* 1970), and clutch age using the candling technique (Weller 1956). We estimated egg hatch dates using the clutch age dates determined by candling eggs and rechecked nests at least every other week until eggs hatched or nests failed. At every subsequent nest check, we recorded the number of eggs, stage of incubation, and state of the nest (normal, missing eggs, partially destroyed, or completely destroyed).

At a subset of nests, we installed continuously recording video surveillance cameras (Model YCC-520TW-24DS; Jet Security USA, Buena Park, CA, USA, and Advanced Security, Bellevue, IL, USA). We deployed cameras at nests where females were incubating eggs, focusing on blue-winged teal in 2016 and 2020, mallards in 2017 and 2018, and gadwall in 2019 and 2020. Cameras recorded colour during the day, black and white at night, and were equipped with 24 light-emitting diodes (LEDs; 950 nm). We attached cameras to a 1.27-m stake placed 0.25–0.5 m from nests and connected to a 12-V, 35-amp battery along with a camouflaged

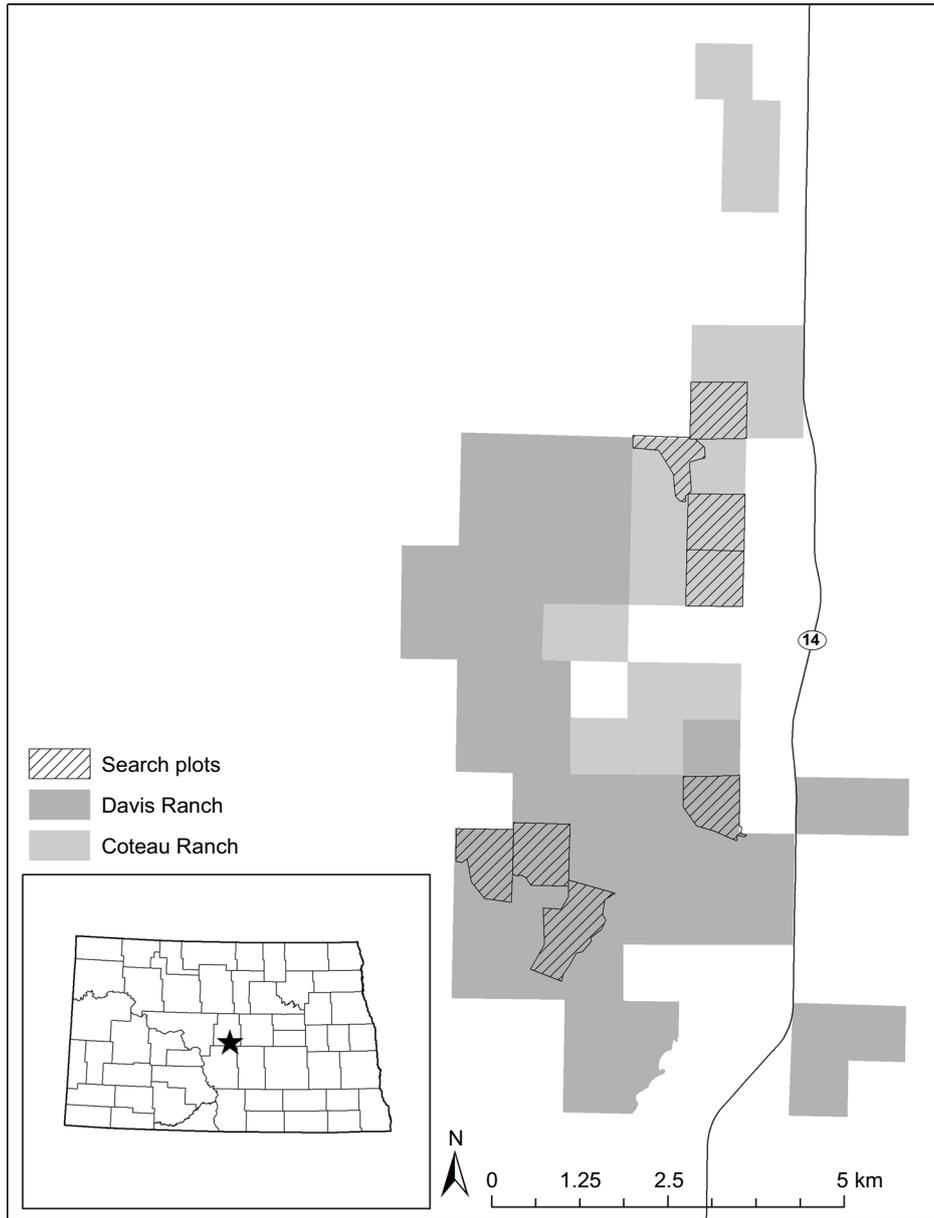


Fig. 1. Map of Coteau (light grey) and Davis Ranches (dark grey) in Sheridan County, North Dakota, USA with plots (~64 ha: hash marks) searched for waterfowl nests from 2016 to 2020.

