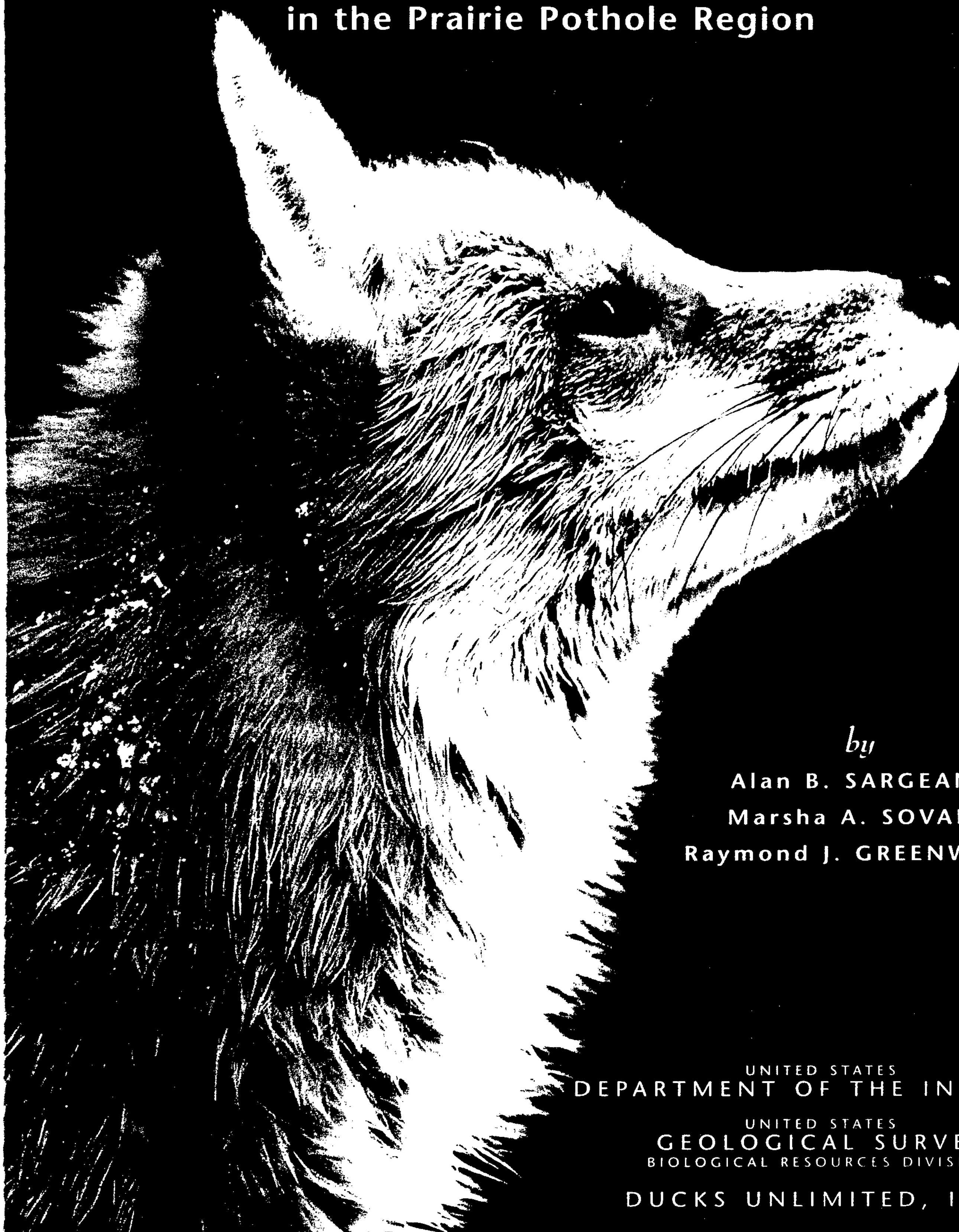
INTERPRETING EVIDENCE *of* DEPREDATION *of* DUCK NESTS in the Prairie Pothole Region



by

Alan B. SARGEANT

Marsha A. SOVADA

Raymond J. GREENWOOD

UNITED STATES
DEPARTMENT OF THE INTERIOR

UNITED STATES
GEOLOGICAL SURVEY
BIOLOGICAL RESOURCES DIVISION

DUCKS UNLIMITED, INC.

Sargeant, A. B., M. A. Sovada, and R. J. Greenwood. 1998. Interpreting evidence of depredation of duck nests in the prairie pothole region. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND and Ducks Unlimited, Inc., Memphis, TN. 72pp.

1998

Interpreting Evidence *of* Depredation *of* Duck Nests in the Prairie Pothole Region

By

Alan B. Sargeant

Marsha A. Sovada

Raymond J. Greenwood

UNITED STATES DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY, BIOLOGICAL RESOURCES DIVISION

DUCKS UNLIMITED, INC.

Table of Contents

Interpreting Evidence of Depredation of Duck Nests in the Prairie Pothole Region

by
Alan B. Sargeant
Marsha A. Sovada
Raymond J. Greenwood

United States Geological Survey
Biological Resources Division
Northern Prairie Wildlife Research Center
8711 37th Street Southeast
Jamestown, North Dakota 58401

Abstract

We examined patterns of depredation of duck nests by 9 species and 2 congeneric species-groups of predators in the Prairie Pothole Region: coyote (*Canis latrans*), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), American badger (*Taxidea taxus*), mink (*Mustela vison*), weasels (ermine [*M. erminea*] and long-tailed weasel [*M. frenata*]), Franklin's ground squirrel (*Spermophilus franklinii*), black-billed magpie (*Pica pica*), American crow (*Corvus brachyrhynchos*), and gulls (ring-billed gull [*Larus delawarensis*] and California gull [*L. californicus*]). We discuss factors affecting amount and types of evidence of depredation left by predators at duck nests, including characteristics of eggs and nest sites, behavior of ducks and predators, anatomy and size of predators, and effects of other animals. Accounts of depredation patterns of individual predator species and species-groups are provided and include summaries of positive and negative indicators of depredation. Information presented is mostly from studies we conducted during 1972-92, which involved offering duck eggs to captive and free-ranging predators and monitoring responses by direct observation, time-lapse camera, or revisiting sites. Variables of depredation were quantified on nest depredation records and included disturbances of eggs, ground surface, and nest material. Patterns of depredation of some predator species varied little (e.g., red fox) but patterns of others varied greatly (e.g., coyote). There was much overlap of patterns among some predator species (e.g., Franklin's ground squirrel, weasels). A format with instructions for preparing nest depredation records is provided. Recommendations for interpreting depredation records are discussed. We applied recommendations to 389 depredation records from waterfowl production areas in Minnesota, North Dakota, and South Dakota and discuss outcomes of that exercise.

Key words: duck clutches, duck eggs, duck nests, evidence of depredation, nest depredation record, nest success, predation, predators, Prairie Pothole Region.

Introduction

Factors affecting duck production in the Prairie Pothole Region (Fig. 1) are of special interest to researchers and managers of waterfowl, because the region is a major breeding ground for North American ducks (Smith et al. 1964, Bellrose 1980). Biologists, concerned about the welfare of prairie ducks, began investigating nest success of these birds in the 1930's (Kalmbach 1937a, 1937b, 1938, 1939). Through these initial and subsequent studies, fates of >25,000 duck nests have been determined (Sargeant and Raveling 1992).

High predation rates of female ducks and nests (Klett et al. 1988, Higgins et al. 1992, Sargeant and Raveling 1992, Greenwood et al. 1995) stimulated interest in identifying the predator species. As a result, literature of duck nest success often includes general (Keith 1961, Higgins 1977) or specific (Stoudt 1971, Duebbert and Lokemoen 1976, Higgins et al. 1992) assignments of depredated nests to predator species. Waterfowl managers need to identify predator species responsible for nest depredations to develop strategies to reduce predation. However, nearly all assignments of destroyed nests to predator species are based on subjective interpretations of evidence found at nests.

Investigators have recognized the difficulty of interpreting evidence of depredation and "...the necessity of correctly reading signs (of predators) at destroyed nests" (Kalmbach 1937a:5). Although several studies provide interpretive evidence of depredation, available information is meager, often ambiguous, and sometimes contradictory (Baker 1978, Appendix A). Because literature on identification of predators of duck nests may be erroneous and lack specific criteria for identifying predators, it cannot be evaluated for accuracy.

We believe that identification of predators of duck nests, based on evidence found at nests, will be valuable to researchers and managers. However, for such information to be useful, it must be collected and interpreted more objectively than in the past. The primary purpose of this report is to help investigators more accurately and objectively collect and interpret evidence of depredation at duck nests in the Prairie Pothole Region. Our report is divided into 3 parts:

I: A summary of biological factors that affect evidence of depredation typically found at duck nests.

II: A summary of literature and our experiences concerning evidence of depredation by predator species.

III: A discussion of interpreting evidence of depredation at duck nests, with examples for certain predators.

This report pertains primarily to duck nests in uplands or dry portions of wetlands. We use subjective terms to describe frequency of most predator behaviors because of a general lack of definitive data. When possible (based on data and personal observations), we use the following *italicized* terms to convey general categories of frequency: *seldom* or *occasionally* = ≤10%, *often* = 11-50%, *usually* = 51-90%, and *customarily* = ≥91%. We use "at nest" or "nest site" to refer to the 3-m radius area around nests, and "near nest" to refer to the radius interval 3-20 m from nests. We include a glossary for clarification of certain terms. We urge readers to become familiar with definitions in the glossary before proceeding. A format for recording evidence of depredation is provided in Appendix D.

Preceding Page Blank

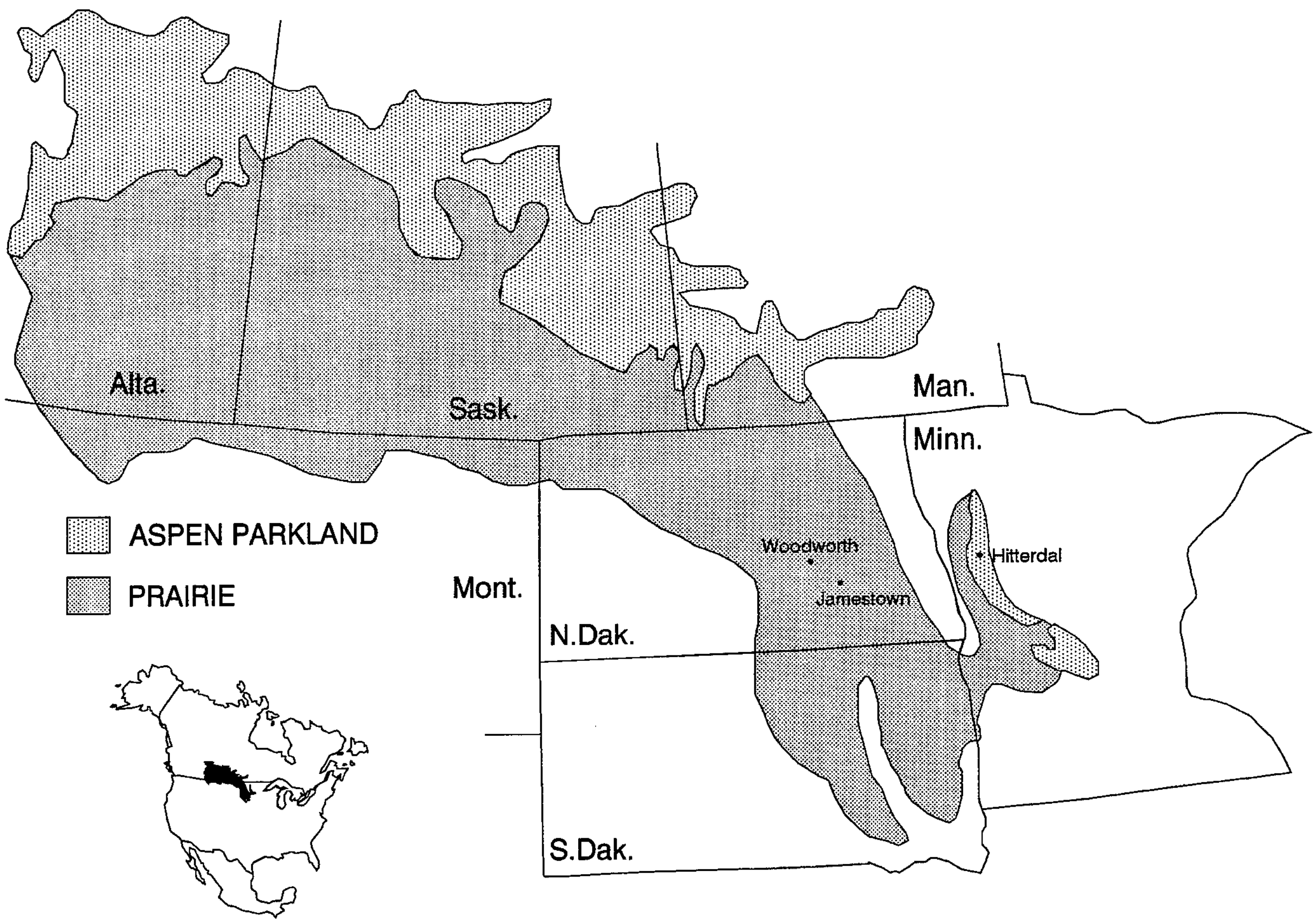


Figure 1. Contemporary Prairie Pothole Region with prairie and aspen parkland zones (adapted from Kiel *et al.* 1972 and Mann 1974).

Reference Area and Predator Species

The contemporary Prairie Pothole Region, including prairie and aspen parkland zones, extends from west central Minnesota and southeastern South Dakota to central Alberta and encompasses about 800,000 km^2 (Fig. 1). Breeding ducks are distributed throughout the region (Bellrose 1980). Common species are American wigeon (*Anas americana*), gadwall (*A. strepera*), North American green-winged teal (*A. crecca carolinensis*), mallard (*A. platyrhynchos*), northern pintail (*A. acuta*), blue-winged teal (*A. discors*), northern shoveler (*A. clypeata*), canvasback (*Aythya valisineria*), redhead (*A. americana*), lesser scaup (*A. affinis*), and ruddy duck (*Oxyura jamaicensis*) (Bellrose 1980). All species *customarily* nest in uplands except canvasback, redhead, and ruddy duck, which *customarily* nest over water.

Nine species and 2 congeneric species-groups of predators with potential to destroy duck nests in the Prairie Pothole Region (Sargeant et al. 1993) are treated herein (hereafter called principal predators). The 9 species are coyote (*Canis latrans*), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), American badger (*Taxidea taxus*), mink (*Mustela vison*), Franklin's ground squirrel (*Spermophilus franklinii*), black-billed magpie (*Pica pica*), and American crow (*Corvus brachyrhynchos*). The 2 congeneric species-groups are weasels (ermine [*Mustela erminea*] and long-tailed weasel [*M. frenata*]) and gulls (ring-billed gull [*Larus delawarensis*] and California gull [*L. californicus*]).

Other animals that may *occasionally* destroy duck nests at widely scattered sites in the Prairie Pothole Region or that may *often* destroy duck nests in a few localities in the region include the following. Cats (*Felis catus*) and dogs (*Canis familiaris*) occur at rural residences throughout the region but *seldom* eat duck eggs (Stoddard 1932, Darrow 1938, Riggert 1977, Figley and VanDruff 1982). Thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*) occur throughout the region (Hall 1981) and eat bird eggs (Lein 1968, Creighton 1971, Graul 1972). However, they *seldom* depredate duck nests because of the large size and thick shell of the eggs (Errington 1938, Sowls 1948, Sargeant *et al.* 1987). Norway rats (*Rattus norvegicus*) eat duck eggs (Anderson 1957) and are widely distributed throughout the region (Jones *et al.* 1983). However, they live primarily in refuse sites near human habitation (Jones *et al.* 1983), where few ducks nest. The northern harrier (*Circus cyaneus*), a common raptor throughout the region (Sargeant *et al.* 1993), *occasionally* preys on pipping duck eggs (Willms and Kreil 1984). The gray wolf (*Canis lupus*), gray fox (*Urocyon cinereoargenteus*), black bear (*Ursus americanus*), spotted skunk (*Spilogale putorius*), and river otter (*Lutra canadensis*) have potential to destroy many duck nests but occur in few localities in the region (Stoddard 1932, Darrow 1938, Banfield 1974, Hall 1981, Jones *et al.* 1983, Sargeant *et al.* 1993). The common raven (*Corvus corax*), a noted depredator of duck nests (Einarsen 1956, Jarvis and Harris 1971, Stiehl and Trautwein 1991), occurs only in scattered sites, mostly along the northern edge of the region (Sargeant *et al.* 1993). The bullsnake (*Pituophis melanoleucus*), another depredator of duck nests (Imler 1945, Glup and McDaniel 1988), occurs only in scattered sites in the southeastern portion of the region (Conant 1958).

Part I: Factors Affecting Evidence of Depredation

In Part I, we discuss certain factors affecting evidence of depredation found at duck nests destroyed by predators, or that cause variation in evidence left by individual predator species.

Characteristics of Eggs

Duck eggs are oblong and usually lie on their side in nests or outside nests when displaced by predators. Consequently, predators open most duck eggs on the side, unless the predator has special egg-holding (e.g., raccoon [Jones *et al.* 1983]) or egg-opening (e.g., Franklin's ground squirrel [Sowls 1948]) behaviors.

Contents of duck eggs change from liquid albumen and yolk to a fully-developed embryo during the approximate 25-day incubation period (Bellrose 1980). The change is especially rapid during the last 10 days of incubation (Weller 1956). Also, eggshells become brittle late in incubation (Terres 1980). Thus, the greatest damage to shells is likely to occur when eggs are depredated late in incubation.

Size of duck eggs and shell thickness vary. For example, the average mallard egg is 1.9 times heavier and the shell is 1.2 times thicker than the average blue-winged teal egg (Mallory and Weatherhead 1990). Egg size influences ability of a predator (especially small species) to transport and/or open the egg, the number of eggs taken and amount of egg contents eaten, and the probability that eggs will be removed from the nest site. Montevecchi (1976) found that American crows were less likely to transport, and more likely to open at acquisition sites, large rather than small poultry eggs. Thickness of the shell affects ability of predators to open eggs, as well as the amount of fracturing of shell during consumption of contents. Fleskes (1988) found that weasels had greater difficulty opening eggs of wood ducks (*Aix sponsa*) and mallards than opening the smaller and thinner-shelled eggs of blue-winged teals.

Characteristics of Nests and Nest Sites

Most duck nests in uplands change from a shallow depression with little nest material and no down when the first egg is laid, to a well-constructed bowl of vegetation, down, and other small feathers when incubation starts (Sowls 1955). Down and other small feathers are gradually added after a few eggs are laid but may not be abundant until incubation starts (Bellrose 1980). Hens have more down to pluck during their initial nesting attempt than when renesting. Thus, potential for obtaining information about predator displacement of nest material is greater for nests destroyed after most eggs are laid, and greater for first nests than renests.

Number of eggs present when a duck nest is destroyed affects amount and quality of evidence likely to be found at the nest. As each egg is depredated, the pattern of depredation becomes more evident and chances of finding evidence to implicate the predator species increases.

Location of a nest affects vulnerability of the nest to individual predator species. For example, Franklin's ground squirrels seldom venture into areas of short or sparse vegetation or into water (Choromanski-Norris *et al.* 1989). Location of a nest also affects amount and types of evidence likely to be found at the nest. Eggs and eggshells from nests over water may be pushed into the water and sink or float away. Moreover, eggshells at over-water nests are more likely to be trampled than are eggshells at nests in uplands, because predators are usually on the platform of an over-water nest when eating at the site.

Vegetation at duck nests may influence amount and types of evidence of depredation left at nests, because predators can maneuver around nests more easily in short, fine-stemmed vegetation than in tall, robust vegetation. Also, density and structure of vegetation at the nest may result in predators choosing different places to eat eggs (e.g., in nest, along trail to nest). These factors may affect number and arrangement of eggshells at nests, distance of eggshells from nests, and degree of trampling of eggshells and vegetation at nests.

Behavior of Ducks

Behavior of hens attending nests may affect evidence of depredation in several ways. During egg-laying, the hen is on the nest for only a few hours each day (Sowls 1955, Gloutney *et al.* 1993). During incubation, she tends to remain on the nest all day, except for short recesses (Afton and Paulus 1992, Gloutney *et al.* 1993). After the first few eggs are laid and throughout incubation, the hen *customarily* covers the eggs with nest material before departing. When the hen is flushed by a predator, the eggs are left uncovered. Whether or not eggs are covered with nest material when depredated may affect amount of the nest material displaced by the predator.