camera box (SEAHORSE Protective Equipment Cases, Fuertes Cases, La Mesa, CA, USA) by a 25-m cable. Inside the camera boxes were a digital video recorder (DVR) which recorded video onto a 32-GB SD card and a remote control for the DVR. We used a tote vision (i.e. small LCD monitor) to view nests during camera setup to be sure the camera was functioning, recording had started and the nest was centred in the field of view. Batteries and camera boxes were placed ~25 m from nests to minimise possible effects on females and predators caused by equipment, battery, and SD card changes. This placement also allowed us to check

nests more frequently via tote vision and exchange batteries and SD cards without disturbing females. We removed cameras after eggs hatched or nests failed. We then deployed cameras at other nests if available.

Field evaluation of nest fate

Waterfowl nests with hatched eggs have eggshell membranes separated from shells. Nest failure is assumed when evidence of these membranes is absent in the nest bowl (Girard 1939; Klett et al. 1986). When this occurred, observers filled out a

predation card (Sargeant *et al.* 1998), recording information within a 3-m radius around the nest about the following variables:

1. The amount (percentage categories of: 0%, <1% (trace), 1–5%, 6–10%, 11–25%, 26–50%, 51–75%, and 76–100%) and displacement of nest materials >5 cm from the edge of nest bowl;
2. Number of cached or buried eggs, size and number of dug areas (holes or areas where soil has been disturbed and may have been piled or refilled with soil and/or debris);
3. Number and location of whole eggs;
4. Number of shell fragments (individual or connected pieces of $\leq 1/2$ egg);
5. Size (small hole = >3/4 of shape intact, large hole = >1/2–3/4 of shape intact, fractured = connected pieces of >1/2 egg but only 1/4–1/2 shape intact, trampled = connected pieces of >1/2 egg on flattened membrane and <1/4 shape intact, and crushed = >1/2 egg wadded in sphere and <1/4 shape intact) and position (side, end, or side and end) of holes on egg remains;
6. Signs of remains of either ducklings or adult females (Fig. 2).

We completed predation cards at all suspected depredated nests to facilitate comparison between efficacy of camera and a visual inspection of nest remains in identifying nest predators.

Field-evidence-based predator identification

We assigned predator identities to nests when characteristics of a predation event matched species-specific criteria identified by Sargeant *et al.* (1998). The original program developed by Sargeant *et al.* (1998) for determining predators from nest remains was written in SAS code. We rewrote this code in program R. According to Sargeant *et al.* (1998), a single nest might have signs consistent with multiple predator species, with similar or varying levels of confidence. Thus, this code assigns a predator to a nest ‘with confidence’ if all criteria are met for one species. However, if some but not all criteria are met, the predator is identified as ‘possible’, and this could result in more than one predator being ‘assigned’ to a nest. To address this potential issue, when a predator was assigned ‘with confidence’ to a nest, we removed any ‘possible’ predators from that same nest. When the Sargeant *et al.* (1998) program assigned a predator as ‘possible’ to a nest, and that nest had no ‘with confidence’ predator assigned, the possible predator was retained as the ‘field-evidence’ predator. In the rare instance ($N = 2$) that multiple possible predators were assigned, and no predator was determined with confidence, or two predators were assigned with confidence, we removed that nest from the dataset. For example, if a nest was assigned to an American badger (*Taxidea taxus*; hereafter badger) with confidence and

raccoon (*Procyon lotor*) as possible, we only considered the badger as the nest predator. In contrast, if a nest had no ‘with confidence’ assignment, but raccoon and striped skunk (*Mephitis mephitis*; hereafter skunk) were each assigned as ‘possible’, we labelled the nest as unknown in the analysis.

Video-evidence-based predator identification

Across all years, when we assumed predation or hatch from nest remains, we corroborated the event with video evidence. We then calculated the proportion of nests that had been correctly and incorrectly identified using the nest remains (Sargeant *et al.* 1998). We reviewed video recordings after nests failed or eggs hatched from the time cameras were installed to the time they were removed. While watching videos, we recorded nest fate, predator (if applicable), and number of eggs that hatched (if applicable).

Evaluation of field-based predator identification accuracy

The Sargeant *et al.* (1998) classification system was developed for applications in proportion of predators across the landscape rather than at specific nests. Therefore, we used a Cochran–Mantel–Haenszel (CMH) chi-squared test of independence to compare the proportion of destroyed nests assigned to each predator at the study area scale between predator identification methods, while accounting for sampling across years. Further, for camera-monitored nests and the program based on evidence of nest remains for all nests (which included nests without cameras), we tested for differences within each year using chi-squared tests. We considered P -values ≤ 0.05 to be significant.

Animal ethics

This research was conducted in compliance with the Guidelines to the Use of Wild Birds in Research. All nest searching and monitoring followed approved methods from the University of North Dakota’s Institutional Animal Care and Use Committee (#A3917-01, Protocols: 1505-10 and 1801-3C), permits from the North Dakota Game and Fish (2016: GNF7701, 2017: GNF8225, 2018: GNF04611027, 2019: GNF04912726, 2020: GNF05182785), and annual approval from The Nature Conservancy.

Results

Evidence of nest predators from nest remains

From 2016 to 2020, we located 989 nests, including 590 blue-winged teal nests, 236 gadwall nests, and 163 mallard nests. Of the 989 nests, eggs hatched in 163 (16.5%). We monitored 752 depredated nests and identified predators at 389, based on Sargeant *et al.* (1998). Criteria assigned 247 predators to