Hens often continue to attend nests after a clutch has been partially depredated (Fleskes 1988). This behavior can affect number and location of the eggshells, as well as appearance of the nest after a clutch is destroyed. Sowls (1955) reported instances of northern pintails and northern shovelers carrying eggshells from nests partially depredated by Franklin's ground squirrels. A blue-winged teal was observed carrying an eggshell from a partially depredated nest at Audubon National Wildlife Refuge, North Dakota (T. D. Kostinec, Audubon National Wildlife Refuge, Coleharbor, ND, pers. commun.). Also, whole eggs (Sowls 1955) or nest material (unpubl. data) displaced during partial depredation of a nest may be returned to the nest by the hen.

Behavior of Predators

Variation exists within predator species in how individuals depredate nests. Our tests with captive striped skunks (discussed later) showed that a skunk opened half of the eggs on an end. This occurrence was about 3 times more often than the 3 other skunks tested. Variation of this type complicates correct identification of offending predators.

Evidence found at nests with eggs destroyed by juvenile predators may differ from that found for eggs destroyed by adults, because juvenile predators are smaller and less experienced in handling eggs. By early to mid-June, juvenile red foxes have potential to destroy nests near their dens, especially in the southern portion of the region where whelping dates are earliest (Sargeant 1978, Sargeant *et al.* 1981). Juvenile American crows have potential to depredate nests in late June, when they begin to fledge (Ignatiuk and Clark 1991). Juvenile striped skunks and juvenile American badgers have potential to depredate duck nests in early July, when they begin to travel independently (unpubl. data and pers. observations).

Sometimes a predator will leave scent, urine, and/or feces at a nest with eggs destroyed. Such evidence shows a particular predator species visited the site, but it is not proof that species depredated any eggs. For example, red foxes *often* mark prey remains (e.g., eggshells) with urine and/or feces (pers. observations).

Anatomy and Size of Predators

Anatomy and size of a predator can reveal much about the types of evidence it leaves at a duck nest. Carnivores have widely spaced canines, rodents have closely spaced incisors, and birds have beaks. Large mammalian predators (coyote, red fox, raccoon, American badger) can grasp a whole duck egg within their mouth. This ability enables them to carry an egg without puncturing the shell, to crush an egg within their mouth, or to puncture an egg on opposite sides when biting into it. Small mammalian predators (striped skunk, mink, weasels, Franklin's ground squirrel) must bite into and grasp a duck egg with their canines or incisors, or push, pull, or roll an egg to remove it from the nest. Paired puncture marks from canine teeth are more likely to be found on shells of eggs depredated by small carnivores, especially minks and weasels (discussed later), than on shells of eggs depredated by large carnivores. This evidence occurs because small carnivores rely on repeated biting and prying to open eggs. The distance between paired canine puncture marks can be used to help identify some predators of duck nests (Appendix B, Table 1).

Franklin's ground squirrels cannot spread their jaws widely enough to easily open duck eggs (Sowls 1948). They rely on repeated biting and gnawing to open duck eggs, which often results in finely serrated edges of openings. Avian predators *usually* transport duck eggs by pecking a hole and then inserting a mandible to grasp the shell. However, some avian individuals can carry a whole duck egg using their beak without puncturing the shell (Odin 1957 [California gull], Montevecchi 1976 [American crow], pers. observations [black-billed magpie, American crow, gulls]). Except for gulls, avian predators open eggs by pecking. Gulls, having slightly hooked beaks, *occasionally* open eggs by biting (pers. observation) or dropping eggs (Odin 1957 [California gull]). Avian predators may peck an egg in several places to gain entry, thereby leaving scattered peck marks on the eggshell and/or ≥2 openings in the eggshell.

A predator's size influences extent of egg contents consumed during a feeding bout. Large carnivores *custom-*

arily eat all contents of an egg (pers. observations). Also, they can eat an entire clutch of duck eggs during a feeding bout (e.g., coyotes [Sooter 1946]), but may not do so (e.g., raccoons [Rearden 1951]). Small carnivores (except possibly large minks), Franklin's ground squirrels, and avian predators can eat only 1 or a few duck eggs during a feeding bout. Fleskes (1988) reported individual captive ermines ate 0.5-2.0 duck eggs/day. Thus, likelihood of finding whole and/or partially eaten eggs at a destroyed duck nest is greater if the offending predator was small.

The feet of a predator affect how it treats duck eggs, nests, and nest sites. The raccoon, with its handlike front feet (Jones *et al.* 1983), is the only predator in the Prairie Pothole Region adept at holding duck eggs upright to eat, although American badgers and striped skunks sometimes prop duck eggs upright. Corvids may hold a duck egg in place on the ground with a foot while pecking into an end (pers. observations of black-billed magpie). We never observed gulls use their webbed feet to open duck eggs in this manner.

American badgers, and to a lesser extent striped skunks, are the only predators of duck nests in the Prairie Pothole Region that have long-clawed feet (Jones *et al.* 1983). Thus, they are species most likely to dig at nests.

Effects of Other Animals

Duck nests with clutches partially or completely depredated may be subsequently visited by another predator or other animals. Baker (1978) used hair-catchers to study depredation patterns of artificial nests containing poultry eggs and found that 20% of 45 nests were visited by both raccoons and striped skunks before he rechecked the nests at weekly intervals. Effect of subsequent visits by animals other than the offending predator on evidence of depredation probably varies greatly. If whole and/or partially eaten eggs are left by the first predator, another predator may depredate those eggs. Some birds, small mammals, and insects may peck or chew on eggshells, and/or may consume uneaten portions of eggs (see Jones [1958] regarding deer mice [*Peromyscus maniculatus*], Greenwood *et al.* [1990] regarding carrion beetles [*Silpha* sp.] and possibly other insects).

Part II: Evidence of Depredation by Predator Species

In Part II, we describe responses to nests, affect on hens and eggs, and evidence of depredation at or near duck nests by the principal predators of duck nests in the Prairie Pothole Region. Accounts are based on literature (Appendix A) and on verification data gathered intermittently during 1972-92. A comparative summary of the relative importance of certain evidence as indicators of depredation by each of the principal predators is in Appendix B, Table 2.

Methods Used to Obtain Original Data

We obtained verification data by (1) offering duck eggs to predators in 2-m^2 cages or 18.6-m^2 pens, (2) offering duck eggs in artificial nests to predators in a 0.1-ha compound or a 4.1-ha enclosure, (3) photographing depredations of duck eggs in artificial nests by free-ranging predators with time-lapse cameras set to photograph at 15-30 s intervals (Sargeant *et al.* 1987), (4) observing free-ranging predators depredate loose eggs placed in unfenced natural sites, (5) opportunistically monitoring depredations of duck eggs in natural nests by radio-equipped free-ranging predators, or recording data from natural duck nests at which free-ranging predators were observed, (6) examining nest depredation records (prototypes of record in Appendix D, Fig. 1) for natural duck nests destroyed by predators for information about the depredations, (7) examining natural duck nests destroyed by predators in a fenced 25-ha exclosure that protected duck nests from most mammalian predators, and (8) examining eggshells from natural duck nests assumed destroyed by a predator species because of unique evidence at the nest.

The cages, pens, and compound were at Jamestown, North Dakota. The enclosure, which included a small pond and elevated observation booth, was at Woodworth, North Dakota (Sargeant and Eberhardt 1975, Rudzinski *et al.* 1982). Work involving time-lapse cameras, observing and monitoring free-ranging predators, and obtaining records of destroyed natural duck nests was conducted at numerous locations in Canada and the United States. The exclosure was at Hitterdal, Minnesota.

Only duck eggs (*usually* unincubated mallard eggs) were offered to predators. Artificial nests (except those offered to red foxes during 1972-73) were made of material salvaged from natural duck nests. Some artificial nests were used repeatedly; all eggshells and shell fragments were removed from them before additional eggs were placed in the nests. Quantification of each depredation variable was estimated from visual examination of evidence.

Verification data obtained for each predator species ranged from general observations to detailed records of specific predator behaviors. Data were written or verbal descriptions, or coded entries on a nest depredation record (prototype of record in Appendix D, Fig. 1). Amount of information gathered increased as the value of variables for describing patterns of depredation became evident. Thus, sample sizes for variables varied within and among predator species. Results are reported as specifically as possible or warranted; means are unweighted averages. Rounding accounts for minor differences in some percentages in text and their corresponding values in tables.

Coyotes and Red Foxes

Two pairs of coyotes and 7 pairs of red foxes were studied in the enclosure. All were captured in spring as juveniles and paired in summer or autumn with a nonsibling. Each pair was held separately until placed in the enclosure at ≥1 year old; their staple ground meat and natural prey diets included ducks and duck eggs. One of each pair was marked with dye for visual identification. Responses of the animals to artificial nests were observed from the elevated booth.

Coyotes were studied in 1983. Study of each pair lasted about 20 days, beginning with 3 days of acclimation to the enclosure. Then, for 16 days, coyotes were offered 4 artificial nests in late afternoon of alternate days. Two of 4 nests contained a physically restrained live mallard to simulate incubation. Coyotes were observed during evenings of days when nests were offered. Responses by coyotes were described verbally on cassettes; pertinent locations (e.g., prey cache sites) were plotted on maps. Investigators visited nests in the morning after eggs were offered to record evidence of depredations.

Six pairs of red foxes were studied in the enclosure during 1972-73. Each pair was offered 21 artificial nests and a restrained live mallard, and 3 artificial nests with no duck. Study sequence for each pair began with 4 days of acclimation to the enclosure. Acclimation was followed by 3, 4-day periods when 1-3 nests were offered daily in late afternoon. Each period was separated from the next period by 1 day. After approximately a 10-day recess, 3 nests were simultaneously offered.

Red foxes were observed during evenings of days when nests were offered and again the next morning. Verbal descriptions of responses to nests were recorded on cassettes; pertinent locations (e.g., prey cache sites) were plotted on maps. After each observation, the investigator visited each nest to record evidence of depredation.

Another pair of red foxes was studied in the enclosure in 1985. The foxes destroyed 11 artificial and 1 natural nest during a 6-day period. Depredation data for each nest were recorded the day after the nest was offered.

Verification data were also obtained in 1984 for 2 free-ranging red foxes, each of which destroyed an artificial nest monitored with time-lapse photography.

Raccoons and Striped Skunks

We obtained verification data for 5 raccoons (4 wild-caught, 1 free-ranging) and 21 striped skunks (4 wild-caught, 17 free-ranging). In 1986, 3 wild-caught raccoons were individually studied for 2-13 days in the compound and 1 wild-caught raccoon was studied for 10 days in the enclosure. Raccoons were first confined individually in pens, where they were fed duck eggs to obtain data on location of openings in eggshells. They were then placed in the compound or enclosure, where, during several days, each was offered 1-3 artificial nests. Nests that were incompletely depredated during a day were left undisturbed and rechecked 1-5 days later. No new nests were offered during the interval. Data analyzed were collected during final visits to nests, 1-5 days after each nest was offered. The free-ranging raccoon was monitored via time-lapse photography in 1991, while it depredated an artificial nest.

Four skunks were individuals studied in the compound during 1986; 15 skunks, radio-equipped and free-ranging, were discovered depredating natural duck nests during a study of striped skunk ecology during 1976-78 (Sargeant *et al.* 1982). The remaining 2 were unmarked, free-ranging individuals encountered depredating natural nests, 1 each in 1983 and 1990.

Radio-equipped skunks were discovered depredating natural nests when we walked to sites after we suspected the skunks were feeding on duck eggs. We avoided disturbing skunks and returned later to examine nest sites. Principal data recorded were number of depredated eggs and the appearance of eggshells. Depredation data for the 2 other free-ranging skunks were recorded after they departed nests.

Skunks placed in the compound were each studied for 10-20 days. Each was offered an artificial nest on most days. Depredation data were recorded 1 day after each nest was offered.

American Badgers

We obtained verification data for American badgers primarily by examining our file of 4,233 nest depredation records for natural duck nests destroyed by predators in the Prairie Pothole Region during 1984-92. Each nest was found before it was destroyed, and it was monitored to determine fate (Klett *et al.* 1986). We restricted our examination to nests with ≥6 eggs upon last visit by an investigator.

We assumed nests were destroyed by badgers if ≥1 egg was cached at the nest and covered by ≥2 cm of soil and/or debris. We believe badgers are unique among predators in the Prairie Pothole Region in caching eggs this way. In addition to selected file data, we obtained eggshells from co-workers during 1986-92. These eggshells were from 17 natural nests, with each nest assumed to have been destroyed by badgers, based on criteria described above. Eggshells were examined for types and locations of openings.

Minks and Weasels

Verification data for minks were limited largely to appearance of loose eggs depredated by 3 wild-caught minks confined individually in cages in 1979. Several eggs were simultaneously offered to each mink, and eggshells were collected daily. We also obtained data during 1988-91 from natural nests in the exclosure, assumed destroyed by free-ranging minks. The exclosure was largely free of predators, except mink (determined by observations, trapping, and monitoring track plots), which could pass through 5-cm diameter openings of the mesh fence.

We did not study weasels, but we obtained shells of duck eggs depredated by captive wild-caught ermines and long-tailed weasels from J. P. Fleskes (Iowa Coop. Fish Wildl. Res. Unit, Iowa State Univ., Ames).

Franklin's Ground Squirrels

Verification data for Franklin's ground squirrels came primarily from artificial duck nests depredated by free-ranging individuals during 1983-84. Nests were placed where each was likely to be encountered by different individuals and were monitored with time-lapse cameras. Nests *usually* were offered in early morning and removed that evening. Nests left overnight were covered with a hood to prevent depredation while cameras were inoperative. Depredation data were recorded during interim and final visits to nests. A nest with ≥1 depredated eggs was classified as depredated by Franklin's ground squirrels if only that species was photographed at the nest. Additional data about treatment of eggs and/or appearances of eggshells were obtained during 1983-84 and 1992 by observing free-ranging Franklin's ground squirrels depredate loose eggs.

Black-billed Magpies, American Crows, and Gulls

Verification data for black-billed magpies, American crows, and gulls were obtained by using time-lapse photography of depredations of artificial duck nests by free-ranging individuals (all species), and by observing free-ranging individuals depredate loose duck eggs (black-billed magpies, crows). Procedures for recording data and determining predator species responsible for depredations were the same as for Franklin's ground squirrels.

Black-billed magpies and crows were studied during 1983-85. Each species was offered artificial nests at locations where nests were likely to be discovered by different individuals. Nests *usually* were ≤100 m from an occupied nest of the target species; each nest was monitored for 1-4 days. Eggs removed by predators between photo-frames were assumed taken by photographed species. Nests known to have been visited by ≥2 predator species were excluded from analyses.

Free-ranging black-billed magpies were watched depredating loose duck eggs at 1 site in 1992. Eggs and eggshells were collected after the magpies left the site.

Gulls were studied during 1985 and 1991 by offering artificial nests at 3 locations where ring-billed gulls and/or California gulls were numerous. Each location was <3 km from a different nesting colony of ring-billed gulls and California gulls. Nests were placed to be conspicuous to aerial predators. Each nest was monitored 1 day. Responses by gulls to loose duck eggs were watched at 2 landfills, 1 site in each of 1985 and 1992. These observations were done to gather data on appearance of eggshells, and to determine how gulls opened and carried duck eggs. Eggshells were collected after depredations ended.

Depredation Patterns of Predator Species

Coyotes

Coyotes forage in uplands and *occasionally* wade or swim to islands used by nesting waterfowl (Sooter 1946, Hanson and Eberhardt 1971). We observed free-ranging coyotes wading offshore in shallow wetlands, and watched a coyote swimming after a brood of ducks in the enclosure. Thus, coyotes likely depredate duck nests in all upland habitats and they may *occasionally* depredate nests over water.

Responses to Hens and Nests—Coyotes *occasionally* capture hens at nests but *often* discard them. They killed nesting Canada geese (*Branta canadensis*) on islands in Washington (Hanson and Eberhardt 1971) and ducks restrained on nests in our studies. Coyotes in our studies killed ducks by biting them in the body or by severing the neck, and *often* left the whole, headless, or partially eaten carcass at or near the nest. We *occasionally* found a whole dead hen at or near a natural nest that we suspected was destroyed by coyotes. When eating ducks, captive coyotes *usually* pulled off and discarded feathers and stripped flesh from the carcass, leaving most of the skeleton intact. Remains *often* resembled those left after raptors fed on bird carcasses (Einarsen 1956).

We observed coyotes in evening visit 52 of 64 artificial nests in the enclosure. By the next morning, when investigators visited nests, coyotes had partially or completely depredated 59 nests. However, we *often* observed coyotes visit a nest without taking the restrained duck or eggs.

Treatment of Eggs—We observed coyotes remove 141 of 312 eggs during 303 visits to 52 artificial nests; 90 (64%) eggs were eaten, 34 (24%) cached, and 17 (12%) dropped and at least temporarily abandoned. Eggs were always taken singly, *often* by first pawing the egg and some nest material from the nest.

The 34 cached eggs were from 16 nests, 1-4 from each clutch. Coyotes cached each egg separately 6-80 m ($\bar{x}$ = 26.8 ±16.6 m [SD, n = 34]) from the nest. Cached eggs were barely covered (*usually* ≤1 cm) with soil and/or debris but were inconspicuous nevertheless. Sooter (1946) also noted that coyotes cached duck eggs individually in shallow cavities and barely covered eggs with debris and soil. On small islands, he found a few duck eggs cached by coyotes <5 m from the nest of origin.

Our examination of nest sites of 59 nests depredated by coyotes revealed highly variable treatment of eggs. One to 5 whole eggs (n = 49 eggs) or eggs with puncture holes only and no contents removed (n = 3 eggs) remained at 18 (31%) nests. We accounted for 105 (35%) of the remaining 302 eggs placed in the nests from eggshells found at the nests. The other 197 (65%) eggs were missing from the nest sites, but 37 were accounted for by whole eggs (n = 3 eggs) and eggshells (n = 34 eggshells) found 3-7 m from 11 nests. Shell fragments were found at 31 (53%) nests, but in each instance were deemed to be less than amount of 1 egg. The number of eggs missing from individual nest sites ranged from 1 to 6. In 8 instances, all eggs were missing and no shell fragments were found at the nest. However, eggshells were found near 2 of those nests.

Appearance of Eggshells and Nest Sites—Most (93%) of 129 eggshells examined for damage by coyotes had small, *usually* round, holes (Appendix B, Table 3; Appendix C, Fig. 1a-c). Coyotes apparently also *often* make large holes in eggs (Sooter 1946) and severely damage eggshells (Appendix C, Fig. 1), but few (7%) examined eggshells were damaged in that manner (Appendix B, Table 3). Coyotes *occasionally* crush an egg within their mouth (Appendix C, Fig. 1l). Sooter (1946) and Baker (1978) also noted that coyotes *often* make small holes in eggs and sometimes crush eggs within their mouth.

Most (97%) of 75 eggshells examined for location of openings had been opened by coyotes in the side; none had been opened on an end (Appendix B, Table 4). Sooter (1946) showed a destroyed gadwall nest with 9 eggshells remaining in the nest, each with a small or large round opening in the side. He attributed the destruction to coyotes.

Eggshells of eggs depredated by coyotes *occasionally* had ≥1 puncture holes in addition to the main opening (Appendix C, Fig. 1b, h, i), *often* opposite the main opening. Eggshells *seldom* contained a conspicuous yolk residue.

We found no evidence of coyotes digging at nests. However, coyotes in the enclosure *occasionally* laid at or near nests, which resulted in trampled vegetation.

The proportion of nest material displaced from 59 artificial nests with eggs depredated by coyotes ranged from 0 to 100%; 40 nests (68%) had >30% of the material displaced (Appendix B, Table 5).

There was no consistent pattern in location of eggshells (n = 129) at nests (Appendix B, Table 6). Thirty eggshells (23%) were ≤20 cm from the nest, *often* in the nest, and 32 (25%) were >1 m from the nest. Eggshells found outside nests *often* were clustered.

Conclusions—Destruction of duck nests by coyotes is difficult to identify because evidence at nests is variable and *often* similar to that produced by other predator species. For example, Sooter (1946:38) stated, "...had the coyotes not been watched while cracking the eggs, some of the work would have been thought to be that of birds...."

Finding a whole carcass of a hen without bite marks in the cranium at or near a nest is a strong, but infrequent, indicator of depredation by coyotes. The following indicates a nest may have been destroyed by coyotes: (1) part of clutch unaccounted for by eggshells and shell fragments, (2) most eggshells have small holes, (3) all openings in eggshells are in the side of the shell, (4) eggshell with ≥1 puncture hole in addition to the main opening, and (5) most eggshells are >1 m from the nest (Appendix B, Table 2).

Evidence indicating a nest was not destroyed by coyotes includes the following: (1) cached egg, (2) dug area, (3) amount of shell fragments exceeds that of 1 egg, (4) eggshell with an opening in an end, or (5) eggshell with a conspicuous yolk residue (Appendix B, Table 2).

Red Foxes

Red foxes forage in uplands but tend to avoid wet areas (Sargeant 1972). We *seldom* saw red foxes in the enclosure enter the pond, even to retrieve readily accessible prey. Thus, red foxes likely depredate duck nests in all upland habitat, but *seldom* depredate nests over water (Sargeant and Arnold 1984, Sargeant *et al.* 1984).