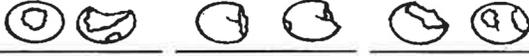
NEST DEPREDATION RECORD

ALL DESCRIPTORS PERTAIN TO EVIDENCE FOUND WITHIN A 3-M RADIUS OF NEST

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| | | % OF NEST MATERIAL PULLED OUT ON GROUND 23 <input type="checkbox"/> | % BY DISTANCE FROM NEST GROUND DISPLACED | | USE FOR ALL (0) NONE (1) TRACE (2) 1-5% (3) 6-10% (4) 11-25% (5) 26-50% (6) 51-75% (7) 76-100% | | |
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| | | 27 <input type="checkbox"/> ≤20 CM | 28 29 <input type="checkbox"/> <input type="checkbox"/> >20 CM - 1M | | | | |
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| <p style="text-align: center;">CACHED EGGS</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 15%; text-align: center;">IN NEST</th> <th style="width: 15%; text-align: center;">OUTSIDE NEST</th> <th style="width: 15%;"></th> </tr> <tr> <td style="text-align: center;">31 32 <input type="checkbox"/><input type="checkbox"/></td> <td style="text-align: center;">33 34 <input type="checkbox"/><input type="checkbox"/></td> <td style="text-align: center;">35 <input type="checkbox"/></td> </tr> </table> <p style="font-size: x-small;">SOIL DEPTH OVER DEEPEST EGG OUTSIDE NEST GIVE NUMBER; ENTER (0) IF NONE (0) NONE (1) ≤1 CM (2) >1 - 3 CM (3) >3 CM</p> | IN NEST | OUTSIDE NEST | | 31 32 <input type="checkbox"/> <input type="checkbox"/> | 33 34 <input type="checkbox"/> <input type="checkbox"/> | 35 <input type="checkbox"/> | <p style="text-align: center;">DUG AREAS</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 15%; text-align: center;">NUMBER</th> <th style="width: 15%; text-align: center;">WIDTH OF WIDEST</th> </tr> <tr> <td style="text-align: center;">36 37 <input type="checkbox"/><input type="checkbox"/></td> <td style="text-align: center;">38 <input type="checkbox"/></td> </tr> </table> <p style="font-size: x-small;">(1) 1-5 CM (2) 6-10 CM (3) 11-20 CM (4) >20 CM (0) NONE (99) UNCERTAIN BUT ≥1</p> | NUMBER | WIDTH OF WIDEST | 36 37 <input type="checkbox"/> <input type="checkbox"/> | 38 <input type="checkbox"/> | <p style="text-align: center;">WHOLE EGGS</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 15%; text-align: center;">IN NEST</th> <th style="width: 15%; text-align: center;">OUTSIDE NEST</th> </tr> <tr> <td style="text-align: center;">39 40 <input type="checkbox"/><input type="checkbox"/></td> <td style="text-align: center;">41 42 <input type="checkbox"/><input type="checkbox"/></td> </tr> </table> <p style="font-size: x-small;">NUMBER FOUND; ENTER (0) IF NONE</p> | IN NEST | OUTSIDE NEST | 39 40 <input type="checkbox"/> <input type="checkbox"/> | 41 42 <input type="checkbox"/> <input type="checkbox"/> | <p style="text-align: center;">INSTRUCTIONS BASED ON SHELL TYPES FOUND</p> <p style="text-align: center;">43 <input type="checkbox"/></p> <p style="font-size: x-small;">(0) NO SHELL(S) OR FRAGMENT(S); SKIP BOXES 44-76 (1) ONLY FRAGMENT(S); SKIP BOXES 44-53 AND BOXES 55-76 (2) ≥1 SHELL; FILL ALL REMAINING BOXES</p> |
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| <p style="text-align: center;">LOCATION OF OPENINGS IN EGGSHELLS</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%; text-align: center;">55 56 <input type="checkbox"/><input type="checkbox"/> SIDE</td> <td style="width: 15%; text-align: center;">57 58 <input type="checkbox"/><input type="checkbox"/> END</td> <td style="width: 15%; text-align: center;">59 60 <input type="checkbox"/><input type="checkbox"/> SIDE-END</td> </tr> </table> <p style="font-size: x-small;">NUMBER OF EACH TYPE; ENTER (0) IF NONE</p>  | 55 56 <input type="checkbox"/> <input type="checkbox"/> SIDE | 57 58 <input type="checkbox"/> <input type="checkbox"/> END | 59 60 <input type="checkbox"/> <input type="checkbox"/> SIDE-END | <p style="text-align: center;">SHELLS WITH MULTIPLE OPENINGS</p> <p style="text-align: center;">61 62 <input type="checkbox"/><input type="checkbox"/></p> <p style="font-size: x-small;">NUMBER OF SHELLS WITH ≥2 OPENINGS; ENTER (0) IF NONE</p>  | <p style="text-align: center;">SHELLS WITH CONTENTS</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%; text-align: center;">63 64 <input type="checkbox"/><input type="checkbox"/> CLEAN</td> <td style="width: 15%; text-align: center;">65 66 <input type="checkbox"/><input type="checkbox"/> CONSPICUOUS YOLK BUT <1/4 CONTENTS PRESENT</td> <td style="width: 15%; text-align: center;">67 68 <input type="checkbox"/><input type="checkbox"/> CONSPICUOUS YOLK AND ≥1/4 CONTENTS PRESENT</td> </tr> </table> <p style="font-size: x-small;">GIVE NUMBER; ENTER (0) IF NONE</p> | 63 64 <input type="checkbox"/> <input type="checkbox"/> CLEAN | 65 66 <input type="checkbox"/> <input type="checkbox"/> CONSPICUOUS YOLK BUT <1/4 CONTENTS PRESENT | 67 68 <input type="checkbox"/> <input type="checkbox"/> CONSPICUOUS YOLK AND ≥1/4 CONTENTS PRESENT |
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| <p style="text-align: center;">SHELL LOCATIONS</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%; text-align: center;">69 70 <input type="checkbox"/><input type="checkbox"/> IN NEST</td> <td style="width: 15%; text-align: center;">71 72 <input type="checkbox"/><input type="checkbox"/> EDGE - 20 CM FROM NEST</td> <td style="width: 15%; text-align: center;">73 74 <input type="checkbox"/><input type="checkbox"/> >20 CM - 1M FROM NEST</td> <td style="width: 15%; text-align: center;">75 76 <input type="checkbox"/><input type="checkbox"/> >1 - 3M FROM NEST</td> </tr> </table> <p style="font-size: x-small;">NUMBER IN EACH CATEGORY; ENTER (0) IF NONE</p> | 69 70 <input type="checkbox"/> <input type="checkbox"/> IN NEST | 71 72 <input type="checkbox"/> <input type="checkbox"/> EDGE - 20 CM FROM NEST | 73 74 <input type="checkbox"/> <input type="checkbox"/> >20 CM - 1M FROM NEST | 75 76 <input type="checkbox"/> <input type="checkbox"/> >1 - 3M FROM NEST | <p style="text-align: center;">DEAD HEN OR DUCKLING(S)</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%; text-align: center;">77 <input type="checkbox"/> HEN</td> <td style="width: 15%; text-align: center;">78 <input type="checkbox"/> DUCKLINGS</td> </tr> </table> <p style="font-size: x-small;">(0) NO EVIDENCE OF DEATH OF DEATH (1) LOOSE FEATHERS OR BLOOD (2) CARCASS PARTS WITH HEAD ATTACHED (3) CARCASS PARTS WITH HEAD DETACHED (4) WHOLE CARCASS NUMBER FOUND DEAD (0) NONE (1-8) NUMBER (9) ≥9</p> | 77 <input type="checkbox"/> HEN | 78 <input type="checkbox"/> DUCKLINGS | <p style="text-align: center;">PREDATOR SPECIES</p> <p style="text-align: center;">79 <input type="checkbox"/></p> <p style="font-size: x-small;">(Y) IF POSITIVELY KNOWN SPECIES _____</p> | <p style="text-align: center;">COMMENTS</p> <p style="text-align: center;">80 <input type="checkbox"/></p> <p style="font-size: x-small;">(1) IMPORTANT COMMENTS PROVIDED</p> |
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| 77 <input type="checkbox"/> HEN | 78 <input type="checkbox"/> DUCKLINGS | | | | | | | | |

Sargeant et al.

Appendix D, Figure 1. Format recommended in the Prairie Pothole Region for recording evidence of depredation found at duck nests destroyed by predators.

REV. 5%

Fig. 2. Picture of nest predation card taken from Sargeant et al. (1998) for recording evidence at waterfowl nests destroyed by predators.

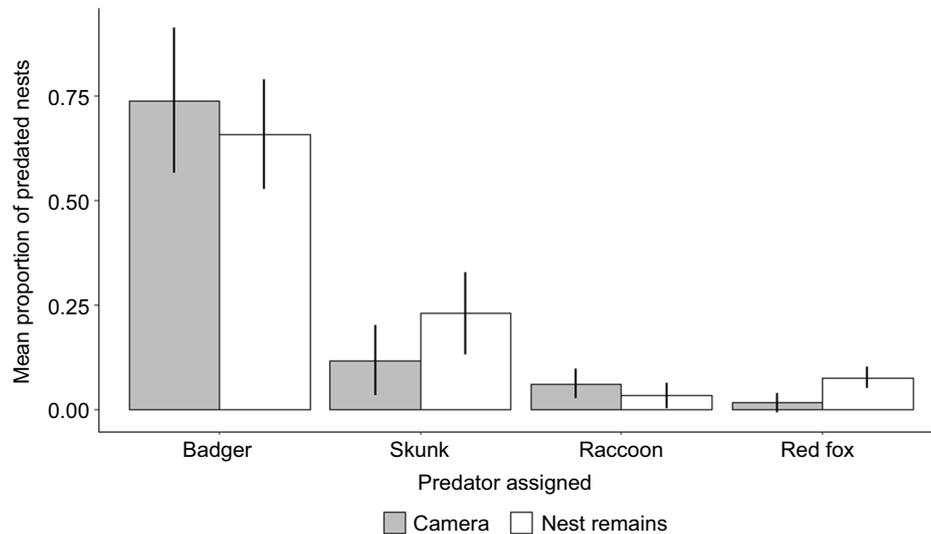


Fig. 3. Bar plot comparing the average proportion (\pm s.d.) of predators of waterfowl nests attributed to each method (camera: light grey, nest remains: white) from 2016 to 2020 on Coteau and Davis Ranches in Sheridan County, North Dakota, USA.

nests ‘with confidence’ and assigned ‘possible’ predators to 142 nests. Of the 389 predators identified, the [Sargeant *et al.* \(1998\)](#) criteria predicted that at least 50% were badgers during each year of our study (range = 50.0% [2020]–81.5% [2017]), with skunks being the second-most common predator (range = 12.7% [2016]–35.0% [2020]). Red foxes (*Vulpes vulpes*; hereafter fox) and raccoons were classified as the third and fourth most abundant predators, respectively ([Fig. 3](#)).

Video evidence of nest predators

We deployed cameras at 249 nests. Of camera-monitored nests, we removed cameras at 67 before determining nest fate due to either camera failure or other circumstances (e.g. cattle grazing). For camera nests where we determined fate ($N = 182$; [Table 1](#)), eggs successfully hatched in 45 nests (apparent nest success = 24.7%), five nests were abandoned (2.7%), and the remaining 132 (72.5%) were consumed

Table 1. Number of camera-monitored waterfowl nests where a hatch or predation event was observed, separated by year and species.

| Year ^A | Blue-winged teal | Mallard | Gadwall | Total |
|-------------------|------------------|---------|---------|----------|
| 2016 | 26 (100) | 9 (33) | 0 (59) | 35 (192) |
| 2017 | 11 (84) | 18 (49) | 0 (51) | 29 (184) |
| 2018 | 12 (74) | 10 (35) | 11 (35) | 33 (144) |
| 2019 | 17 (127) | 4 (29) | 10 (31) | 31 (187) |
| 2020 | 26 (205) | 5 (17) | 23 (60) | 54 (282) |

Total number of nests monitored regardless of camera presence in parentheses. ^AData were collected on Coteau and Davis Ranches in Sheridan County, North Dakota, USA from 2016 to 2020.

by predators. We accurately determined nest fate (hatch or failure) at 98% of nests with a camera ($N = 129$), using evidence at nests. We misclassified nest fate at three nests (2%) because membranes were present, but camera footage revealed that predation by a badger occurred mid-hatch.