Response to Hens and Nests—Red foxes *often* capture nesting hens (Sargeant *et al.* 1984). Sargeant and Eberhardt (1975) reported that ducks did not struggle when captured by red foxes, and foxes *customarily* killed ducks by biting them in the body or by severing their neck. Red foxes killed most ducks restrained on nests in our study. They *often* laid the duck at or near the nest temporarily, but *seldom* ate it there. Foxes *customarily* left no more than a few breast and/or tail feathers at nests. We inspected a mallard nest in a grassy fence row after watching a red fox depart carrying the hen. The only evidence of depredation was a few breast feathers and a small area of slightly matted vegetation, where the hen had been laid. When eating ducks, red foxes *usually* ingest nearly all feathers and bones, except wings or wing tips (Sargeant 1978).

All but 5 of 144 artificial nests offered to foxes in the enclosure in 1972-73 had all eggs depredated during the first night. Foxes observed discovering the nests *seldom* left the nest without depredating the clutch.

Treatment of Eggs—Ten of 12 foxes studied in the enclosure in 1972-73 were observed removing 454 eggs from 77 artificial nests. A fox would grab an egg (always 1), *often* after first pawing it from the nest, and immediately depart to cache it. This process was repeated until all eggs were cached, which resulted in foxes spending little time at the nest. Nearly all (99.8%) of the 454 eggs observed taken were cached; only 1 (0.2%) was eaten at the nest.

The straight-line distance from nest to cache of 420 eggs ranged from 4 to 163 m ($\bar{x}$ = 43.9 ± 27.6 m [SD]). Eggs were cached separately, *usually* in different distances and directions from the nest. Cached eggs were inconspicuous but barely covered (*usually* by ≤1 cm) with soil and/or debris.

Records for a pair of foxes placed in the enclosure in 1985 and for 2 free-ranging foxes revealed the same pattern of depredation described above. All 87 eggs in 14 nests (13 artificial nests containing 78 eggs and 1 natural nest with 9 eggs) were missing when exposure periods ended. No cached eggs, eggshells, or shell fragments were found at the nests.

No eggs of any artificial nest known to have been discovered by foxes in the enclosure were at the nest when the 1-night exposure period ended. When 3 nests were offered simultaneously, foxes *often* discovered the second or third nest while caching eggs from the earlier discovered nest. This resulted in the foxes caching eggs, *often* interchangeably, from different nests until all eggs were taken. This behavior may also *occasionally* result in red foxes partially depredating duck nests, especially where nests are numerous.

Other investigators have noted the tendency of red foxes to remove *usually* all eggs from nests and to cache or eat eggs away from nests of birds (Darrow 1938, Rearden 1951, Kruuk 1964, Tinbergen 1965) and turtles (Macdonald *et al.* 1994).

Appearance of Eggshells and Nest Sites—We found hundreds of eggshells of duck eggs depredated by foxes in the enclosure but only 1 was at a nest. Eggshells in Appendix C, Figure 2 were of eggs eaten in the enclosure or pens. Most (73%) of 42 eggshells examined for damage by the foxes had large holes, but small holes were common (20%). Few eggshells (7%) were severely damaged (Appendix B, Table 3; Appendix C, Fig. 2). We *seldom* found puncture marks on eggshells. We *occasionally* found an eggshell with ≥1 puncture hole in addition to the main opening (Appendix C, Fig. 2g, i). We never observed a fox crush a duck egg within its mouth.

Most (88%) of 42 eggshells examined for location of openings made by foxes had the opening in the side; only 1 (2%) had the opening in an end (Appendix B, Table 4). We *seldom* found a conspicuous yolk residue in an eggshell.

We found no evidence of red foxes digging at nests. Although no nest material was used in construction of 77 artificial nests observed depredated by foxes in the enclosure during 1972-73, the pattern of egg removal indicated little nest material would have been displaced. Nest material was present in the 14 other nests depredated by foxes. Seven (50%) nests had no nest material displaced; 4 (29%) nests had >30% displaced (Appendix B, Table 5). Darrow (1938) reported that nests of ruffed grouse (*Bonasa umbellus*) destroyed by red foxes were also undisturbed.

Little vegetation was trampled at nests destroyed by foxes in the enclosure, because foxes spent little time at the nests and *seldom* ate ducks or eggs there.

Conclusions—Red foxes have the most distinct pattern of destruction of duck nests, because they cache all eggs of the clutch away from the nest site. The following combination of evidence at nests is characteristic of destruction of a nest by red foxes: (1) all eggs missing, (2) no disturbance of ground surface or vegetation, and (3) ≤10% of nest material displaced (Appendix B, Table 2; Fig. 2). Although red foxes *often* kill the hen, they *customarily* leave little or no evidence of hen mortality at the nest.

Evidence at the nest that indicates a nest was not destroyed by red foxes includes the following: (1) all or part of a hen carcass, (2) cached egg, (3) eggshell or shell fragment, (4) dug area, or (5) aerially displaced nest material (Appendix B, Table 2).

Raccoons

Raccoons forage primarily in wetlands or in uplands at sites where seeds from agricultural crops are available (Greenwood 1981). Raccoons spend little time in grassland (Fritzell 1978). Thus, duck nests in or near wetlands are at greatest risk to depredation by raccoons (Sargeant and Arnold 1984).

Response to Hens and Nests—Raccoons rarely capture hens (Sargeant and Arnold 1984). We did not observe raccoons encounter duck nests. We obtained information on depredation of 28 artificial nests by 4 captive raccoons in our studies. Raccoons *often* did not take all 6 eggs from a nest during the first night but returned subsequently to complete the depredation. Rearden (1951) reported an instance of partial depredation of a clutch of 8 chicken eggs in an artificial nest by a free-ranging raccoon. That raccoon ate 4 eggs when it first depredated the nest; the remaining eggs were eaten 9 days later.

Treatment of Eggs—Raccoons *seldom* removed eggs or eggshells from nest sites. Four captive raccoons depredated 159 (95%) of 168 eggs placed in the 28 artificial nests. We accounted for 144 (91%) eggs from eggshells found at the nests. We found eggshells from 5 of the 15 missing eggs near the nests. Shell fragments found at nests may have accounted for the 10 other missing eggs. Rearden (1951:389) noted that "When destroying a nest located in dry cover near water, a raccoon will frequently carry the eggs near the water to eat, at times leaving shells in shallow water." Nevertheless, he found eggshells <9 m (mostly <2 m) from all (n = 20) nests. We found no evidence of raccoons caching or otherwise hiding eggs.

Appearance of Eggshells and Nest Sites—Most (66%) of 144 eggshells examined for damage by raccoons had large holes; few (13%) had small holes (Appendix B, Table 3). Openings *usually* were round with numerous coarsely broken pieces of shell caved inward (Appendix C, Fig. 3a-e). We found no evidence of raccoons crushing duck eggs within their mouth. However, they *often* trampled eggshells (Appendix C, Fig. 3j-l), nest material, and vegetation at nests. We found no evidence of raccoons digging at nests. Greenwood (1979) also reported that raccoons opened duck eggs by biting a hole, and then ingesting contents.

Most (59%) of 226 eggshells of duck eggs examined for location of openings made by raccoons had the opening in an end (Appendix B, Table 4; Appendix C, Fig. 3a-f), presumably made while the raccoon held the egg upright. Only 27 (12%) of the eggshells had the opening in the side (Appendix B, Table 4). Other investigators (Darrow 1938, Rearden 1951, Baker 1978) also noted that raccoons tend to open most eggs in an end. Examined eggshells *seldom* had puncture marks or puncture holes in addition to the main opening, or conspicuous yolk residue.

Raccoons did not displace nest material at 18 (64%) of 28 artificial nests they depredated, although material was loosely packed. Only 2 (7%) nests had >30% of the material displaced (Appendix B, Table 5). Darrow (1938) and Baker (1978) also reported that raccoons tend to displace little nest material from nests when destroying clutches. However, Rearden (1951:389) reported that "...80 per cent of the nests [n = 20] destroyed by raccoon were found to be pawed to some extent."

Most (64%) of 144 eggshells found at 28 artificial nests were ≤20 cm (including in nests) from the nest; few (4%) were >1 m from the nest (Appendix B, Table 6). Baker (1978) found eggshells (poultry eggs) ≤3 m from 15 (83%) of 18 artificial nests depredated by raccoons. We observed that eggshells outside nests *often* were clustered or in a line away from the nest.

Figure 2. Typical appearance of a duck nest destroyed by a red fox.

Conclusions—The raccoon is 1 of 2 principal predator species (the other is the striped skunk) that *customarily* leaves at duck nests eggshells and/or shell fragments of all depredated eggs. Evidence that implicates raccoons includes finding at the nest most or all of the following: (1) eggshells of ≥50% of eggs of a clutch and sufficient shell fragments to account for other eggs, (2) each eggshell has a large hole or is severely damaged, (3) ≥50% of openings in eggshells are in an end, (4) ≤10% of nest material displaced, and (5) all eggshells are <1 m from the nest (Appendix B, Table 2).

Evidence at the nest that indicates a nest was not destroyed by raccoons includes any of the following: (1) the hen was killed, (2) cached egg, (3) <50% of eggs of a clutch represented by eggshells, (4) >50% of eggshells have small hole openings, (5) dug area, (6) aerially displaced nest material, and (7) eggshell with conspicuous yolk content (Appendix B, Table 2).

Striped Skunks

Striped skunks forage throughout uplands (Storm 1972). They are likely to depredate duck nests in all upland habitats but *seldom* depredate nests over water (Sargeant and Arnold 1984, Sullivan 1990).

Response to Hens and Nests—Striped skunks are not known to capture hens (Sargeant and Arnold 1984). We did not observe striped skunks encounter duck nests but occasionally observed them at nests. We encountered a radio-equipped striped skunk at a gadwall nest during the night the eggs hatched. The hen and brood were present the next morning, suggesting that some hens can defend their nests from skunks.

Striped skunks *often* did not completely depredate duck nests during their initial visit to the nest. Of 13 duck nests at which radio-equipped striped skunks were encountered without interrupting the depredation, skunks ate all eggs (n = 4-8 eggs/nest) of 8 nests and partially depredated the other 5 nests. At each of the latter nests, skunks ate 3-9 eggs and left 2-5 whole eggs. Each of these was completely depredated, presumably by striped skunks, when rechecked 1-2 days later. Maximum number of eggs known to be eaten by a radio-equipped striped skunk in 1 night was 13 (an entire gadwall clutch). The skunk ate 11.5 of the eggs early in the night. Then, after traveling ≥1.5 km from the nest, it returned at dawn and ate the remaining 1.5 eggs. Of 46 artificial duck nests in the compound depredated by striped skunks, 1-3 whole eggs of 6 placed in each nest remained in each of 4 (9%) nests the next day.

Treatment of Eggs—We found that striped skunks *seldom* removed eggs or eggshells from nest sites, unless the nest was near their den or retreat. We accounted for 157 (91%) of 173 eggs depredated by 3 of 4 skunks studied in the compound, based on eggshells found at the nests. The other 16 eggs seemed to be accounted for by shell fragments. In contrast, we accounted for only 51 (53%) of 96 eggs depredated by the fourth skunk studied in the compound from eggshells found at nests. That skunk had an underground den about 10 m from the nests. We found numerous eggshells along the trail between the nests and the den. We once found duck eggshells (n = 2) near the den of a radio-equipped striped skunk. We have no other evidence of striped skunks removing eggs from nest sites or of striped skunks hiding eggs.

Appearance of Eggshells and Nest Site—Several investigators describe appearance of eggs depredated by striped skunks, but data are few and most descriptions vague (Appendix A). However, there is general agreement between their findings and ours that shells of eggs depredated by striped skunks *usually* have a large elliptical hole with coarsely broken pieces of shell caved inward (Appendix C, Fig. 4b, d, f-k). Most of 275 eggshells examined for damage by striped skunks had large holes (64%) or were severely damaged (25%; Appendix B, Table 3).

We examined 206 eggshells from artificial duck nests and 48 eggshells from natural duck nests destroyed by striped skunks for location of openings (Appendix B, Table 4). Collectively, 102 (40%) eggshells had the opening in the side, 96 (38%) in a side-end, and 56 (22%) in an end. However, 1 captive skunk opened eggs differently than the other skunks. Fifty percent of openings made by that skunk were in an end of the eggshell compared with 11% of openings made by the other skunks. We *seldom* found an eggshell with puncture marks, a puncture hole, or conspicuous yolk residue.

We found no dug areas at duck nests destroyed by skunks. However, Baker (1978) found small holes had been dug at 4 (27%) of 15 artificial nests destroyed by striped skunks.

Skunks *often* displaced considerable nest material from nests and *often* matted vegetation where they ate eggs. Most (78%) of 46 artificial nests depredated by skunks in the compound had >30% of the material displaced; only 4 nests (9%) had no material displaced (Appendix B, Table 5). Displaced nest material *usually* was pulled out from 1 side of the nest. Darrow (1938) and Rearden (1951) reported that striped skunks may tear apart or demolish nests; however, none of the nests we examined were disturbed in that manner. We *often* noticed a trail of trampled vegetation extending out about 1 m from nests destroyed by the radio-equipped skunks, especially in dense vegetation. Displaced nest material and eggshells found outside those nests were on the trails.

Skunks *customarily* ate duck eggs ≤1 m from the nest. Of 151 eggshells found at nests depredated by 3 captive skunks without a den near the nests, most (72%) were ≤20 cm from the nest. Eggshells were *often* in the nest, and few (4%) were >1 m from the nest (Appendix B, Table 6).

Conclusions—The striped skunk is 1 of 2 principal predator species (the other is the raccoon) that *customarily* leaves eggshells and/or shell fragments of all depredated eggs at duck nests. Evidence that strongly indicates a nest was destroyed by striped skunks includes finding at the nest most or all of the following: (1) eggshells of ≥50% of eggs of the clutch and sufficient shell fragments to account for the other eggs, (2) each eggshell has a large hole or is severely damaged, (3) ≥50% of openings in eggshells are in the side or a side-end, (4) >10% of nest material displaced (on ground), and (5) all eggshells are ≤1 m from the nest (Appendix B, Table 2).

Evidence that indicates a nest was not destroyed by striped skunks includes finding at the nest any of the following: (1) the hen was killed, (2) cached egg, (3) <50% of eggs of clutch represented by eggshells, (4) ≥50% of eggshells have small hole openings, (5) dug area, (6) aerially displaced nest material, or (7) eggshell with a conspicuous yolk residue (Appendix B, Table 2).

American Badgers

Badgers forage in uplands. They likely depredate duck nests in all upland habitats but *seldom* depredate nests over water (Sargeant and Arnold 1984, Brandt 1994).

Response to Hens and Nests—Badgers are not known to capture hens (Sargeant and Arnold 1984). We never observed any badgers encounter duck nests and found no descriptions of such in the literature.

Treatment of Eggs—We found no descriptions of depredations of eggs by badgers. Our examination of records of natural nests destroyed by predators produced 61 records with at least 1 egg cached ≥2 cm under soil and/or debris at the nest. We believe this is a characteristic solely of badgers and therefore attributed destruction of those nests to badgers. Those nests contained 571 eggs when last visited by investigators about 1 week before the nests were discovered destroyed. Assuming 571 eggs were present when the nests were destroyed, we accounted for 234 (41%) eggs from eggshells and 57 (10%) from whole eggs found at the nests (includes uneaten cached eggs). Whole eggs not cached (1-3/nest) were found at 9 (15%) nests, suggesting that badgers *often* partially depredate duck nests. Many missing eggs were represented by shell fragments. Other missing eggs may have been completely eaten, or may have been cached and not discovered by the investigators. We do not know the frequency badgers cache ≥1 eggs at the nest sites.

Investigators found evidence that 116 eggs were cached at the nests described above; only 37 (32%) were still in caches. Remaining eggs had been retrieved and eaten, presumably by badgers. Badgers *customarily* cached only part of a clutch; ≥1 egg was eaten at 58 (95%) nests. Badgers *usually* cached eggs individually, but there were 5 instances of 2-4 eggs cached together. Badgers *customarily* cached eggs in small freshly-dug holes (Fig. 3); there were 2 instances of eggs cached in the nest. Depth of covering over the deepest cached egg was ≥5 cm at 33 (54%) nests; maximum depth was 14 cm.

Appearance of Eggs and Nest Site—We obtained data on damage to shells of 265 duck eggs assumed to have been depredated by badgers (Appendix B, Table 3), 169 from nests from the investigated file and 96 from the 17

Figure 3. Duck egg assumed to have been cached by an American badger at a duck nest. Egg was partially uncovered by the investigator.

other natural nests at which cached eggs were found by coworkers. Most of 265 eggshells had large holes (40%) or were severely damaged (57%) (Appendix B, Table 3). Openings in eggshells *usually* were asymmetrical with coarsely broken edges and numerous pieces of shell caved inward (Appendix C, Fig. 5c-e, g-i). Badgers *often* crushed a duck egg within their mouth, resulting in crushed eggshells (Appendix C, Fig. 5l). Nine (24%) of 38 eggshells found at 7 nests with prevalence of crushed eggshells reported were crushed.

We obtained data concerning location of openings in 79 eggshells of duck eggs assumed depredated by badgers (Appendix B, Table 4), 33 from 14 nests in the investigated file, and 46 from 17 other natural nests with cached eggs. Most had an opening in the side (30%) or a side-end (61%) (Appendix B, Table 4). Eggshells of eggs depredated by badgers *seldom* had puncture marks or puncture holes, or conspicuous yolk residue.

There were dug areas at all 61 nests destroyed by badgers because eggs had been cached. Dug areas >10 cm diameter were found at 36 (59%) nests. We do not know the frequency of badger digging at nests, but assume digging *usually* is associated with egg caching.

The proportion of nest material displaced from 61 nests destroyed by badgers ranged from 0 to 100%, and was >30% at 32 (52%) nests (Appendix B, Table 5). Large size and squat physique of badgers *often* resulted in considerable matting of vegetation at nests, especially where eggs were eaten. Badgers *often* made wide trails at and/or near nests.

Most (89%) of 173 eggshells found at 61 nests destroyed by badgers were ≤1 m from the nest, 74 (43%) were ≤20 cm (including in nest) from the nest (Appendix B, Table 6). Eggshells outside nests *usually* were to 1 side of the nest site.

Conclusions—Of the principal predators, badgers cause the most disturbance at nest sites. Cached egg(s) at the nest, especially if covered by ≥2 cm of debris, implicates badgers in nest destruction. Other indications of badgers include finding at the nest most or all of the following: (1) part of clutch missing without trace, (2) most eggshells have a large hole or are severely damaged, (3) crushed eggshell(s), (4) ≥50% of openings in eggshells in a side or side-end, (5) dug area, and (6) >30% of nest material displaced on ground (Appendix B, Table 2).

Evidence that indicates a nest was not destroyed by badgers includes finding at the nest any of the following: (1) evidence the hen was killed, (2) all eggs missing without trace, (3) eggshell with a small hole, or (4) aerially displaced nest material (Appendix B, Table 2).

Minks

Minks forage primarily in or near permanent and semipermanent wetlands and probably destroy few duck nests in uplands (Sargeant and Arnold 1984, Arnold and Fritzell 1990). Nests over water or on small islands are especially vulnerable to minks (Aufforth *et al.* 1990).

Response to Hens and Nests—Minks prey on nesting hens (Sargeant and Arnold 1984, Aufforth *et al.* 1990). Minks *customarily* kill ducks by biting them in the cranium or upper neck (pers. observations). Minks killed the hen at several of 31 nests destroyed by predators in the exclosure, and *often* removed the carcass from the nest site (e.g., to a retreat). Aufforth *et al.* (1990) also found dead hens and dead ducklings with severely bitten heads and upper necks at or near duck nests depredated by minks. Darrow (1938) and Sargeant *et al.* (1973) commented that minks often drag prey into shelters, such as dens or retreats.

We have no information on the response of minks to hens or duck nests. However, minks seem to be especially attracted to nests with eggs in late stages of incubation (Eberhardt and Sargeant 1977), when noise is present from pipping and hatching ducklings.

Treatment of Eggs—We have little information about treatment of eggs by minks. Eggshells *often* were scattered along trails, sometimes in small groups, leading away from 31 duck nests in the exclosure. Whole eggs were present at 6 nests. Investigators found no eggshells at 7 (23%) nests and no shell fragments at 16 (52%) nests. (The latter included 12 nest sites with eggshells with damage that indicated shell fragments may have been present but overlooked by investigators). Thus, minks may partially depredate nests and remove eggs from nest sites.