Predators observed on camera included badgers, skunks, raccoons, red foxes, ground squirrels (*Urocyon richardsonii* and *Poliocitellus franklinii*), coyotes (*Canis latrans*), weasels (*Mustela* spp.), and white-tailed deer (*Odocoileus virginianus*). Using cameras to confirm predator identity, we determined that, with sufficient evidence (50% of nests), the [Sargeant *et al.* \(1998\)](#) criteria correctly predicted the predator at 69.7% of failed nests and incorrectly identified 30.3% of predators. Overall, the [Sargeant *et al.* \(1998\)](#) criteria allowed us to correctly predict predator identity at 34.8% of nests. Of the four main species we assessed using the [Sargeant *et al.* \(1998\)](#) criteria, our data suggested that raccoons were most likely to be misclassified ([Table 2](#)).

Evaluation of field-based predator identification accuracy

Across the study area, proportions of nest predators determined using the [Sargeant *et al.* \(1998\)](#) classification system were different from those determined using nest cameras ($N = 514$, $\chi^2 = 16.55$, d.f. = 3, $P < 0.05$). Results of within-year tests suggested that differences between the methods were greatest in 2020 (2016: $N = 93$, $\chi^2 = 7.11$, d.f. = 3, $P = 0.07$; 2017: $N = 103$, $\chi^2 = 2.27$, d.f. = 3, $P = 0.52$; 2018: $N = 81$, $\chi^2 = 7.43$, d.f. = 3, $P = 0.06$; 2019: $N = 90$, $\chi^2 = 1.90$, d.f. = 3, $P = 0.59$; 2020: $N = 147$, $\chi^2 = 16.11$, d.f. = 3, $P < 0.05$).

Table 2. Number of predations of waterfowl nests attributed to badger, red fox, raccoon, and skunk based on camera evidence versus evidence from nest remains (Sargeant et al. 1998).

| | Camera evidence | | | | |
|-----------------------|-----------------|---------|---------|-------|-------|
| | Badger | Red fox | Raccoon | Skunk | Other |
| Nest remains | | | | | |
| Badger | 42 | 0 | 2 | 2 | 1 |
| Red fox | 3 | 0 | 2 | 0 | 0 |
| Raccoon | 0 | 0 | 1 | 1 | 0 |
| Skunk | 8 | 0 | 0 | 3 | 1 |
| Insufficient evidence | 47 | 2 | 3 | 9 | 5 |

'Other' includes ground squirrels, coyotes, weasels, and white-tailed deer. Italicised boxes represent the number of nests that were identified correctly by remains in the field. Data were collected from 2016 to 2020 on Coteau and Davis Ranches in Sheridan County, North Dakota, USA.

Discussion

We conducted an empirical evaluation of the Sargeant et al. (1998) classification system's accuracy for fating nests and identifying nest predators of waterfowl. Our field-based estimates of nest fate accuracy (98%) were higher than those reported in previous studies of snowy plovers (*Charadrius nivosus*: Ellis et al. 2018: 84%), grassland-nesting passerines (Pietz and Granfors 2000: 85%), wood thrushes (*Hylocichla mustelina*: Williams and Wood 2002: 85%), and boreal-forest songbirds (Ball and Bayne 2012: 85%). Causes of misclassification in these studies included removal of eggshells by adults, size of remaining fragments, terrain surrounding nests, partial nest predation, and removal of eggs by large predators (Pietz and Granfors 2000; Ball and Bayne 2012; Ellis et al. 2018). Although we also encountered some of the challenges mentioned by these other studies, the only errors observed in our study were caused by a predator eating ducklings while they were hatching. Even these misclassifications could have been considered correct because ducklings were in the process of emerging from the eggs at the time of predation. We hypothesise that the larger eggs and clutch sizes of waterfowl compared with passerines and shorebirds might provide more evidence post-predation.