Appearance of Eggshells and Nest Sites—Captive minks *often* opened eggs by biting or prying with their canines an elongated irregular slot across the side of the egg (Appendix C, Fig. 6d-f, i). Darrow (1938:837) commented that, "Shell remains left by a weasel [and minks] usually show a longitudinal sectioning of the eggs and the edges of the remaining portion are finely chewed...." Aufforth *et al.* (1990) noted that small tooth marks were visible on edges of openings in duck eggs depredated by minks. Rearden (1951:390) concluded that, "Tooth marks found on unbroken portions of egg shells are one of the most helpful identifying signs left by mink." Distance between paired canine puncture marks can be used to help distinguish between eggs depredated by minks and other carnivores (Appendix B, Table 1).

Most of the 28 eggshells examined for damage by minks had small (36%) or large holes (50%) (Appendix B, Table 3). Most of 27 eggshells examined for location of openings made by minks had the opening in the side (63%) or a side-end (30%) (Appendix B, Table 4). Conspicuous residue of egg yolk *often* was present in eggshells.

We found no evidence of minks digging at nests. Additionally, no nest material was displaced from most (65%) of 31 nests in the exclosure presumably destroyed by minks; only 1 (3%) nest had >30% of the material displaced (Appendix B, Table 5). Rearden (1951) and Aufforth *et al.* (1990) noted that little nest material was displaced from duck nests destroyed by minks.

Nests destroyed by minks in the exclosure *often* had ≥1 well-defined narrow trail leading away from the nest, sometimes to a retreat. Rearden (1951:390) noted that "...mink runways frequently are found quite close to destroyed nests."

Most (70%) eggshells found at 31 nests destroyed by minks in the exclosure were outside the nest but ≤1 m from the nest.

Conclusions—Scant information exists concerning destruction of duck nests by minks. Presence of a hen carcass with bite marks in the cranium and/or neck suggests mink predation. Other indications that a nest was destroyed by minks include finding at the nest most or all of the following: (1) ≥1 whole egg, (2) ≥50% of eggs missing without a trace, (3) eggshells with numerous puncture marks, (4) no displaced nest material, and (5) well-defined narrow trails leading away from the nest (Appendix B, Table 2).

Evidence that indicates a nest was not destroyed by minks includes finding at the nest any of the following: (1) cached egg, (2) all of a clutch represented by eggshells and shell fragments, (3) all eggshells are in nest, (4) aerially displaced nest material, (5) dug area, and (6) ≥30% of nest material displaced (Appendix B, Table 2).

Weasels

Ermines and long-tailed weasels forage primarily in uplands (Sargeant *et al.* 1993). They likely destroy duck nests in all types of upland habitats but are not known to destroy duck nests located over water.

Response to Hens and Nests—Hens have been reported killed at nests by long-tailed weasels (Keith 1961), but methods used to identify cause of mortality were not provided. Hens were not killed at nests destroyed by smaller ermines (Fleskes 1988, J. P. Fleskes, Iowa Coop. Fish and Wildlife Res. Unit, Iowa State Univ., Ames, pers. commun.). Long-tailed weasels, being similar to minks in morphology and habits, probably kill ducks by biting them in the cranium, and may drag the carcass away from the nest site.

We found no descriptions of weasels encountering duck nests. However, destruction of a nest by weasels *usually* involves gradual removal of eggs during a period of several days (Fleskes 1988). Fleskes (1988) found that weasels commonly partially depredate nests, and that hens attending such nests usually continued laying or incubating until most eggs were depredated. In that study, 36 (95%) of 38 nests believed destroyed by weasels (probably all by ermines) had repeated losses of eggs between visits (3-10 day intervals) to nests by investigators. Each nest had ≥1 whole egg remaining when it was abandoned by the hen, and the clutch was considered destroyed.

Treatment of Eggs—Weasels remove many duck eggs from nest sites. Barkley (1972) observed an ermine carry 6 whole eggs in its mouth (1 at a time) from the nest of a ruffed grouse. Fleskes (1988) accounted for only 20% of eggs from duck nests that failed because of depredation by weasels, based on eggshells found at or near the nest. Twenty-nine percent of the eggs of those nests were accounted for by whole eggs; 51% were missing without a trace of shell. Most (79%) whole eggs were in the nest. Most eggshells and a few whole eggs were in narrow trails under dense vegetation, sometimes in small groups.

Appearance of Eggshells and Nest Sites—Weasels have difficulty opening duck eggs (Teer 1964, Fleskes 1988). Generally, they begin opening an egg by biting into an end or side-end. They enlarge the hole by biting- and prying-out pieces of shell. This action often results in an elongated narrow slot with finely chipped edges across or down the egg (Appendix C, Fig. 7e, g, i, j; also see Teer [1964] and Fleskes [1988]). Fleskes (1988:15) described the openings as "...ringed with numerous small shell fragments and "bite-outs"...."

A factor in identifying destruction of some duck nests by weasels is presence of paired canine puncture marks on ≥1 eggshells. Fleskes (1988) found such marks on ≥1 eggshell at 4 (17%) of 24 duck nests at which eggshells of eggs depredated by weasels were found. Teer (1964) found paired canine puncture marks on duck eggs depredated by long-tailed weasels. Distance between paired canine puncture marks *usually* will distinguish eggshells of eggs depredated by ermines from those depredated by long-tailed weasels, and between eggs depredated by weasels and other carnivores (Appendix B, Table 1).

Most of 15 eggshells examined for damage by weasels had small (60%) or large (33%) holes (Appendix B, Table 3). We examined 13 eggshells of duck eggs depredated by weasels for location of openings and found little difference in proportions with openings in the end, side, or side-end (Appendix B, Table 4). Fleskes (1988) found conspicuous egg residue (presumably included yolk) in ≥1 eggshell at 10 (42%) of 24 nests at which eggshells of eggs depredated by weasels were found.

We found no evidence of weasels digging at nests. Fleskes (1988) found no displaced nest material at 38 nests apparently destroyed by weasels.

Conclusions—Scant information exists concerning destruction of duck nests by weasels. Where weasels are major predators of duck nests, many clutches should have eggs missing before any egg hatches or the clutch is destroyed. Evidence that strongly indicates a nest was destroyed by weasels includes finding at the nest most or all of the following: (1) ≥1 whole egg, (2) eggshells of <50% of clutch, (3) eggshells with numerous puncture marks, (4) eggshell with fine serrations along edge of an opening, and (5) no displaced nest material (Appendix B, Table 2). Finding a dead hen with bite marks in the cranium may indicate a nest was destroyed by long-tailed weasels.

Evidence indicating a nest was not destroyed by weasels includes the following: (1) cached egg, (2) eggshell in nest, (3) eggshells of ≥50% of clutch, (4) displaced nest material, or (5) dug area (Appendix B, Table 2).

Franklin's Ground Squirrels

Franklin's ground squirrels forage in dense grass, forb, or brush habitats and hence are unlikely to destroy duck nests in sites with short or sparse vegetation or those in nests over water (Sowls 1948, 1955, Choromanski-Norris *et al.* 1989).

Response to Hens and Nests—Franklin's ground squirrels rarely attack nesting hens but *occasionally* prey on ducklings (Sowls 1948, 1955). Sargeant *et al.* (1987) found that free-ranging Franklin's ground squirrels *customarily* began depredating duck eggs placed near their trails or burrows ≤2 min after encountering the eggs. Ground squirrels took an average of 2.2 days (range 1-5 days) to depredate 6 eggs in an artificial duck nest. Thus, Franklin's ground squirrels probably *often* partially depredate natural duck nests.

We compiled information for 15 artificial duck nests with eggs thought to have been depredated exclusively by free-ranging Franklin's ground squirrels. Each nest was available to the ground squirrels for 1-3 days after being discovered by them. After discovering a nest, ground squirrels *occasionally* left all eggs undamaged. At other times they consumed eggs at the nest site or removed them from the site.

Treatment of Eggs—Duck eggs are not easily opened by Franklin's ground squirrels. Sowls (1948) described the process as follows. First, the egg is usually moved to a site where it will not easily roll. Then, the egg is embraced lengthwise under the body and hard thrusting and even vigorous rolling is employed to obtain the leverage needed to penetrate the shell. The initial opening, often near an end (Appendix C, Fig. 8a), is enlarged by biting off small pieces of shell. Close examination of eggshells *often* reveals finely serrated edges along openings.

In our studies, free-ranging Franklin's ground squirrels were observed opening duck eggs on 3 occasions, twice by straddling the egg lengthwise to hold it in place and then biting (no hard thrusting or rolling) into an end, and once as described by Sowls (1948). Franklin's ground squirrels were observed 3 times holding shell fragments off the ground with their front feet and eating portions of the shell.

Seventy-three (81%) of 90 eggs from 15 artificial nests depredated exclusively by Franklin's ground squirrels were depredated. Number of eggshells and amount of shell fragments found at individual nests ranged from none to portions of all eggs. Only 35 (48%) of 73 depredated eggs were represented by eggshells at the nest. A few additional eggs (exact number undetermined) were represented by shell fragments.

Appearance of Eggshells and Nest Sites—Most (57%) of 35 eggshells of duck eggs examined for damage by Franklin's ground squirrels had large holes, but eggshells with small holes and severely damaged eggshells were also common (Appendix B, Table 3). Openings in eggshells *usually* were broad and irregularly shaped, *often* extended lengthwise along the shell, and *usually* had few pieces of shell caved inward (Appendix C, Fig. 8).

Most (65%) of 31 eggshells of duck eggs examined for location of openings made by Franklin's ground squirrels had the opening in a side-end, but openings *often* were in the side (23%) or in an end (13%; Appendix B, Table 4). *Usually*, there was no conspicuous yolk residue in eggshells. However, ground squirrels *often* did not complete eating contents of depredated eggs during a single visit to the nest or in a single day. Hence, partially eaten eggs with fresh evidence of depredation *occasionally* may be found at duck nests depredated by Franklin's ground squirrels.

There was no digging at any of 15 artificial nests depredated by Franklin's ground squirrels. Nest material was displaced from each nest; >30% of nest material was displaced from each of 10 (67%) nests (Appendix B, Table 5).

Franklin's ground squirrels *occasionally* covered whole eggs left in artificial nests with nest material. These nests looked the same as natural nests with eggs covered by the hen before taking a recess. Narrow indistinct trails, under dense vegetation, *occasionally* were present at nests destroyed by Franklin's ground squirrels.

Fifteen (43%) of 35 eggshells found at 15 artificial nests depredated by Franklin's ground squirrels were ≤20 cm from the nest (including in the nest); 11 (31%) were >1 m from the nest (Appendix B, Table 6). Eggshells *usually* were scattered around the nest, sometimes in indistinct trails. We found an eggshell at the entrance to a Franklin's ground squirrel burrow, indicating that they take some duck eggs into burrows.

Conclusion—Where Franklin's ground squirrels are major predators of duck eggs, many nests should have eggs missing before any egg hatches or the nest is destroyed. Evidence indicating a nest was destroyed by Franklin's ground squirrels includes finding at the nest most or all of the following: (1) ≥1 whole egg in nest, (2) eggshells of <50% of clutch, (3) eggshells with irregularly shaped openings and fine serrations along openings, (4) recently opened eggshell with much content present, and (5) ≥50% of eggshells >1 m from the nest (Appendix B, Table 2).

Evidence indicating a nest was not destroyed by Franklin's ground squirrels includes finding at the nest any of the following: (1) the hen was killed, (2) cached egg, (3) eggshells of >50% of clutch, (4) aerially displaced nest material, or (5) dug area (Appendix B, Table 2).

Black-billed Magpie

Black-billed magpies range widely over uplands and wetlands but are most likely to depredate duck nests near their own nests or perches (Williams and Marshall 1938, Jones and Hungerford 1972). Little is known about the vulnerability of duck nests in different habitats to this predator.

Response to Hens and Nests—We have no information about interactions between black-billed magpies and hens at nests, and found no evidence in literature of black-billed magpies attacking nesting hens.

We obtained information for 29 artificial duck nests visited by black-billed magpies and at which there was no evidence of interference from other potential predators. Nests were monitored for 1-4 days, after discovery by magpies. Film records revealed that ≥1 magpies visited nests at least 266 times during 45 exposure-days.

Depredation of the artificial nests *usually* was by individuals but *occasionally* 2 or 3 magpies were photographed together at a nest. Depredations *customarily* involved infrequent brief visits to the nests.

Black-billed magpies appeared only moderately interested in depredating duck eggs. There were numerous instances of a magpie visiting a nest without depredating an egg. Eggs in 5 (17%) of 29 artificial nests known discovered by magpies were not depredated. These nests were visited at least 22 times by magpies during 9 exposure-days. One artificial nest that was visited 23 times by ≥1 magpies during 4 exposure-days had only 3 of its 6 eggs depredated. Only 4 (14%) of 29 nests detected by magpies were destroyed on the day the nest was discovered.

Black-billed magpies *occasionally* covered whole eggs in artificial nests with nest material. These looked like nests at which hens had covered their eggs before departing for a recess. Magpies sometimes uncovered and then recovered eggs, *often* moving, eating, or removing eggs in the process.

Treatment of Eggs—Black-billed magpies depredated 122 (70%) of 174 eggs placed in 29 artificial nests visited exclusively by magpies. At each of 5 nests a depredated egg was left whole, but moved ≥1 m from the nest. Magpies removed most depredated eggs from the nest sites. We accounted for only 23 (19%) of 122 depredated eggs based on eggshells found at the nests. Eight eggshells each had a small hole pecked in the side and little contents removed. Magpies probably would have continued feeding on those eggs had exposure periods been longer. When exposure periods ended, ≥1 egg was missing from 21 (88%) of 24 nest sites with a depredated clutch. All eggs were missing from 12 (50%) sites. A few shell fragments were found at some nests.

We observed several instances of a black-billed magpie in flight and carrying a duck egg in its bill. Black-billed magpies *customarily* picked up a duck egg by first piercing it, and inserting a mandible to grasp the shell. However, we once observed a black-billed magpie fly and carry an intact duck egg (13 x 55 mm) 13 m and then hide the egg in vegetation. We recovered the egg and found it had no puncture marks or puncture holes. Jones (1958:68) reported that, "The magpie [black-billed magpie] carries eggs [of mallard and ring-necked pheasant (*Phasianus colchicus*)] a short distance before plugging [pecking open] them and eating the partially incubated chick and other foods inside the eggshell."

Appearance of Eggshells and Nest Sites—Black-billed magpies *customarily* opened duck eggs by first pecking a small hole in the side or a side-end. They enlarged the hole to a narrow slit, then made a round opening (Appendix C, Fig. 9). Most of 23 eggshells examined for damage by magpies had small (39%) or large (57%) holes; only 1 (4%) was severely damaged (Appendix B, Table 3). There *occasionally* was a puncture hole near the main opening (Appendix C, Fig. 9c).

Most of 12 eggshells examined for location of openings made by black-billed magpies had the opening in the side (58%) or a side-end (33%); only 1 (8%) had the opening in an end (Appendix B, Table 4). There was little inward caving of shell pieces.

We found no evidence of black-billed magpies digging at nests. The proportion of nest material displaced by magpies from each of 24 artificial nests that were depredated ranged from 5 to 100%, and was >30% at 19 (79%) nests (Appendix B, Table 5). Magpies *often* dropped and/or scattered with their bill tufts of nest material, which became entangled on erect vegetation.

Most (65%) of 23 eggshells found at nests depredated by black-billed magpies were ≤20 cm from the nest (including in nest), but 7 (30%) were >1 m from the nest (Appendix B, Table 6). Conspicuous yolk residue *usually* was present in eggshells.

Conclusions—Black-billed magpies probably destroy completely few duck nests but may partially depredate numerous nests. Evidence indicating a nest was destroyed by black-billed magpies includes finding at the nest most or all of the following: (1) ≥1 whole egg, (2) eggshells of <50% of clutch or no eggshells, (3) trace of shell fragments or no shell fragments, (4) most eggshells have small or large holes, (5) conspicuous yolk residue in most eggshells, and (6) aerially displaced nest material (Appendix B, Table 2).

Evidence indicating a nest was not destroyed by black-billed magpies includes finding at the nest any of the following: (1) the hen was killed, (2) cached egg, (3) eggshells of ≥50% of clutch, (4) shell fragments that equal that of ≥1 egg, (5) dug area, and (6) no conspicuous egg content in any eggshell (Appendix B, Table 2).

American Crow

American crows range widely over uplands and wetlands, but duck nests in uplands appear more vulnerable to destruction by crows than those in wetlands (Sullivan and Dinsmore 1990).

Response to Hens and Nests—We found evidence of American crows harassing but not killing nesting hens. An American crow was observed jumping up and down on a nesting duck (large dabbling duck). When the duck flushed, the crow immediately flew off with an egg.

We obtained information for 54 artificial duck nests known to have been visited by American crows and at which we detected no interference from other potential predators. Each nest was monitored 1-3 days (*n* = 62 exposure-days) after detection by a crow was confirmed. Fifty-one (94%) nests were partially or completely depredated. Three nests not depredated were visited at least twice by crows.

Depredations of artificial nests *usually* were by individuals. Maximum number of crows photographed simultaneously at a nest was 1 individual during 48 (77%), 2 during 12 (19%), and 3-4 during 2 (3%) of 62 exposure-days. The latter records of crows at a nest site occurred during July, and may have included recently fledged individuals.

Crows *usually* depredated duck eggs placed in 54 artificial nests. Film records showed crows visited nests ≥352 times during 62 exposure-days. Two hundred fifty-seven (79%) of 324 eggs placed in the nests were depredated. Thirty-two (59%) nests had all eggs depredated on the day the nest was discovered. All eggs were missing without a trace of shell from 19 (59%) nest sites. Sowls (1948), Rearden (1951), Einarsen (1956), and Montevecchi (1976) also reported that American crows often remove eggs from nest sites.

Treatment of Eggs—Depredations of 51 artificial nests by American crows *usually* involved removal of eggs from nest sites. Of 257 depredated eggs, only 61 (24%) were accounted for by eggshells found at the nests. Forty-one (80%) nests had ≥1 egg missing; 19 (37%) had all eggs missing. Thirty-six (70%) nests had all eggs depredated, but eggshells of all 6 eggs were present at only 2 (6%) of those nests. Rearden (1951:392) concluded, "...it seems practically impossible for a crow to puncture an egg shell and pick it up without leaving some shell fragments, however small, in the nest." We found shell fragments at only 4 (21%) of 19 nests from which all eggs were missing, but shell fragments are easily overlooked. Only 1 (1%) of 67 whole eggs at depredated nests was outside the nest when the exposure periods ended.

Montevecchi (1976:316) found that, "The most common predation method of the crows [American crows] was to fly off with eggs [large and medium-size domestic fowl eggs and small Japanese quail (*Coturnix coturnix*) eggs] and to cache (bury) or eat them at a distance from the site of predation. The larger eggs were more frequently pecked open at the egg site and were less effectively picked up and carried off by the crows." Crows carried off eggs by puncturing the egg and inserting a mandible to grasp the shell, or by grasping eggs with their bill without puncturing the shell (Montevecchi 1976:308). We photographed 14 instances of American crows holding a duck egg with their bill; in 13 instances, the egg was pierced, and in 1 instance, the egg was grasped without being pierced.

Crows *usually* spent little time at nests when removing an egg, *often* too little to be photographed during 15-30 s photo intervals. For 19 nests with all eggs missing on day of nest discovery, crows visited the nests 3 times on average (range = 1-6). All 6 eggs of 1 clutch were missing from the nest site 20 min after a crow was first photographed at the nest. In contrast, individual crows visited another nest 47 times during a 3-day period before all 6 eggs were depredated.

Appearance of Eggshells and Nest Sites—Most of 61 eggshells examined for damage by American crows had small (51%) or large (43%) holes; only 4 (7%) were severely damaged (Appendix B, Table 3). *Occasionally*, there were ≥2 openings in an eggshell, sometimes in opposite sides of the egg (Appendix C, Fig. 10j, l). Most openings were round or irregularly shaped, with coarse edges but few inwardly caved pieces.

Most (60%) of 42 eggshells examined for location of openings had the opening in the side; only 4 (10%) had the opening in an end (Appendix B, Table 4). Conspicuous yolk residue *often* remained in eggshells after feeding by crows was completed. We *occasionally* found depredated eggs with small pecked holes and little contents removed.

Sowls (1948) and Einarsen (1956) reported that American crows and common ravens, respectively, leave little egg contents in eggshells or nests after feeding on eggs.

We never observed crows digging at nests. The proportion of nest material displaced from each of 51 artificial nests depredated exclusively by crows ranged from 0 to 100%, but exceeded 30% at 32 (63%) nests (Appendix B, Table 5). Characteristically, crows tossed and/or dropped nest material, which *often* became entangled on erect vegetation.

Most (84%) of 61 eggshells found at the 51 artificial nests depredated exclusively by American crows were ≤1 m from the nest, *usually* ≤20 cm from the nest (Appendix B, Table 6).

Conclusions—Evidence of destruction of duck nests by American crows varies greatly depending on whether depredated eggs were removed from the nest site (most common in our studies) or eaten at the nest. American crows *usually* removed depredated eggs from nest sites, but a few shell chips *often* are left at the site and may be overlooked. If eggs were eaten at the nest, eggshells and numerous shell fragments *customarily* are present. Other evidence that indicates a nest was destroyed by American crows includes finding at the nest most or all of the following: (1) ≥1 whole egg in nest; (2) eggshell with ≥2 openings, sometimes on opposite sides; (3) eggshell with conspicuous yolk residue; and (4) aerially displaced nest material (Appendix B, Table 2).

Evidence that indicates a nest was not destroyed by American crows includes finding at the nest any of the following: (1) the hen was killed, (2) cached egg, (3) whole egg outside the nest, and (4) dug area (Appendix B, Table 2).

Gulls

Gulls are most likely to depredate duck nests near, but not in, gull nesting colonies (Williams and Marshall 1938, Odin 1957, Anderson 1965, Vermeer 1970, Dwernychuk and Boag 1972). We found no evidence in literature of gulls depredating duck nests over water.

Response to Hens and Nests—We found no evidence in literature of gulls killing or harassing hens at nests. Ducks commonly nest among gulls on nesting islands (Anderson 1965, Vermeer 1970, Dwernychuk and Boag 1972).

We found weak responses by gulls to duck eggs. Only 17 (27%) of 63 artificial nests offered to gulls were visited by ring-billed gulls and/or California gulls. Loose eggs offered to gulls at 2 landfill sites *usually* were ignored by the gulls.

Responses by gulls to the artificial nests ranged from infrequent brief visits by individuals to lengthy ones (up to 38 min) by ≤6 birds. Two (13%) of 16 nests visited exclusively by gulls were not depredated; 5 (31%) nests had all eggs depredated. Of 84 eggs placed in 14 nests depredated exclusively by gulls, 30 (36%) eggs were whole, 28 (33%) were missing, and 26 (31%) were represented by eggshells when exposure periods ended. One or more eggs were missing, mostly without a trace of shell, from 12 nest sites. All eggs were missing from 1 site.

Treatment of Eggs—Odin (1957:188) reported that California gulls used the following methods to open duck eggs: "...(1) pecking a hole in the egg at the nest, (2) dropping the egg over water and retrieving the contents, (3) carrying the egg intact to the gull nesting islands or to a favorite loafing site, and (4) swallowing the egg whole." We observed several instances of a gull carrying an intact egg with its bill (Fig. 4). Once, we observed a California gull swallow a whole blue-winged teal egg. Gulls *usually* punctured, and sometimes partially consumed, an egg before carrying it off. Shell fragments were found at 2 (33%) of 6 nests at which there were missing eggs and no eggshells (but shell fragments are easily overlooked). We found no evidence indicating gulls hide eggs.

Appearance of Eggshells and Nest Sites—Both species of gulls *customarily* opened duck eggs by pecking, and California gulls *occasionally* bit eggs to open them. Eggs *often* were turned while being opened or eaten. This action resulted in the same or a different gull making another opening on the opposite side of the egg, and spillage of egg contents. Multiple openings (Appendix C, Fig. 11a, i, j) were present in 3 (6%) of 48 eggshells.

Most of 80 eggshells examined for damage by gulls had small (35%) or large (44%) holes (Appendix B, Table 3). Each opening *usually* was an elongated slit with pointed ends extending across 1 side of the egg (Appendix C, Fig. 11a, b, e, f). Twenty-seven (50%) of 54 eggshells from loose eggs depredated by gulls at landfills had openings of this shape.

Most (89%) of 75 eggshells examined for location of openings made by gulls had all openings in the side; no eggshell had an opening in an end (Appendix B, Table 4). Conspicuous yolk residue *usually* was present in eggshells.

We found no evidence of gulls digging at nests. Nest material was displaced from only 4 (29%) of 14 nests depredated exclusively by gulls. In each instance, ≤30% of the material was displaced (Appendix B, Table 5).

Most (81%) of 26 eggshells at nests depredated exclusively by gulls were ≤20 cm from the nest (Appendix B, Table 6).

Conclusions—Gulls probably destroy few duck nests. Evidence indicating a nest was destroyed by gulls includes finding at the nest most or all of the following: (1) ≥1 whole egg in nest, (2) part of clutch missing without trace, (3) ≥50% of openings in eggshells are small or large holes, (4) all openings in eggshells are on the side or a side-end, (5) eggshell with 2 openings of similar size, (6) eggshell with opening that is narrow elongated slit with pointed ends, (7) all eggshells have conspicuous yolk residue, and (8) no displaced nest material (Appendix B, Table 2).

Evidence indicating a nest was not destroyed by gulls includes finding at the nest any of the following: (1) the hen was killed, (2) cached egg, (3) eggshell with opening in an end, (4) all eggshells are clean inside, (5) dug area, and (6) >30% of nest material was displaced (Appendix B, Table 2).

Figure 4. California gull holding a whole duck egg in its bill.

Part III: Interpreting Evidence of Depredation

In Part III, we provide recommendations for interpreting evidence of depredation found at duck nests and apply them to duck nests found on waterfowl production areas in Minnesota, North Dakota, and South Dakota.

Identification of predators responsible for destruction of duck nests involves interpretation of circumstantial evidence. Thus, results are always subjective rather than definitive. Our examination of literature and our research suggest potential for error in interpreting evidence of depredation. We question the accuracy of identification of offending predators in most literature because of limited information available to investigators attempting to make determinations. Investigators not treating all principal predator species present in their study areas as potential depredators of nests, or investigators unaware of variations within or similarities among depredation patterns of certain predators, were likely to have made identification errors. We hope our findings will cause investigators to be more cautions in identifying depredators of duck nests, and to base their findings on objective rather than subjective methods.

Investigators interested in identifying predators of duck nests can use information provided herein as a field guide while examining evidence at nests. However, investigators interested in credible data for research or management should not rely on identifications made at nests. Rather, they should carefully record evidence of depredation on a nest depredation record (e.g., Appendix D, Fig. 1) for subsequent determination and analyses.

Our findings suggest much variability in evidence left at nests by individuals of some predator species and much similarity in evidence left by individuals of different predator species. Moreover, other factors (e.g., age of nest, weather, habitat) can affect amount and types of evidence of depredation found at nests. These variants, however, do not preclude usefulness of recording evidence of depredation.

We found major differences in depredation patterns among most predator species, with some species being easier to identify from evidence found at nests than others. Moreover, we found that certain factors (e.g., knowledge of the predator community, restricting analyses to certain types of nests) often can be used to improve the chances of identifying offending predator species. By using all available information, it often is possible to estimate the proportion of nests destroyed by a particular predator species.

Limitations of Data

Verification data for individual predator species generally are scant and based on small samples, as are data concerning frequency with which most predators leave various types of evidence. We found treatment of eggs, types of damage to shells, and location of openings in eggshells to be most useful for distinguishing among depredations by various predator species. Other evidence enables ruling out certain predator species because of its uniqueness to 1 or a few species (e.g., cached egg, dug area, dead hen, conspicuous yolk residue), or to substantiate other evidence (e.g., locations of eggshells, displacement of nest material).

Investigators should use judgement when applying our findings. For example, our findings for artificial nests probably exaggerate amount of nest material likely to be displaced by predators, because nest material at natural nests is packed more tightly. Also, hens at natural nests may return displaced nest material. However, our findings that some species displaced little or no nest material from loosely packed artificial nests (e.g., raccoon, gulls) is strong evidence that these predators are unlikely to displace nest material from natural nests.

We limited our recording of evidence of depredation to factors that could be accurately and easily recorded by investigators with varied backgrounds. Investigators, however, may wish to record other evidence that they are confident pertains to a predator species. Such evidence might include trails and matted areas at nests, tooth puncture marks in eggshells, shapes of openings in eggshells, and edges of openings in eggshells (e.g., finely serrated, connected pieces caved inward).

Estimating Proportion of Nests Destroyed by a Predator Species

There are 3 steps to estimate the proportion of nests destroyed by a predator species: (1) defining the question, (2) delineating the data set, and (3) establishing a hierarchy of criteria for assigning a destroyed nest to a predator species. Details of each step will vary depending on investigator needs and amount and quality of available data.

Defining the Question

Defining questions to be addressed is a critical first step. A question, such as — What is the estimated proportion of the nests destroyed by red foxes? — is too general. For evaluations to proceed, that question must be refined using qualifiers such as duck species, time periods, habitat, and age and size of clutch. A precise question might be: What is the estimated proportion of nests of dabbling ducks initiated during May and June in uplands and have ≥6 eggs at time of destruction that are destroyed by red foxes?

Delineating the Data

After the question has been defined, the data base is delineated using information from both nest records and nests depredation records. We recommend that evaluations be restricted to nests with ≥6 eggs when last visited by an investigator before the nest was destroyed. These nests contain a sufficient number of eggs for a predator to establish its pattern of depredation. Moreover, these nests are unlikely to be abandoned by the hen because of investigator disturbance, as often occurs with nests discovered early in the egg laying phase (pers. observations). It may be advantageous to restrict evaluations to nests with incubated eggs when last visited by the investigator, because additional eggs are rarely added to such nests. This enables determining with greater certainty the proportion of eggs in the clutch at the time of destruction that are represented by eggshells of the various types.

Investigators also may wish to restrict evaluations to nests discovered destroyed within a specific time interval after the nest was last visited, because evidence of depredation deteriorates and/or becomes compromised over time. During 1992, we revisited destroyed duck nests at 11 locations in South Dakota to determine temporal changes in occurrence and appearance of eggshells. Data were from 81 nests with ≥1 eggshell at the nest when discovered destroyed, and no additional eggs depredated between subsequent visits. Evidence of depredation was not disturbed by investigators. Each nest was revisited on average 8.9 days (range = 2-16 days) after the nest was discovered destroyed, for a total of 718 exposure-days. Of 393 eggshells present during the first visit, 348 (89%) remained during the second visit for an average loss rate of 0.06 eggshells/exposure-day. There was no change in number of eggshells at 37 (46%) nests. All nests with shell fragments during the first visit (n = 75) had shell fragments during the second visit. We also examined fate of whole eggs (n = 101) found at 18 nests during the first visit. Additional eggs (n = 83) were depredated at 15 (83%) of these nests during the average 8.1-day revisit period. Based on these findings, we recommend restricting analyses to nests destroyed during a revisit interval of ≤2 weeks.

Establishing a Hierarchy of Criteria

The purpose of the hierarchy of criteria is to reduce the overall data set to nest depredation records with evidence characteristic of the predator species of interest. This is done by first excluding records with evidence unlikely to have been left by that species. For remaining records, criteria characteristic of depredation by species of interest are ordered from most to least definitive, with the most definitive treated first. At any step, records with evidence unique to that species (e.g., cached eggs for badgers) can be assigned to the species, and the query continued to isolate records with other evidence characteristic of the species. With each subsequent query, number of candidate records in the pool decreases until no further exclusions or retentions are desired or possible. The proportion of initial records remaining after queries are completed, plus those already assigned to the species, is the total proportion of destroyed nests attributed to the predator species.

In general, the likelihood of obtaining definitive estimates of the proportion of nests destroyed by a predator species increases as number of predator species decreases. Investigators should establish criteria for assigning destroyed nests to predator species only from information for species that were present in habitats where nests were located. Because the suite of predator species at individual sites varies greatly throughout the Prairie Pothole Region (Sargeant *et al.* 1993), we urge investigators to obtain predator population data as part of their studies of duck nest success.

Examples of Interpreting Data Recorded on Nest Depredation Records

Sovada *et al.* (1995) used the above approach to assign destructions of duck nests to red foxes in their evaluation of differential effects of coyotes and red foxes on duck nest success. The suite of predator species at each study area was determined and central to the evaluation. They found that the proportion of nests of ≥6 eggs depredated in a manner attributed to red foxes was lower in the coyote areas (2%) than in the red fox areas (17%). The findings confirmed the authors' hypothesis that the difference in nest success (32% [coyote areas] vs. 17% [fox areas]) between areas occupied by each species was attributable to the difference in the canid community.

We used combined data from Sovada *et al.* (1995) and from sites without predator removal (Sargeant *et al.* 1995) to provide examples of interpreting data recorded on nest depredation records. We examined depredations by red foxes, striped skunks, and raccoons (Appendix B, Tables 7-9). These species are considered to be major predators of duck nests in the Prairie Pothole Region (Sargeant and Arnold 1984).

Data were from destroyed nests in uplands of 48 federal waterfowl production areas in Minnesota, North Dakota, and South Dakota during 1987-92. Data collection was similar in both studies. Nests were found throughout the duck nesting season and visited at about 7-10 day intervals until fate was determined. Data from each nest were recorded similar to procedures described by Klett *et al.* (1986). Evidence of depredation was recorded on prototypes of the nest depredation record (Appendix D, Fig. 1).

Predator population data revealed that striped skunks and raccoons were common at all areas. Coyotes, red foxes, and Franklin's ground squirrels were common at about half of areas. American badgers, minks, and weasels were present at most areas but generally were not common. American crows, black-billed magpies, and gulls were absent or only occasional visitors at nearly all areas. Based on these findings, we excluded avian species as potential depredators of the duck nests. We wished to estimate the proportion of nests that were destroyed by red foxes, striped skunks, and raccoons. Qualifiers for delineating the data set included the following: (1) nests of all duck species in all months, (2) nests in uplands only, (3) nests of ≥6 incubated eggs when last visited before being destroyed, and (4) nests discovered destroyed ≤2 weeks after the nest was last visited by an investigator (Appendix B, Tables 7-9). Qualifiers 1 and 2 resulted in a sample of 636 destroyed nests. Qualifiers 3 and 4 and removal of 6 other nests with incomplete information reduced the sample for analyses to 389 nests.

For foxes, we selected nests with no eggshells or shell fragments at the nest (Appendix B, Table 7). These criteria are strongest indicators of nest depredation by red foxes. These criteria resulted in retention of 86 (22%) nests. That sample was further reduced to 81 (21%) nests by eliminating nests with dug areas, carcasses or carcass parts, or evidence of a cached egg at the nest. Such evidence is rarely left by red foxes. Some investigators may further reduce the sample by eliminating nests with ≥1 whole egg at the nest and nests with >30% of nest material displaced (evidence *seldom* left by red foxes at nests). Thus, we estimated that 19-21% of the nests were destroyed by red foxes.

For striped skunks and raccoons (Appendix B, Tables 8-9), we first excluded from the usable sample of 389 destroyed nests those with evidence indicating the hen was killed or an egg was cached. Both species rarely leave such evidence. The hierarchy of nest depredation criteria for the 2 species then diverged.

For striped skunks, we retained only nests (n = 118) with eggshells of >50% of eggs present when the nest was last visited by an investigator. This is a strong indicator of depredation by both striped skunks and raccoons because both species seldom remove eggs from nest sites when they eat the eggs. We then eliminated nests for which >50% of eggshells had small holes, those with >50% of openings in eggshells in an end of the eggshells, and those with >25% of eggshells >1 m from the nest. These are strong indicators that a nest was not depredated by skunks. Application of the above criteria reduced the sample of usable nests to 87 (22%). A conservative estimate of 69 (18%) nests destroyed by skunks was obtained by eliminating nests with ≥1 dug area at the nest, those with ≥1 whole egg at the nest, those with no eggshell fragments at the nest, and those with no nest material displaced. These types of evidence are only occasionally found at duck nests with clutches destroyed by striped skunks.

For raccoons, we eliminated nests with ≥1 dug area at the nest, a behavior never exhibited by raccoons in our study, and then retained nests with eggshells of >50% of eggs present when the nest was last visited. These criteria reduced the sample to 110 (28%) nests. We then eliminated nests for which >50% of the eggshells had small holes and those with >50% of openings in eggshells in the side or a side-end of the eggshells. These are strong indicators that a nest was not depredated by raccoons. This process left 31 (8%) nests likely destroyed by raccoons. A conservative estimate of 17 (4%) of the usable nests destroyed by raccoons was obtained by eliminating nests with >25% of eggshells >1 m from the nest, those with >30% of nest material displaced, those with ≥1 whole egg at the nest, and those with no eggshell fragments at the nest. These types of evidence are only occasionally found at duck nests destroyed by raccoons.

In these examples, we identified the offending predator for about 40% of the usable nests. We found that red foxes and striped skunks were major depredators of the nests, and that raccoons were minor depredators of the nests. About 60% of nests were not assigned to the 3 examined species. Most of those nests probably were destroyed by other species. Some may have been destroyed by these 3 species, but were unassigned because of variations in the manner in which individuals destroyed nests. Others may have been sequentially visited by ≥2 species, each leaving additional evidence of depredation.

Using the above hierarchy of criteria, it is possible to assign destruction of an individual nest to >1 predator species. In our examples, no nest with destruction assigned to red foxes was assigned to the other species. However, this would have been likely had our evaluation included destructions by other species such as American crows and Franklin's ground squirrels. For raccoons and striped skunks, 11 nests were assigned to both species. This is to be expected because of similarities of depredation patterns of certain individuals of these species.

The above examples illustrate how data recorded on nest depredation records can be interpreted to assign destroyed nests to predator species and provide results suitable for comparison among studies. Other investigators might have chosen slightly different sets of qualifiers and/or slightly different hierarchies of criteria to estimate proportion of nests destroyed by each species and obtained slightly different, but equally valid, results. As more information on nest depredation patterns of individual predator species becomes available, ability of investigators to more completely assign destructions of nests to predator species will improve.

Acknowledgments

Data for this report were collected intermittently during a 20-year period in conjunction with numerous investigations by staff at the Northern Prairie Wildlife Research Center. We especially thank former Directors W. R. Goforth, H. K. Nelson, and R. C. Stendell, and Section Chiefs F. B. Lee and D. H. Johnson for their encouragement and support. A major phase of our work was part of a study of waterfowl recruitment conducted in collaboration with the Canadian Wildlife Service and U.S. Fish and Wildlife Service, Office of Migratory Bird Management. We especially appreciate the assistance R. S. Pospahala, Office of Migratory Bird Management, and R. K. Brace, Canadian Wildlife Service, for financial, logistical, and field support. We thank R. K. Brace and G. F. Bogdan, Canadian Wildlife Service, for arranging for necessary permits to conduct work with artificial duck nests in Canada.

We appreciate the help of many individuals who assisted with this study, especially W. B. Bicknell, T. K. Bollinger, J. M. Callow, E. J. Clem, J. O. Hastings, L. E. Eberhardt, A. D. Kruse, J. T. Lokemoen, S. A. Norland, J. L. Piehl, E. M. Preston, J. L. Preston, and J. M. Roaldson for data collection; S. H. Allen for help in obtaining study animals; J. P. Fleskes, S. A. Norland, T. D. Kostinec and C. VanFossen for certain observations referred to in text; J. P. Fleskes for providing eggshells of eggs depredated by weasels; E. C. Birney, W. J. Bleier, and R. W. Seabloom for cooperation in obtaining measurements from skulls of carnivores in collections in museums; and K. Forman, M. A. Johnson, D. A. Leschisin, L. A. Lysne, D. T. McKinnon, R. E. Reynolds, A. J. Rondeau, M. Rule, and G. C. Trottier for field trials of nest depredation records. We thank J. A. Beiser, K. M. Kraft, and C. L. Nustad for assistance with data analyses, and R. D. Thielman for photographic assistance. We thank D. P. Fellows, H. A. Kantrud, J. T. Lokemoen, D. T. McKinnon, R. E. Reynolds, and G. C. Trottier for review of manuscript drafts. We thank E. D. Rockwell of former National Biological Service, Information Transfer Center, and 2 anonymous referees for peer review of the manuscript. We thank R. M. Kaminski for editorial assistance, and Ducks Unlimited, Incorporated, for making possible publication of the manuscript. We especially thank Ducks Unlimited's Cecile Birchler who designed the publication and Heather Bond who provided invaluable assistance in managing the production process.

Literature Cited

Afton, A. D., and S. L. Paulus. 1992. Incubation and brood care. Pages 62-108 *in* B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, eds. Ecology and management of breeding waterfowl. Univ. of Minnesota Press, Minneapolis. 635pp.

Anderson, W. 1957. A waterfowl nesting study in the Sacramento Valley, California, 1955. Calif. Fish and Game 43:71-90.

Anderson, W. 1965. Waterfowl production in the vicinity of gull colonies. Calif. Fish and Game 51:5-15.

Arnold, T. W., and E. K. Fritzell. 1990. Habitat use by male mink in relation to wetland characteristics and avian prey abundances. Can. J. Zool. 68:2205-2208.

Aufforth, A. D., H. Goetz, and K. F. Higgins. 1990. Duck nesting on islands at J. Clark Salyer Refuge in North Dakota, 1983-1984. Prairie Nat. 22:1-12.

Baker, B. W. 1978. Ecological factors affecting wild turkey nest predation on south Texas rangelands. Proc. Ann. Conf. S.E. Assoc. Fish and Wildl. Agencies 32:126-136.