Although highly accurate (98%) for identifying waterfowl nest fates, the Sargeant et al. (1998) classification system was less clear-cut regarding predator identification. When sufficient evidence was available, estimates of accuracy for predator identification at the scale of individual nests were relatively high compared with those in previous studies (e.g. Williams and Wood 2002: 43%, Staller et al. 2005: 30% vs 69.7% in our study). However, based on Sargeant et al. (1998), 50% of the nests we examined via camera ($N = 66$) had insufficient evidence to assign a predator species. Many of those were removed early in the classification process because they had too few eggs (less than the

six eggs) to provide evidence for identifying behavioural patterns of predation (Sargeant et al. 1998). Video footage revealed on several occasions that the low egg count was due to removal of eggs from nests by smaller predators (e.g. ground squirrels) or predation of nests before six eggs were laid. Although useful for eliminating sources that provide poor to no data, removing nests from the classification process due to insufficient evidence could unintentionally eliminate predators in a biased manner, suggesting that caution is needed when using this method for predator identification.

The Sargeant et al. (1998) classification system was developed as an approach to determine study site-level predation rates, suggesting that higher levels of accuracy might be expected at this scale. However, based upon the results of our pooled tests we also recommend that investigators should apply Sargeant et al. (1998) at the study area scale with equal amounts of caution. Although the Sargeant et al. (1998) classification system did identify badgers and skunks as the first and second-most abundant predators, it placed a heavier emphasis on red foxes and striped skunks than the camera data. Incidentally, these two predators were also the ones for which Sargeant et al. (1998) were able to obtain the highest sample size for verification data in their development of the classification system, which might play a role in this observed bias.

Based on our observations, some misclassifications likely occurred because the assumptions about predator behaviour made using the classification system were not fully supported. For example, according to Sargeant et al. (1998), dug areas were supposed to occur at almost 100% of badger predations, but we saw evidence of this behaviour at less than 40% of our nests where we observed badgers on camera ($N = 100$). Our observations at badger-depredated nests also suggest that other behaviours, like the size or position of holes left in eggs, might be more helpful in accurately identifying badgers as predators. At nests destroyed by badgers, we found large holes in 70% of eggs and those holes were mostly commonly located on the side of the eggs (67% of nests).

Because of the large number of misclassifications, the current Sargeant et al. (1998) criteria are likely to be unreliable for providing researchers with information about the proportion of predators in the study area population. The only reliable use of this system would be for identifying nest fate. However, it may be possible to improve field protocols such as those of Sargeant et al. (1998) by using camera observations at the nest to enhance our understanding of predator behaviours. To do this, cameras will need to be positioned with a field of view to capture predator behaviours both in the nest bowl and in the surrounding areas where behaviours like digging or caching may occur. Alternatively, recent studies have demonstrated that DNA from saliva samples can be used to identify predators of ground-nesting birds (Hopken et al. 2016), although this approach might not be as accessible. We recommend the continued use of camera studies and

exploration of DNA-based identification where possible, and suggest that investigators in future studies explore the possibility of improving the Sargeant *et al.* (1998) criteria using data collected with video cameras.