Banfield, A. W. F. 1974. The mammals of Canada. University of Toronto Press, Ontario. 438pp.

Barkley, W. D. 1972. The application of closed-circuit television to nature interpretation. Can. Field-Nat. 86:162.

Bellrose, F. C. 1980. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pa. 540pp.

Brandt, D. A. 1994. Overwater foraging by a badger. Prairie Nat. 26:171.

Choromanski-Norris, J., E. K. Fritzell, and A. B. Sargeant. 1989. Movements and habitat use of Franklin's ground squirrels in duck-nesting habitat. J. Wildl. Manage. 53:324-331.

Conant, R. 1958. A field guide to reptiles and amphibians of the United States and Canada east of the 100th Meridian. Houghton Mifflin Co., Boston. 366pp.

Cowardin, L. M., D. S. Gilmer, and C. W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildl. Monogr. 92. 37pp.

Cowardin, L. M., and D. H. Johnson. 1979. Mathematics and mallard management. J. Wildl. Manage. 43:18-35.

Creighton, P. D. 1971. Nesting of the lark bunting in north-central Colorado. Tech. Rep. 68. Grassland Biome, U.S. Int. Biol. Progr. 17pp.

Darrow, R. 1938. Possibilities of recognizing the evidence of predation and the species involved in the remains of grouse and grouse nests found destroyed. Trans. N. Am. Wildl. Conf. 3:834-838.

Duebbert, H. F., and J. T. Lokemoen. 1976. Duck nesting in fields of undisturbed grass-legume cover. J. Wildl. Manage. 40:39-49.

Dwernychuk, L. W., and D. A. Boag. 1972. Ducks nesting in association with gulls - an ecological trap? Can. J. Zool. 50:559-563.

Eberhardt, L. E., and A. B. Sargeant. 1977. Mink predation on prairie marshes during the waterfowl breeding season. Pages 33-43 *in* R. L. Phillips and C. Jonkel, eds. Proc. 1975 Predator Symp., Univ. of Montana, Missoula. 68pp.

Einarsen, A. S. 1956. Determination of some predator species by field sign. Oreg. State Monogr. Stud. Zool. 10. 34pp.

Errington, P. L. 1938. Experimental evidence of the eating of bob-white eggs by small Sciuridae. J. Mammal. 19:107-108.

Figley, W. K., and L. W. VanDruff. 1982. The ecology of urban mallards. Wildl. Monogr. 81. 40pp.

Fleskes, J. P. 1988. Predation by ermine and long-tailed weasels on duck eggs. J. Iowa Acad. Sci. 95:14-17.

Literature Cited (continued)

Fritzell, E. K. 1978. Habitat use by prairie raccoons during the waterfowl breeding season. J. Wildl. Manage. 42:118-127.

Girard, G. L. 1941. The mallard: its management in western Montana. J. Wildl. Manage. 5:233-259.

Gloutney, M. L., R. G. Clark, A. D. Afton, and G. J. Huff. 1993. Timing of nest searches for upland nesting waterfowl. J. Wildl. Manage. 57:597-601.

Glup, S. S., and L. L. McDaniel. 1988. Bullsnake predation on waterfowl nests on Valentine National Wildlife Refuge, Nebraska. Pages 149-152 *in* D. W. Uresk, G. L. Schenbeck, and R. Cefkin, tech. coordinators. Proc. 8th Great Plains Wildl. Damage Control Workshop, U.S. Forest Serv. Gen. Tech. Rep. RM-154. 23pp.

Graul, W. D. 1972. Breeding biology of the mountain plover (*Charadrius montanus*), 1969-1972. Tech. Rep. 199. Grassland Biome, U.S. Int. Biol. Progr. 15pp.

Greenwood, R. J. 1979. Relating residue in raccoon feces to food consumed. Am. Midl. Nat. 102:191-193.

Greenwood, R. J. 1981. Foods of prairie raccoons during the waterfowl nesting season. J. Wildl. Manage. 45:754-760.

Greenwood, R. J., P. M. Arnold, and B. G. McGuire. 1990. Protecting duck nests from mammalian predators with fences, traps, and toxicant. Wildl. Soc. Bull. 18:75-82.

Greenwood, R. J., A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T, L. Shaffer. 1995. Factors associated with duck nest success in the prairie pothole region of Canada. Wildl. Monogr. 128. 57pp.

Hall, E. R. 1981. The mammals of North America. John Wiley and Sons, Inc. New York. 2 volumes. 1,271pp.

Hanson, W. C., and L. L. Eberhardt. 1971. A Columbia River Canada goose population, 1950-1970. Wildl. Monogr. 28. 61pp.

Higgins, K. F. 1977. Duck nesting in intensively farmed areas of North Dakota. J. Wildl. Manage. 41:232-242.

Higgins, K. F., L. M. Kirsch, A. T. Klett, and H. W. Miller. 1992. Waterfowl production on the Woodworth Station in south-central North Dakota, 1965-1981. U.S. Fish and Wildl. Serv. Resour. Publ. 180. 79pp.

Ignatiuk, J. B., and R. G. Clark. 1991. Breeding biology of American crows in Saskatchewan parkland habitat. Can. J. Zool. 69:168-175.

Imler, R. H. 1945. Bullsnakes and their control on a Nebraska wildlife refuge. J. Wildl. Manage. 9:265-273.

Jarvis, R. L., and S. W. Harris. 1971. Land-use patterns and duck production at Malheur National Wildlife Refuge. J. Wildl. Manage. 35:767-773.

Jones, J. K., Jr., D. M. Armstrong, R. S. Hoffmann, and C. Jones. 1983. Mammals of the northern great plains. Univ. of Nebraska Press, Lincoln. 379pp.

Jones, R. E. 1958. The effect of magpie predation on pheasant and waterfowl populations in southern Idaho. M.S. Thesis. Univ. of Idaho, Moscow. 103pp.

Jones, R. E., and K. E. Hungerford. 1972. Evaluation of nesting cover as protection from magpie predation. J. Wildl. Manage. 36:727-732.

Kalmbach, E. R. 1937a. Crow-waterfowl relationships. U.S. Dep. Agric. Circ. 433. 36pp.

Kalmbach, E. R. 1937b. Crow-waterfowl relationships in the prairie provinces. Trans. N. Am. Wildl. Conf. 2:380-392.

Kalmbach, E. R. 1938. A comparative study of nesting waterfowl on the Lower Souris refuge: 1936-1937. Trans. N. Am. Wildl. Conf. 3:610-623.

Literature Cited (continued)

Kalmbach, E. R. 1939. Nesting success: its significance in waterfowl reproduction. Trans. N. Am. Wildl. Conf. 4:591-604.

Keith, L. B. 1961. A study of waterfowl ecology on small impoundments in southeastern Alberta. Wildl. Monogr. 6. 88pp.

Kiel, W. H., Jr., A. S. Hawkins, and N. G. Perret. 1972. Waterfowl habitat trends in the aspen parkland of Manitoba. Can. Wildl. Serv. Rep. 18. 61pp.

Klett, A. T., H. F. Duebbert, C. A. Faanes, and K. F. Higgins. 1986. Techniques for studying nest success of ducks in upland habitats in the prairie pothole region. U.S. Fish and Wildl. Serv. Resour. Publ. 158. 24pp.

Klett, A. T., T. L. Shaffer, and D. H. Johnson. 1988. Duck nest success in the prairie pothole region. J. Wildl. Manage. 52:431-440.

Kruuk, H. 1964. Predators and anti-predator behavior of the black-headed gull (*Larus ridibundus L.*). Behaviour Supplement 11:1-130.

Lein, M. R. 1968. The breeding biology of the savanna sparrow, *Pesserculus sandwichensis* (Gmelin), at Saskatoon, Saskatchewan. M.S. Thesis. Univ. of Saskatchewan, Saskatoon. 171pp.

Macdonald, D. W., L. Brown, S. Yerli, and A-F. Canbolat. 1994. Behavior of red foxes, *Vulpes vulpes*, caching eggs of loggerhead turtles, *Caretta caretta*. J. Mammal. 75:985-988.

Mallory, M. L., and P. J. Weatherhead. 1990. Effects of nest parasitism and nest location on eggshell strength in waterfowl. Condor 92:1031-1039.

Mann, G. E. 1974. The prairie pothole region: a zone of environmental opportunity. Naturalist 25:2-7.

Montevecchi, W. A. 1976. Egg size and the egg predatory behavior of crows. Behaviour 57:307-320.

Odin, C. R. 1957. California gull predation on waterfowl. Auk 74:185-202.

Rearden, J. D. 1951. Identification of waterfowl nest predators. J. Wildl. Manage. 15:386-395.

Riggert, T. L. 1977. The biology of the mountain duck on Rottnest Island, western Australia. Wildl. Monogr. 52. 67pp.

Rudzinski, D. R., H. B. Graves, A. B. Sargeant, and G. L. Storm. 1982. Behavioral interactions of penned red and arctic foxes. J. Wildl. Manage. 46:877-884.

Sargeant, A. B. 1972. Red fox spatial characteristics in relation to waterfowl predation. J. Wildl. Manage. 36:225-236.

Sargeant, A. B. 1978. Red fox prey demands and implications to prairie duck production. J. Wildl. Manage. 42:520-527.

Sargeant, A. B., S. H. Allen, and R. T. Eberhardt. 1984. Red fox predation on breeding ducks in midcontinent North America. Wildl. Monogr. 89. 41pp.

Sargeant, A. B., S. H. Allen, and D. H. Johnson. 1981. Determination of age and whelping dates of live red fox pups. J. Wildl. Manage. 45:760-765.

Sargeant, A. B., and P. M. Arnold. 1984. Predator management for ducks on waterfowl production areas in the northern plains. Pages 161-167 *in* D. O. Clark, ed. Proc. Eleventh Vertebr. Pest Conf., Univ. of California, Davis. 238pp.

Sargeant, A. B., and L. E. Eberhardt. 1975. Death feigning by ducks in response to predation by red foxes (*Vulpes vulpes*). Am. Midl. Nat. 94:108-119.

Sargeant, A. B., R. J. Greenwood, and W. B. Bicknell. 1982. Recurrence, mortality, and dispersal of prairie striped skunks, *Mephitis mephitis*, and implications to rabies epizootiology. Can. Field-Nat. 96:312-316.

Literature Cited (continued)

Sargeant, A. B., R. J. Greenwood, M. A. Sovada, and T. L. Shaffer. 1993. Distribution and abundance of predators that affect duck production — prairie pothole region. U.S. Fish and Wildl. Serv. Resour. Publ. 194. 96pp.

Sargeant, A. B., and D. H. Raveling. 1992. Mortality during the breeding season. Pages 396-422 *in* B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, eds. Ecology and management of breeding waterfowl. Univ. of Minnesota Press, Minneapolis. 635pp.

Sargeant, A. B., M. A. Sovada, and R. J. Greenwood. 1987. Responses of three prairie ground squirrel species, *Spermophilus franklinii*. *S. richardsonii*, and *S. tridecemlineatus*, to duck eggs. Can. Field-Nat. 101:95-97.

Sargeant, A. B., M. A. Sovada, and T. L. Shaffer. 1995 Seasonal predator removal relative to hatch rate of duck nests in waterfowl production areas. Wildl. Soc. Bull. 23:507-513.

Sargeant, A. B., G. A. Swanson, and H. A. Doty. 1973. Selective predation by mink, *Mustela vison*, on waterfowl. Am. Midl. Nat. 89:208-214.

Smith, A. G., J, H. Stoudt, and J. B. Gollop. 1964. Prairie potholes and marshes. Pages 39-50 *in* J. P. Linduska, ed. Waterfowl tomorrow. U.S. Fish and Wildl. Serv., Washington, D. C. 770pp.

Sooter, C. A. 1946. Habits of coyotes in destroying nests and eggs of waterfowl. J. Wildl. Manage. 10:33-38.

Sovada, M. A., A. B. Sargeant, and J. W. Grier. 1995. Differential effects of coyotes and red foxes on duck nest success. J. Wildl. Manage. 59:1-9.

Sowls, L. K. 1948. The Franklin ground squirrel, *Citellus franklinii* (Sabine), and its relationship to nesting ducks. J. Mammal. 29:113-137.

Sowls, L. K. 1955. Prairie ducks. Stackpole Co., Harrisburg, Pa. 193pp.

Stiehl, R. B., and S. N. Trautwein. 1991. Variations in diets of nesting common ravens. Wilson Bull. 103:83-92.

Stoddard, H. L. 1932. The bobwhite quail; its habits, preservation and increase. Charles Scribner's Sons. New York. 559pp.

Storm, G. L. 1972. Daytime retreats and movements of skunks on farmlands in Illinois. J. Wildl. Manage. 36:31-45.

Stoudt, J. H. 1971. Ecological factors affecting waterfowl production in the Saskatchewan parklands. U.S. Fish and Wildl. Serv. Resour. Publ. 99. 58pp.

Sullivan, B. D. 1990. Striped skunk swims to overwater duck nest. Prairie Nat. 22:271-272.

Sullivan, B. D., and J. J. Dinsmore. 1990. Factors affecting egg predation by American crows. J. Wildl. Manage. 54:433-437.

Teer, J. G. 1964. Predation by long-tailed weasels on eggs of blue-winged teal. J. Wildl. Manage. 28:404-406.

Terres, J. K. 1980. The Audubon Society encyclopedia of North American birds. Alfred A. Knopf, Inc., New York. 1109pp.

Tinbergen, N. 1965. Von den vorratskammern des rotfuchses (*Vulpes vulpes* L.). Z. Tierpsychol. 22:119-149.

Trevor, J. T., R. W. Seabloom, and R. D. Sayler. 1991. Identification of mammalian predators at artificial waterfowl nests. Prairie Nat. 23:93-99.

Vermeer, K. 1970. Breeding biology of California and ring-billed gulls: a study of ecological adaptation to the inland habitat. Can. Wildl. Serv. Rep. 12. 52pp.

Weller, M. W. 1956. A simple field candler for waterfowl eggs. J. Wildl. Manage. 20:111-113.

Williams, C. S. and W. H. Marshall. 1938. Duck nesting studies, Bear River Migratory Bird Refuge, Utah, 1937. J. Wildl. Manage. 2:29-48.

Willms, M. A., and R. L. Kreil. 1984. Northern harrier feeding on pipping mallard eggs. Prairie Nat. 16:187.

Glossary

Artificial nest - Depression scraped in soil and usually lined with nest material (to simulate the appearance of a natural nest) by an investigator in which eggs (always 6 in the present study) were placed by the investigator.

Cached egg - Egg deliberately hidden in vegetation, buried, or otherwise partially or completely covered with soil and/or debris by a predator.

Chip of shell - Single detached piece of shell <1 cm diameter.

Depredated egg - Egg completely or partially eaten, cached, or removed from a nest by a predator.

Depredated nest - Nest with ≥1 egg known depredated.

Destroyed nest - Nest with all eggs depredated, or nest abandoned by attendant hen after ≥1 egg was depredated.

Displaced nest material - Nest material pulled or otherwise removed from a nest by a predator and located >5 cm outside the original nest edge established by the attendant hen or the investigator. Nest material >5 cm outside the original nest edge but connected to the nest is displaced. Nest material rearranged or matted in the nest is not displaced.

Eggshell - Single piece of shell or pieces of shell connected by membrane that represent >50% of the total shell of an egg.

Eggshell that is crushed - Eggshell of egg crushed within the mouth of a predator resulting in a cylindrical or spherical mass of connected shell pieces, but with <25% of the original shape of the egg intact.

Eggshell that has large hole - Eggshell with ≥1 opening and >50% but ≤75% of the original shape of the egg intact.

Eggshell that has small hole - Eggshell with ≥1 opening and >75% of the original shape of the egg intact.

Eggshell that is fractured - Eggshell with ≥1 opening and 25-50% of the original shape of the egg intact.

Eggshell that is severely damaged - Eggshell with ≤50% of the original shape of the egg. Includes crushed, fractured, and trampled eggshells.

Eggshell that is trampled - Eggshell of egg that was trampled or otherwise smashed and looks flattened, and has <25% of the original shape of the egg intact.

Eggshell with opening in an end - Eggshell with >50% of original shape of the egg intact in which all openings in the egg were in 1 or both ends of the egg.

Eggshell with opening in the side - Eggshell with >50% of original shape of the egg intact in which all openings in the egg were in the side of the egg.

Eggshell with opening in a side-end - Eggshell with >50% of original shape of the egg intact in which the opening extended from the side into an end or there was an opening in the side and another in an end.

Exposure-day - One nest at risk of depredation during all or part of a 24-h period.

Fragment of shell - Single detached piece of shell or connected pieces of shell that represent ≤50% of the shell of an intact egg. Shell chips are small shell fragments.

Loose egg(s) - Individual egg or small number of eggs placed on the ground surface to attract predators but with no attempt to simulate a clutch in a nest. All loose eggs offered to predators in this investigation were duck eggs.

Membrane of egg - Thin pliable lining separating the embryonic content of an egg from the outer calciferous shell.

Missing egg - Egg that is no longer present or represented by an eggshell at the nest, but may be represented by shell fragments at the nest.

Nest depredation record - The record of information describing evidence of depredation found at a nest destroyed by predators.

Nest material - Vegetation, down, and other small feathers used by a hen to construct its nest.

Nest record - The record of information describing the species, location, history, and fate of a nest.

Nest site - The 3-m radius zone around and including an artificial or natural duck nest (synonymous with "at nest").

Glossary (continued)

Nest success - The probability that ≥1 egg of a clutch hatches (Cowardin and Johnson 1979).

Offending predator - Individual predator that depredated or destroyed a nest.

Principal predator - One of 9 species and 2 groups of congeneric species with potential to destroy significant numbers of duck nests in the Prairie Pothole Region.

Puncture hole - Small hole (≤1 cm diameter) punctured through the shell and membrane of an egg by a predator but which is not the main opening in the eggshell.

Puncture mark - Small visible indentation in the shell of an egg that was made by a predator when biting, pecking, or grasping the egg but which does not penetrate the membrane.

Retreat - Site used by a mammalian predator for resting.

Verification data - Data describing nest depredations for which the offending predator species was known or presumed known.

Appendix A. Sources of information and amount of detail from literature and present study concerning evidence of depredation at duck nests destroyed by principal predators of duck nests in the Prairie Pothole Region.

Source	Data type	Egg type	Predator species[a]										
			Coyote	Red fox	Raccoon	Striped skunk	American badger	Mink	Weasels[b]	Franklin's ground squirrel	Black-billed magpie	American crow	Gulls[c]
Stoddard (1932)	Nests[d]	Quail				L-V[e]							
Darrow (1938)	Nests[d]	Grouse		L-V	L-V	L-V		L-V	L-V			L-V	
Sowls (1948)	Nests[f]	Duck[g]				L[g]-V							
	Eggs[d]	Duck[g]							L[g]-V			L[g]-V	
Rearden (1951)	Nests	Duck						L-V					
	Nests[f]	Duck, chicken		M-V	M-E	L-V						M-V	
Einarsen (1956)	Nests	Pheasant				L-V						L-V	
Sooter (1946)	Nests	Duck	M-E										
	Eggs[d]	Chicken	L-E										
Kruuk (1964)	Nests	Gull		L-E									
Teer (1964)	Nests	Duck							L-E				
	Eggs[d]	Duck, chicken							L[g]-E				
Tinbergen (1965)	Nests	Gull		M-E									
Barkley (1972)	Eggs[h]	Grouse							L-V				
Montevecchi (1976)	Eggs[h]	Chicken, quail										S-E	
Baker (1978)	Nests[f]	Turkey, chicken	L-E		S-E	M-E							
Sargeant et al. (1987)	Nests[f],eggs[h]	Duck								S-E			
Fleskes (1988)	Nests	Duck							S-E				
	Eggs[d]	Duck							L-E				
Aufforth el. al. (1990)	Nests	Duck						L-V					
Trevor et al. (1991)	Nests[f]	Chicken[i]		S-E		S-E							
Present study	Nests[j]	Duck	S-E	S-E	S-E	S-E							
	Eggs[d]	Duck						L-E					
	Nests[f]	Duck		L-E	L-E	L-E				M-E	S-E	S-E	S-E
	Nests	Duck		L-E		S-V	S-E	L-V					
	Eggs[h]	Duck								L-E	L-E	L-E	M-E

a Codes refer to amount of data and detail of descriptions as follows: L = limited data (1-5 nests or individual predators known or thought to have been involved), M = moderate data (6-15 nests or individual predators known or thought to have been involved), S = substantial data ($\geq$16 nests or individual predators known or thought to have been involved), E = descriptions include explicit details, V = descriptions are vague.

b Ermine and long-tailed weasel.

c Ring-billed gull and California gull.

d Loose eggs depredated by captive predators in cages, pens, or enclosures.

e Includes data for the spotted skunk.

f Artificial nests with clutch depredated by free-ranging predators.

g Estimated from information provided.

h Loose eggs depredated by free-ranging predators.

i Eggs were boiled for 1 min to solidify the albumen and, therefore, the results were not included in the discussion in text.

j Artificial nests with clutch depredated by captive predators in a compound, enclosure, or both.

Appendix B, Table 1. Distance (mm) between tips of both upper and lower canine teeth of principal mammalian carnivores of duck nests in the Prairie Pothole Region.[a]

	Females								Males							
	Upper canines				Lower canines				Upper canines				Lower canines			
Predator	*n*	$\bar{x}$	SD	Range	*n*	$\bar{x}$	SD	Range	*n*	$\bar{x}$	SD	Range	*n*	$\bar{x}$	SD	Range
Coyote	12	30.2	2.0	27-33	6	27.7	1.5	26-29	10	31.2	3.2	24-35	6	26.0	3.3	22-30
Red fox	18	22.3	0.8	21-24	12	19.6	0.7	19-21	31	23.1	1.6	20-27	22	20.4	1.3	18-23
Raccoon	4	25.3	2.1	23-28	3	23.0	2.0	21-25	5	23.0	2.0	21-25	5	21.6	3.1	17-25
Striped skunk	1	16.0			1	14.0			5	16.8	0.8	16-18	5	14.8	0.4	14-15
American badger	7	27.7	2.8	22-30	6	25.7	1.2	24-27	8	30.4	1.3	29-33	6	27.7	3.1	22-31
Mink	17	10.0	0.4	9-11	11	9.0	0.5	8-10	23	11.6	1.9	10-19	22	9.9	1.0	9-12
Ermine	4	4.5	0.0	4-5	6	4.1	0.2	4-5	27	5.5	0.6	4-7	29	4.8	0.5	3-6
Long-tailed weasel	7	7.8	1.0	6-9	6	6.0	0.6	5-7	8	8.4	0.6	7-9	4	6.9	0.9	6-8

[a] Measurements are from intact and partial skulls of adult-size individuals of indicated species and sex from the Prairie Pothole Region in cataloged collections at the Biology Department, University of North Dakota, Grand Forks; Department of Zoology, North Dakota State University, Fargo; and James Ford Bell Museum of Natural History, University of Minnesota, Minneapolis, July 1992.

Appendix B, Table 2. Comparison among principal predators of duck nests in the Prairie Pothole Region of various types of evidence found at duck nests destroyed by predators. Indicator ratings of depredation by each species are positive (P), negative (N), inconclusive[a] (I), or not applicable[b] (na). Indicator ratings are based on available data and authors' experience and are for nests with ≥6 eggs when destroyed.

Evidence[b]	Principal predators										
	Coyote	Red fox	Raccoon	Striped skunk	American badger	Mink	Weasels[c]	Franklin's ground squirrel	Black-billed magpie	American crow	Large gulls[d]
Hen killed											
Feathers or blood only	P	P	N	N	N	P	N, I[e]	N	N	N	N
Carcass or carcass parts	P	N	N	N	N	P	N, I[e]	N	N	N	N
Cranium intact if present	P	na	na	na	na	N	na, I[e]	na	na	na	na
Cranium punctured if present	N	na	na	na	na	P	na, I[e]	na	na	na	na
Nest material[f]											
≤1% displaced	P	P	P	N	I	P	P	P	I	P	P
1-10% displaced on ground	P	P	P	I	I	P	P	P	P	P	P
11-30% displaced on ground	P	I	I	P	P	N	N	I	P	P	I
>30% displaced on ground	P	N	N	P	P	N	N	I	P	P	N
>1% displaced aerially	N	N	N	N	N	N	N	N	P	P	I
Ground surface disturbance											
≥1 dug area	N	N	N	N	P	N	N	N	N	N	N
Number cached or whole eggs											
Evidence of ≥1 cached egg	N	N	N	N	P	N	N	N	N	N	N
≥1 uncached whole egg	P	N	N	N	P	P	P	P	P	P/N[g]	P
Number of eggshells											
No eggshells	I	P	N	N	N	I	P	P	P	P	N
Eggshells of <50% of clutch	P	N	N	N	P	P	P	P	P	P	N
Eggshells of ≥50% of clutch	I	N	P	P	I	N	N	N	N	I	P
Amount of shell fragments											
None	I	P	N	N	N	P	P	P	P	P	N
Trace	P	N	N	N	N	P	P	P	P	P	N
>trace but <1 egg	P	N	P	P	P	P	I	P	I	P	P
≥1 egg	N	N	P	P	P	I	I	P	N	P	P

Table 2. Continued.

Evidence[b]	Principal predators: Coyote	Red fox	Raccoon	Striped skunk	American badger	Mink	Weasels[c]	Franklin's ground squirrel	Black-billed magpie	American crow	Large gulls[d]
Damage to eggshells[h]											
All have small holes	P	na	N	N	N	N	P	N	P	P	I
≥50% have small holes and all others have large holes or are fractured	P	na	N	N	N	N	P	P	P	P	P
≤50% have small holes and all others have large holes or are fractured	I	na	P	I	N	P	P	P	P	P	P
All eggshells have large holes or are fractured	N	na	P	P	P	P	N	P	N	I	I
≥1 trampled eggshell	N	na	P	N	P	N	N	N	N	N	N
≥1 crushed eggshell	N	na	N	N	P	N	N	N	N	N	N
Location and number of openings in eggshells[h]											
All openings on side	P	na	N	P	N	I	I	I	P	P	P
Mix of openings on side and side-end	P	na	I	P	P	P	P	P	P	P	P
≥1 opening on side and 1 on end, but <50% on end	N	na	P	P	I	I	I	P	I	I	N
≥50% of eggshells with opening on end	N	na	P	N	N	N	I	P	I	N	N
≥1 eggshell with ≥2 openings	P	na	N	N	N	N	N	N	I	P	P
Puncture marks and serrated edges											
≥1 eggshell with numerous small puncture marks	N	na	N	N	N	P	P	N	N	N	N
≥1 eggshell with finely serrated edge of opening	N	na	N	N	N	N	P	P	N	N	N
Amount of conspicuous yolk residue											
No eggshell has residue	P	na	P	P	P	I	I	I	N	I	N
≥1 eggshell has residue	N	na	N	N	N	P	P	P	P	P	P
≥50% of eggshells have residue	N	na	N	N	N	I	I	N	P	N	P
≥1 eggshell has ≥25% of egg contents	N	na	N	N	N	I	I	P	P	P	P
Locations of eggshells											
None in nest	P	na	P	P	P	P	P	P	I	I	P
All in nest	P	na	I	I	N	N	N	N	N	N	N
≥1 outside nest but all ≤20 cm from nest	P	na	P	P	N	N	N	N	I	I	N

Table 2. Continued.

Evidence[b]	Principal predators: Coyote	Red fox	Raccoon	Striped skunk	American badger	Mink	Weasels[c]	Franklin's ground squirrel	Black-billed magpie	American crow	Large gulls[d]
≥50% of eggshells >1 m from nest	P	na	N	N	N	I	I	P	P	N	N
Disturbance to vegetation at nest											
No disturbance	P	P	N	N	N	I	P	P	P	P	P
Matted area >1 m from nest but not connected to nest by trail	P	N	N	N	N	N	N	N	N	N	I
Matted area or wide trail <1 m from nest	N	N	P	P	P	N	N	N	N	N	N
Wide trail extending out 1-3 m from nest	N	N	N	N	P	N	N	N	N	N	N
Narrow runway(s) leading away many meters from nest	N	N	N	N	N	P	P	I	N	N	N

[a]Information is inadequate to assign an indicator value to the evidence or the evidence has little value in deciding if the predator species caused the destruction.

[b]See glossary for definitions of terms; na = not applicable because eggshells or evidence hen was killed are *customarily* absent.

[c]Includes ermine and long-tailed weasel.

[d]Includes ring-billed gull and California gull.

[e]First entry is the response for the ermine; second entry is the response for the long-tailed weasel.

[f]In making assignments we took into account that the proportion of nest material displaced from artificial nests in our studies (Table 5) probably exceeded that at natural nests because the material was not packed as tightly as at natural nests.

[g]Positive indicator if egg(s) are in nest, but negative indicator if ≥1 egg is outside nest.

[h]For nests at which ≥6 were found.

Appendix B, Table 3. Frequency of various types of damage among eggshells of duck eggs depredated by principal predators of duck nests in the Prairie Pothole Region, 1972-92.

Predator	Data type	No. eggshells[a]	Frequency (%)		
			Small holes	Large holes	Severly damaged[b]
Coyote	Artificial nest	129	93	2	5
Red fox	Artificial nest, loose egg	42	20	73	7
Raccoon	Artificial nest	144	13	66	21
Striped skunk	Artificial nest	208	12	66	22
	Natural nest	67	4	58	36
American badger	Natural nest	265	3	40	57
Mink	Loose egg	28	36	50	14
Weasels[c]	Loose egg	15[d]	60	33	7
Franklin's ground squirrel	Artificial nest	35	23	57	20
Black-billed magpie	Artificial nest	23	39	57	4
American crow	Artificial nest	61	51	43	7
Gulls[e]	Artificial nest	26	35	50	15
	Loose egg	54	35	41	22

[a]Examined eggshells whose connected parts made up $\geq$50% of the intact shell of an egg.

[b]Includes fractured, trampled, and crushed eggshells (see Glossary for definitions).

[c]Ermine and long-tailed weasel.

[d]Includes 12 eggshells provided by J. P. Fleskes, Iowa Cooperative Fish and Wildlife Research Unit, Ames, and 3 eggshells interpreted from photos in Teer (1964).

[e]Ring-billed gull and California gull.

Appendix B, Table 4. Frequency of eggshells of duck eggs depredated by predators of duck nests in the Prairie Pothole Region during 1972-92 with opening located in an end, side, or both (side-end).

Predator	Data type	No. eggshells[a]	Location of openings (%)		
			End	Side	Side-end
Coyote	Artificial nest	75	0	97	3
Red fox	Artificial nest	42	2	88	10
Raccoon	Artificial nest	226	59	12	29
Striped skunk	Artificial nest	136[b]	14	50	36
	Natural nest	48	4	48	48
American badger	Natural nest	79	9	30	61
Mink	Loose egg	27	7	63	30
Weasels[c]	Loose egg	13	38	23	38
Franklin's ground squirrel	Artificial nest	31	13	23	65
Black-billed magpie	Artificial nest	12	8	58	33
American crow	Artificial nest	42	10	60	31
Gulls[d]	Artificial nest	26	0	96	4
	Loose egg	49	0	86	14

[a]Number of eggshells examined whose connected parts made up ≥50% of the intact shell of an egg.

[b]Excludes 70 eggs eaten by a captive striped skunk that opened 50% of eggs on an end, 16% on the side, and 34% on a side-end.

[c]Ermine and long-tailed weasel.

[d]Ring-billed gull and California gull.

Appendix B, Table 5. Frequency of depredated duck nests by classes of percentage of nest material displacement for principal predators of duck nests in the Prairie Pothole Region, 1972-92.

			Frequency (%) of depredated nests by classes of percent of nest material displaced						
Predator	**Nest type**[a]	**No. nests**	**0**	**1-10**	**11-30**	**31-50**	**51-70**	**71-90**	**91-100**
Coyote	Artificial	59	8	12	12	2	3	14	49
Red fox	Artificial[b]	14	50	7	14	21	0	7	0
Raccoon	Artificial	28	64	18	11	7	0	0	0
Striped skunk	Artificial	46	9	7	7	28	20	20	11
American badger	Natural	61	13	11	23	13	2	13	25
Mink	Natural	31	65	23	10	3	0	0	0
Weasels[c]	Natural	38	100	0	0	0	0	0	0
Franklin's ground squirrel	Artificial	15	0	20	13	33	0	20	13
Black-billed magpie	Artificial	24	0	13	8	8	13	46	13
American crow	Artificial	51	10	14	14	12	6	27	18
Gulls[d]	Artificial	14	71	21	7	0	0	0	0

[a]All nests were in uplands or dry wetlands and were known or thought to have ≥6 eggs when last visited by an investigator before nest was destroyed.

[b]Includes 1 natural nest with 5% of nest material displaced.

[c]Ermine and long-tailed weasel; data from Fleskes (1988).

[d]Ring-billed gull and California gull.

Appendix B, Table 6. Distribution of eggshells by distance intervals at duck nests depredated by the principal predators of duck nests in the Prairie Pothole Region, 1972-92.

				Eggshell (%) by distance intervals from nest			
Predator	**Nest type[a]**	**No. nests**	**No. eggshells**	**≤20 cm[b]**	**>20 cm - 1 m**	**>1 - 2 m**	**>2 - 3 m**
Coyote	Artificial	59	129	23	52	16	9
Red fox	Artificial	152	1[c]	0	0	0	0
	Natural	1	0	0	0	0	0
Raccoon	Artificial	28	144	64	32	3	1
Striped skunk	Artificial[d]	30	151	72	25	3	1
American badger	Natural	61	173	43	46	9	2
Mink[e]							
Weasels[e,f]							
Franklin's ground squirrel	Artificial	15	35	43	26	29	3
Black-billed magpie	Artificial	24	23	65	4	27	4
American crow	Artificial	51	61	52	31	10	7
Gulls[g]	Artificial	14	26	81	12	8	0

[a]All nests had ≥6 eggs when last visited by an investigator before nest was destroyed.

[b]Includes eggshells in nests.

[c]Only 1 eggshell was found at the nest and the distance interval was not recorded.

[d]Excludes eggs from 16 nests depredated by a striped skunk that had a den near the nests and exhibited unusual behavior by taking many eggs from the nest sites toward or to the den.

[e]No data available.

[f]Ermine and long-tailed weasel.

[g]Ring-billed gull and California gull.

Appendix B, Table 7. Stepwise application of specified criteria to estimate the proportion of destroyed (by predators) incubated duck nests of ≥6 eggs in uplands of 48 federal waterfowl production areas in Minnesota, North Dakota, and South Dakota with destruction caused by red foxes.

		Number of nests	
Criteria	Indicator[a]	Affected	Remaining in sample
Nests[b]			1,108
Destroyed by predator		636	636
≥6 eggs present when last visited		564	564
Eggs incubated when last visited		421	421
Visit interval of ≤14 days		395	395
Excluded because of missing data[c]		6	389[d]
No eggshells	P	124	124
No shell fragments	P	86	86[e]
Dug area	N	2	84[e]
Carcass or carcass parts of hen	N	3	81[e]
Evidence egg cached	N	0	81[e]
≥1 whole egg	N	6	75[e]
>30% of nest material displaced	N	3	72[f]

[a]Positive (P) or negative (N) indicators of depredation by red foxes. For each category of evidence, all nest depredation records remaining in the sample are examined for presence or absence of that evidence. Records with that evidence are retained (P) for possible assignment of destruction to foxes. Records without that evidence (N) are removed from further consideration of possible assignment of destruction to foxes.

[b]Total nests found that were suitable for analyses (excludes nests with eggs broken or hens injured by investigators, nests abandoned within a few days after discovery, and nests parasitized by another species).

[c]Nests excluded because data were absent for ≥1 examined variable.

[d]Sample of nests used in analysis.

[e]Nests likely to have been destroyed by red foxes.

[f]Nests with cause of destruction assigned to red foxes.

Appendix B, Table 8. Stepwise application of specified criteria to estimate the proportion of destroyed (by predators) incubated duck nests of ≥6 eggs in uplands of 48 federal waterfowl production areas in Minnesota, North Dakota, and South Dakota with destruction caused by striped skunks.

		Number of nests	
Criteria	Indicator[a]	Affected	Remaining in sample
Nests[b]			1,108
Destroyed by predator		636	636
≥6 eggs present when last visited		564	564
Eggs incubated when last visited		421	421
Visit interval of ≤14 days		395	395
Excluded because of missing data[c]		6	389
Evidence hen was killed	N	19	370
Evidence egg cached	N	13	357
Eggshells of >50% of depredated eggs	P	118	118
>50% of eggshells have small holes	N	12	106
>50% of openings in eggshells with small or large holes were in an end	N	12	94[d]
>25% of eggshells >1 m from nest	N	7	87[d]
Dug area	N	7	80[d]
Whole egg(s) at nest	N	5	80[d]
No eggshell fragments	N	6	75[d]
No nest material displaced	N	9	69[e]

[a]Positive (P) or negative (N) indicators of depredation by striped skunks. For each category of evidence, all nest depredation records remaining in the sample are examined for presence or absence of that evidence. Records with that evidence are retained (P) for possible assignment of destruction to skunks. Records without that evidence (N) are removed from further consideration of possible assignment of destruction to skunks.

[b]Total nests found that were suitable for analyses (excludes nests with eggs broken or hens injured by investigators, nests abandoned within a few days after discovery, and nests parasitized by another species).

[c]Nests excluded because data were absent for ≥1 examined variable.

[d]Nests likely to have been destroyed by striped skunks.

[e]Nests with cause of destruction assigned to striped skunks.

Appendix B, Table 9. Stepwise application of specified criteria to estimate the proportion of destroyed (by predators) incubated duck nests of ≥6 eggs in uplands of 48 federal waterfowl production areas in Minnesota, North Dakota, and South Dakota with destruction caused by raccoons.

Criteria	Indicator[a]	Number of nests	
		Affected	Remaining in sample
Nests[b]			1,108
Destroyed by predator		636	636
≥6 eggs present when last visited		564	564
Eggs incubated when last visited		421	421
Visit interval of ≤14 days		395	395
Excluded because data missing[c]		6	389
Evidence hen killed	N	19	370
Evidence egg cached	N	13	357
Dug area	N	21	336
Eggshells of >50% of depredated eggs	P	110	110
>50% of eggshells have small holes	N	12	98
>50% of openings in eggshells with small or large holes were in the side or a side-end	N	67	31
>25% of eggshells >1 m from nest	N	3	28[d]
>30% of nest material displaced	N	8	20[d]
Whole egg(s) at nest	N	3	20[d]
No eggshell fragments	N	0	17[e]

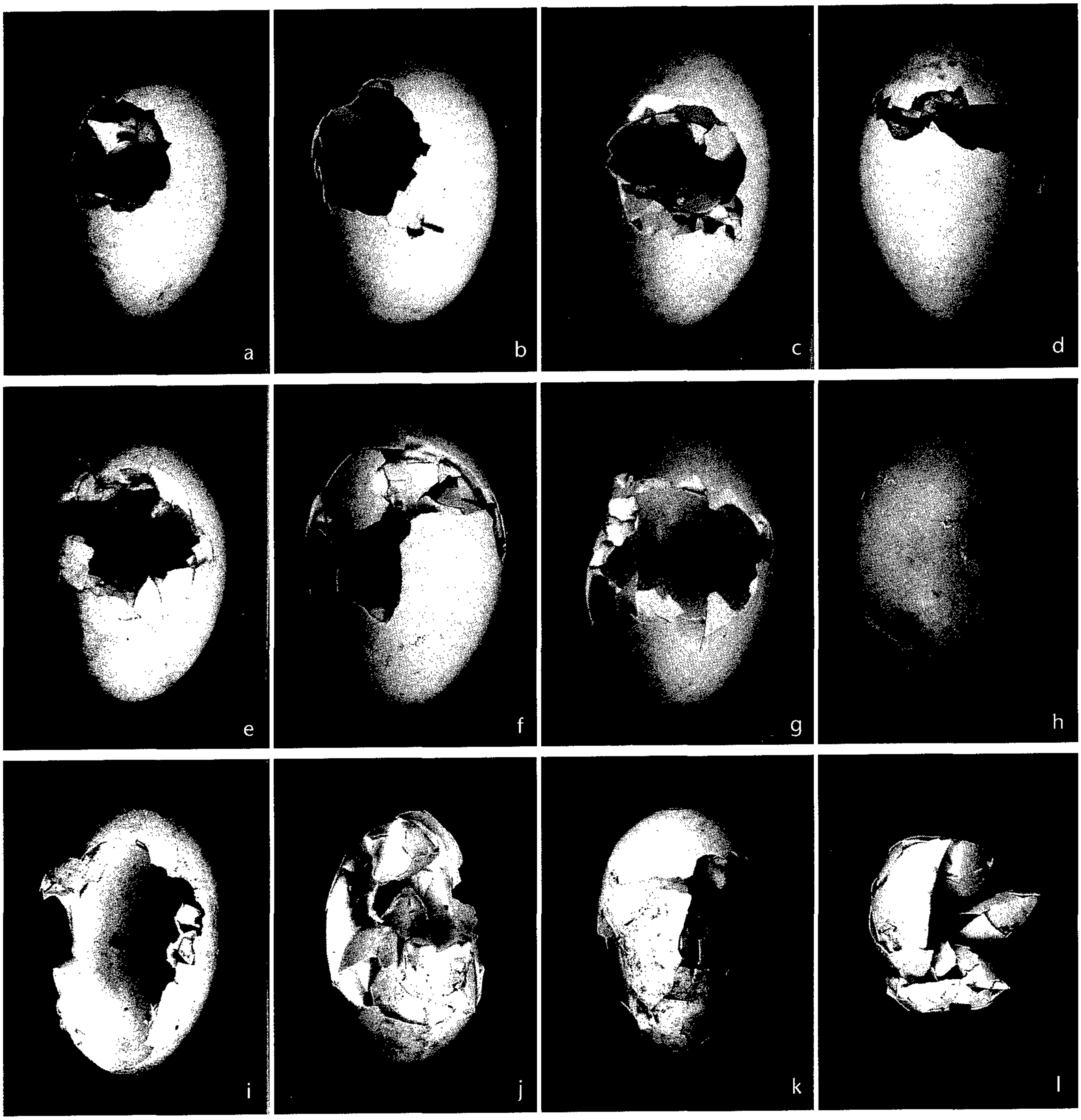
[a]Positive (P) or negative (N) indicators of depredation by raccoons. For each category of evidence, all nest depredation records remaining in the sample are examined for presence or absence of that evidence. Records with that evidence are retained (P) for possible assignment of destruction to raccoons. Records without that evidence (N) are removed from further consideration of possible assignment of destruction to raccoons.