References

- Andes AK, Shaffer TL, Sherfy MH, Hofer CM, Dovichin CM, Ellis-Felege SN (2019) Accuracy of nest fate classification and predator identification from evidence at nests of least terns and piping plovers. *Ibis* **161**, 286–300. doi:10.1111/ibi.12629
- Anthony RM, Grand JB, Fondell TF, Manly BFJ (2004) A quantitative approach to identifying predators from nest remains. *Journal of Field Ornithology* **75**, 40–48. doi:10.1648/0273-8570-75.1.40
- Ball JR, Bayne EM (2012) Using video monitoring to assess the accuracy of nest fate and nest productivity estimates by field observation. *The Auk* **129**, 438–448. doi:10.1525/auk.2012.11224
- Blythe EM, Boyce MS (2020) Trappings of success: predator removal for duck nest survival in Alberta parklands. *Diversity* **12**, 119. doi:10.3390/d12030119
- Burnam JS (2008) Using continuous video to monitor patterns of nest defense and incubation behavior in northern bobwhites *Colinus virginianus*. MS thesis, University of Georgia, Athens, GA, USA.
- Burr PC, Robinson AC, Larsen RT, Newman RA, Ellis-Felege SN (2017) Sharp-tailed grouse nest survival and nest predator habitat use in North Dakota's Bakken oil field. *PLoS One* **12**, e0170177. doi:10.1371/journal.pone.0170177
- Cox WA, Pruett MS, Benson TJ, Chiavacci SJ, Thompson FR III (2012) Development of camera technology for monitoring nests. In 'Video Surveillance of Nesting Birds'. (Eds CA Ribic, FR Thompson III, PJ Pietz) pp. 185–210. Studies in Avian Biology No. 43. (University of California Press: Berkeley, CA, USA)
- Ellis KS, Cavitt JF, Larsen RT, Koons DN (2018) Using remote cameras to validate estimates of nest fate in shorebirds. *Ibis* **160**, 681–687. doi:10.1111/ibi.12607
- Ellis-Felege SN, Carroll JP (2012) Gamebirds and nest cameras: present and future. In 'Video Surveillance of Nesting Birds'. (Eds CA Ribic, FR Thompson III, PJ Pietz), pp. 35–44. Studies in Avian Biology No. 43. (University of California Press: Berkeley, CA, USA)
- Girard GL (1939) Life history of the shoveler. In 'Transactions of the 14th North American Wildlife Conference', Vol. 4. pp. 364–371. (Wildlife Management Institute: Washington, DC, USA)
- Hopken MW, Orning EK, Young JK, Piaggio AJ (2016) Molecular forensics in avian conservation: a DNA-based approach for identifying mammalian predators of ground-nesting birds and eggs. *BMC Research Notes* **9**, 14. doi:10.1186/s13104-015-1797-1
- Klett AT, Duebbert HF, Faanes CA, Higgins KF (1986) Techniques for studying nest success of ducks in upland habitats in the Prairie Pothole Region. Resource Publication 158. United States Department of the Interior Fish and Wildlife Service, Washington, DC, USA. Available at <https://apps.dtic.mil/sti/pdfs/ADA323206.pdf> [Accessed 20 April 2021]
- Lariviere S (1999) Reasons why predators cannot be inferred from nest remains. *The Condor* **101**, 718–721. doi:10.2307/1370209
- Opermanis O, Mednis A, Bauga I (2001) Duck nests and predators: interaction, specialisation and possible management. *Wildlife Biology* **7**, 87–96. doi:10.2981/wlb.2001.012
- Pietz PJ, Granfors DA (2000) Identifying predators and fates of grassland passerine nests using miniature video cameras. *The Journal of Wildlife Management* **64**, 71–87. doi:10.2307/3802976
- Pietz PJ, Granfors DA, Ribic CA (2012) Knowledge gained from video-monitoring grassland passerine nests. In 'Video Surveillance of Nesting Birds'. (Eds CA Ribic, FR Thompson III, PJ Pietz) pp. 3–22. Studies in Avian Biology No. 43. (University of California Press: Berkeley, CA, USA)
- Prinz ACB, Taank VK, Voegeli V, Walters EL (2016) A novel nest-monitoring camera system using a Raspberry Pi micro-computer. *Journal of Field Ornithology* **87**, 427–435. doi:10.1111/jof.12182
- Ribic CA, Thompson FR, Pietz PK (Eds) (2012) 'Video Surveillance of Nesting Birds.' Studies in Avian Biology No. 43. (University of California Press: Berkeley, CA, USA)
- Robel RJ, Briggs JN, Dayton AD, Hulbert LC (1970) Relationships between visual obstruction measurements and weight of grassland vegetation. *Journal of Range Management* **23**, 295–297. doi:10.2307/3896225
- Sargeant AB, Sovada MA, Greenwood RJ (1998) Interpreting evidence of depredation at duck nests in the Prairie Pothole Region. US Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND, USA.
- Sherfy MH, Anteau MJ, Shaffer TL, Johnson MA, Reynolds RE, Ringelman JK (2018) Density and success of upland duck nests in native- and tame-seeded conservation fields. *Wildlife Society Bulletin* **42**, 204–212. doi:10.1002/wsb.880
- Staller EL, Palmer WE, Carroll JP, Thornton RP, Sisson DC (2005) Identifying predators at northern bobwhite nests. *Journal of Wildlife Management* **69**, 124–132. doi:10.2193/0022-541X(2005)069<0124:IPANBN>2.0.CO;2
- Thompson FR, Dijak W, Burhans DE (1999) Video identification of predators at songbird nests in old fields. *The Auk* **116**, 259–264. doi:10.2307/4089477
- Weidinger K (2008) Identification of nest predators: a sampling perspective. *Journal of Avian Biology* **39**, 640–646. doi:10.1111/j.1600-048X.2008.04418.x
- Weller MW (1956) A simple field candler for waterfowl eggs. *The Journal of Wildlife Management* **20**, 111–113. doi:10.2307/3797414
- Williams GE, Wood PB (2002) Are traditional methods of determining nest predators and nest fates reliable? An experiment with wood thrushes (*Hylocichla mustelina*) using miniature video cameras. *The Auk* **119**, 1126–1132. doi:10.1093/auk/119.4.1126

Data availability. Predation data and R code are available upon request. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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