[b]Total nests found that were suitable for analyses (excludes nests with eggs broken or hens injured by investigators, nests abandoned within a few days after discovery, and nests parasitized by another species).

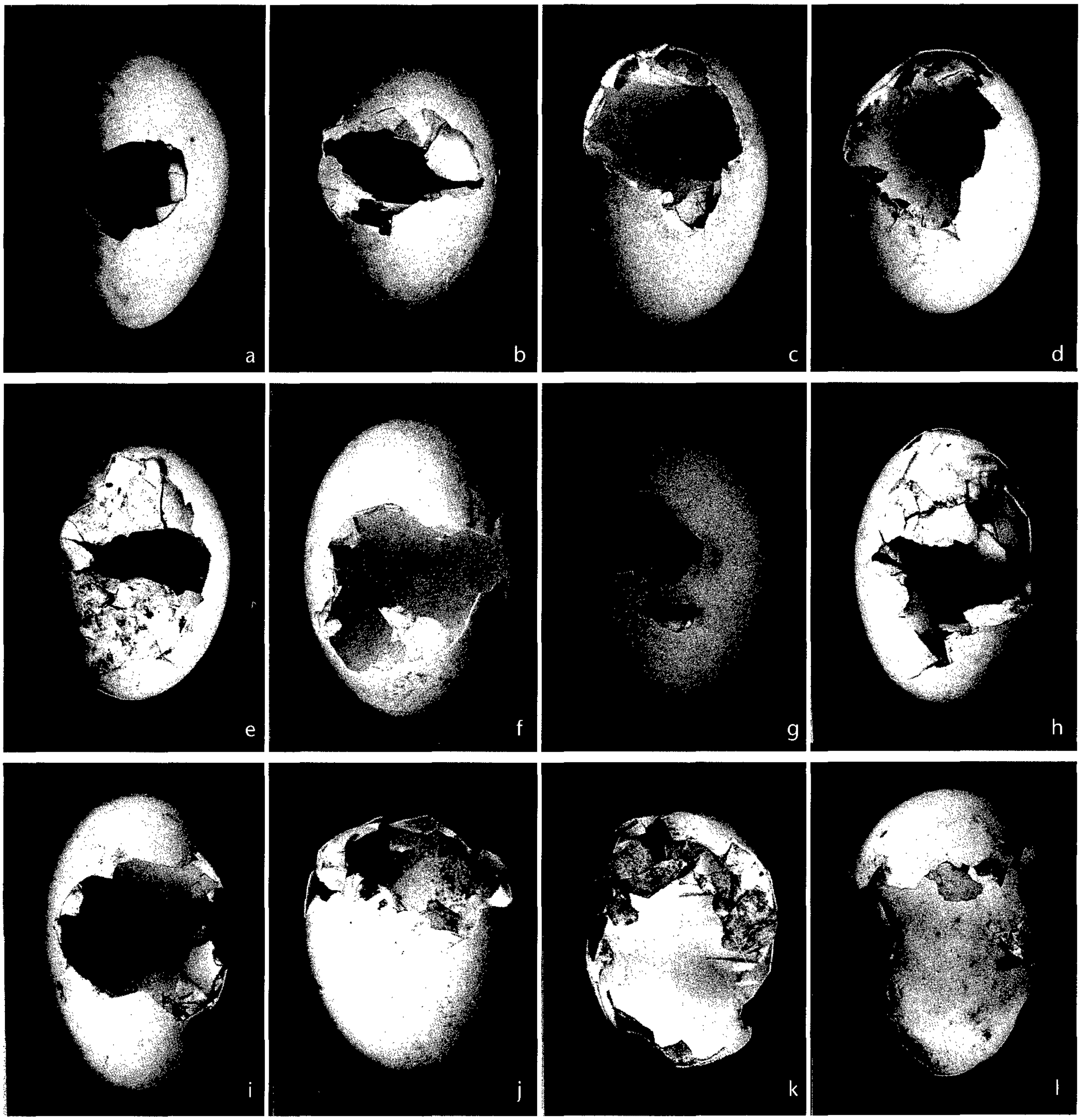
[c]Nests excluded because data were absent for ≥1 examined variable.

[d]Nests likely to have been destroyed by raccoons.

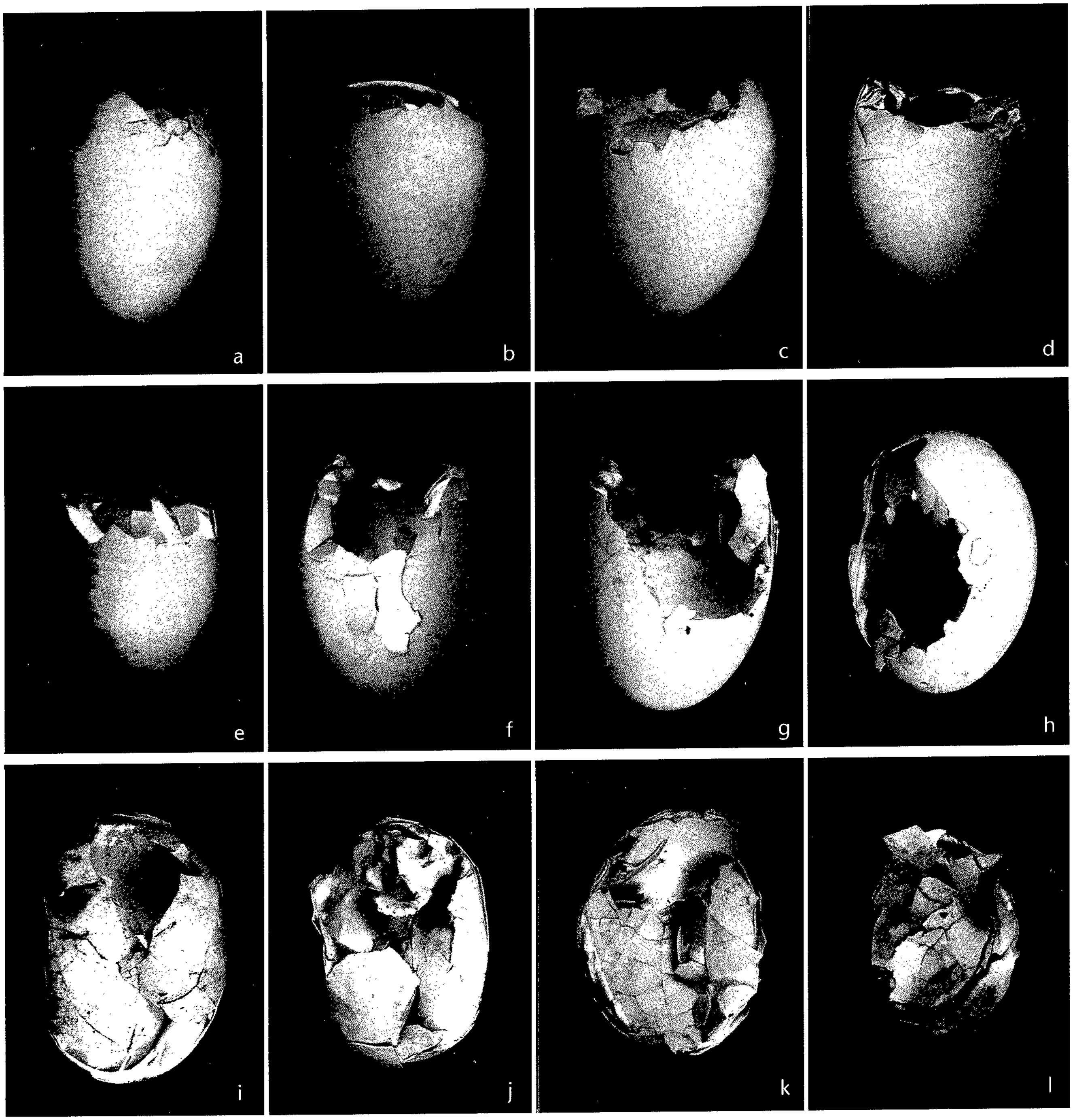
[e]Nests with cause of destruction assigned to raccoons.



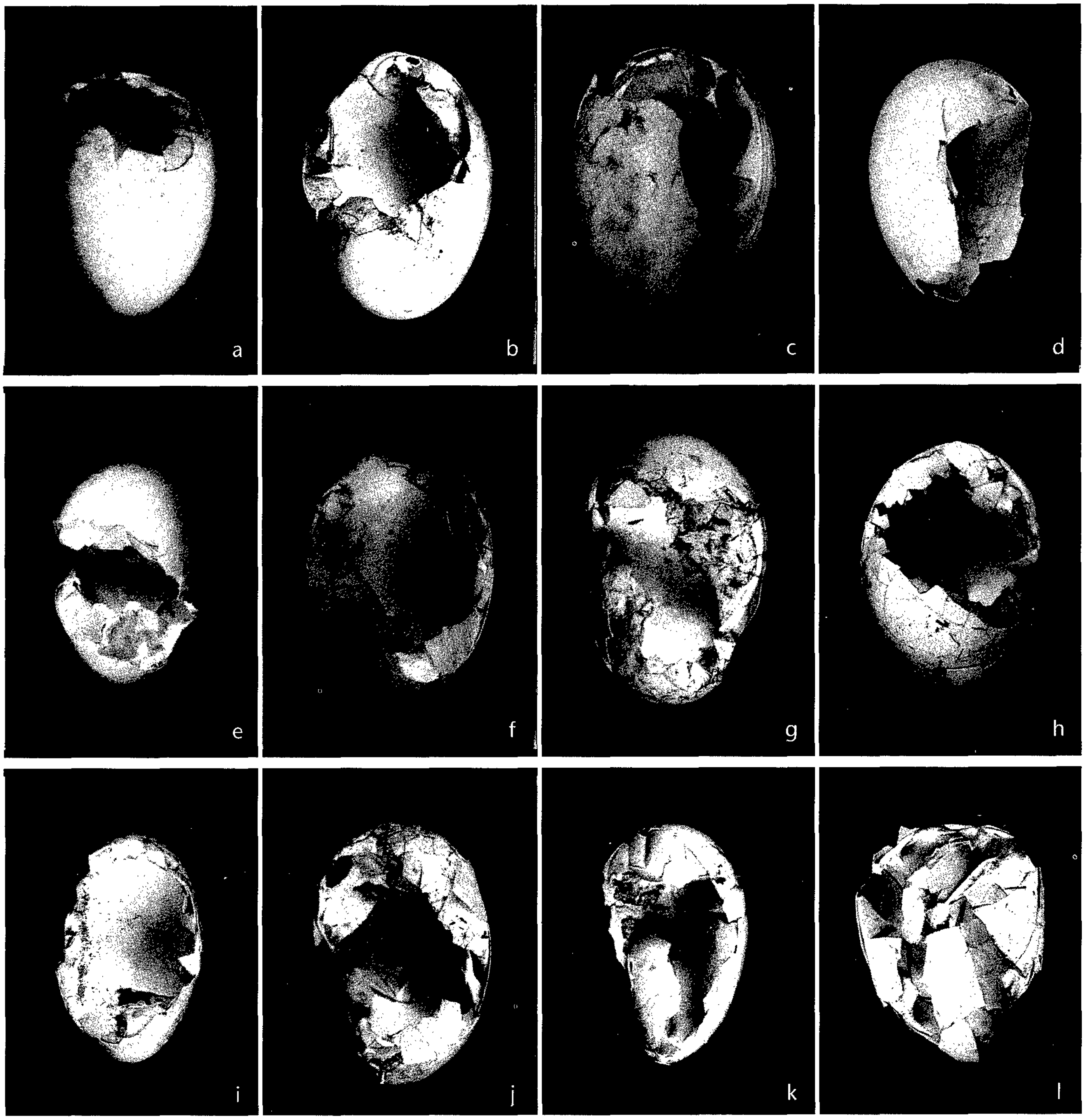
Appendix C, Figure 1. Eggshells of duck eggs depredated by coyotes showing different types of destruction.



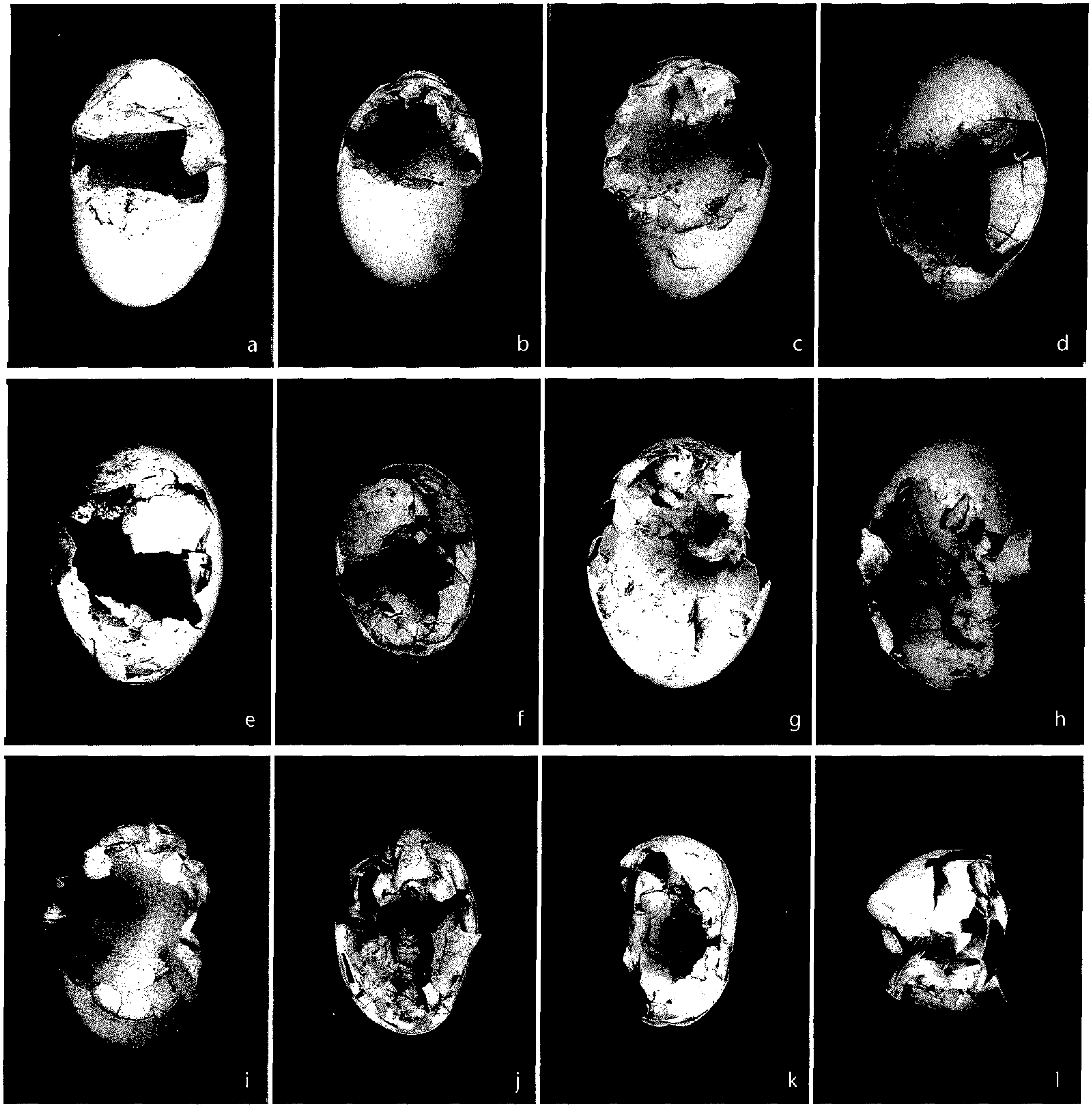
Appendix C, Figure 2. Eggshells of ducks eggs depredated by red foxes showing different types of destruction.



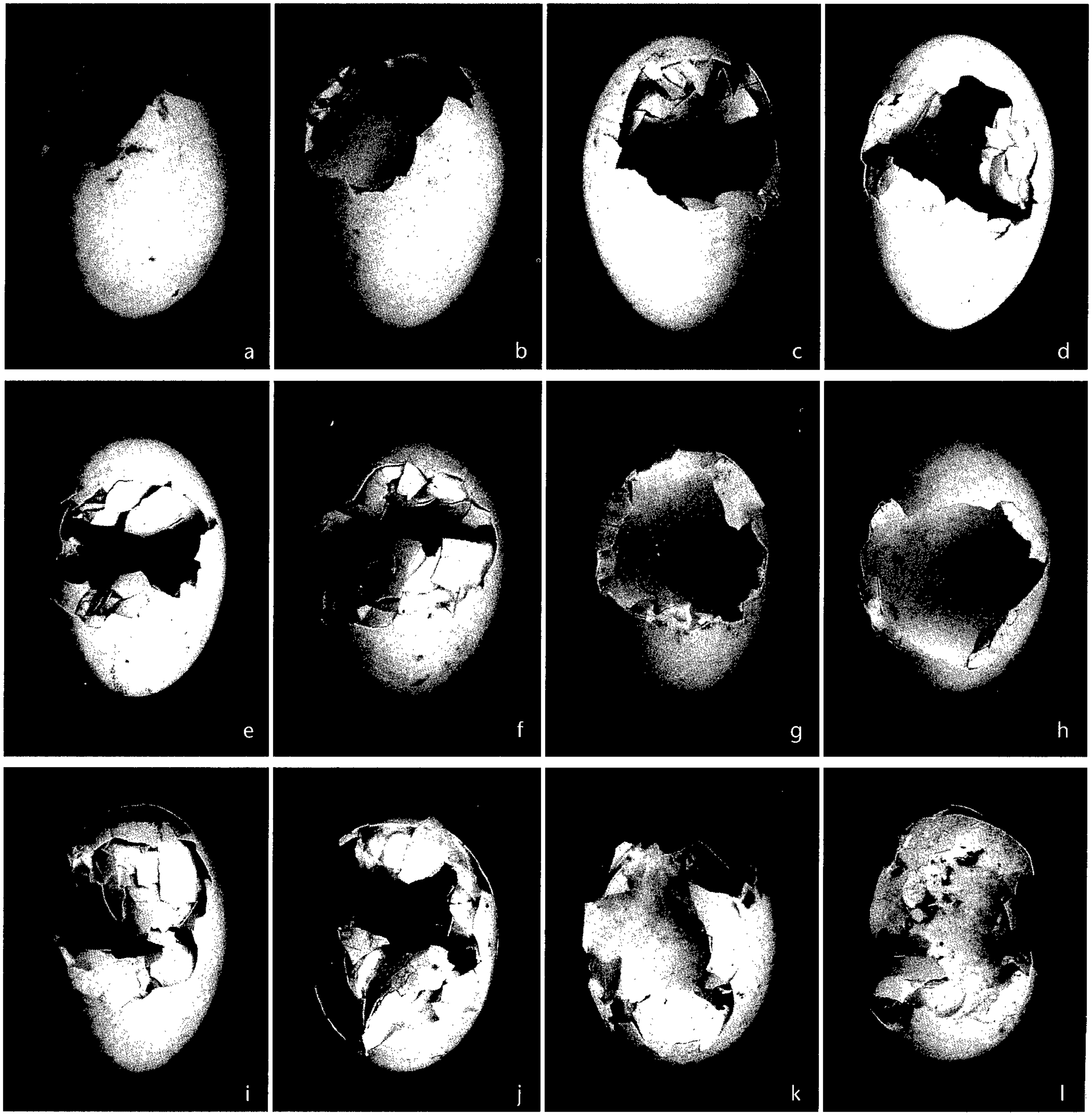
Appendix C, Figure 3. Eggshells of duck eggs depredated by raccoons showing different types of destruction.



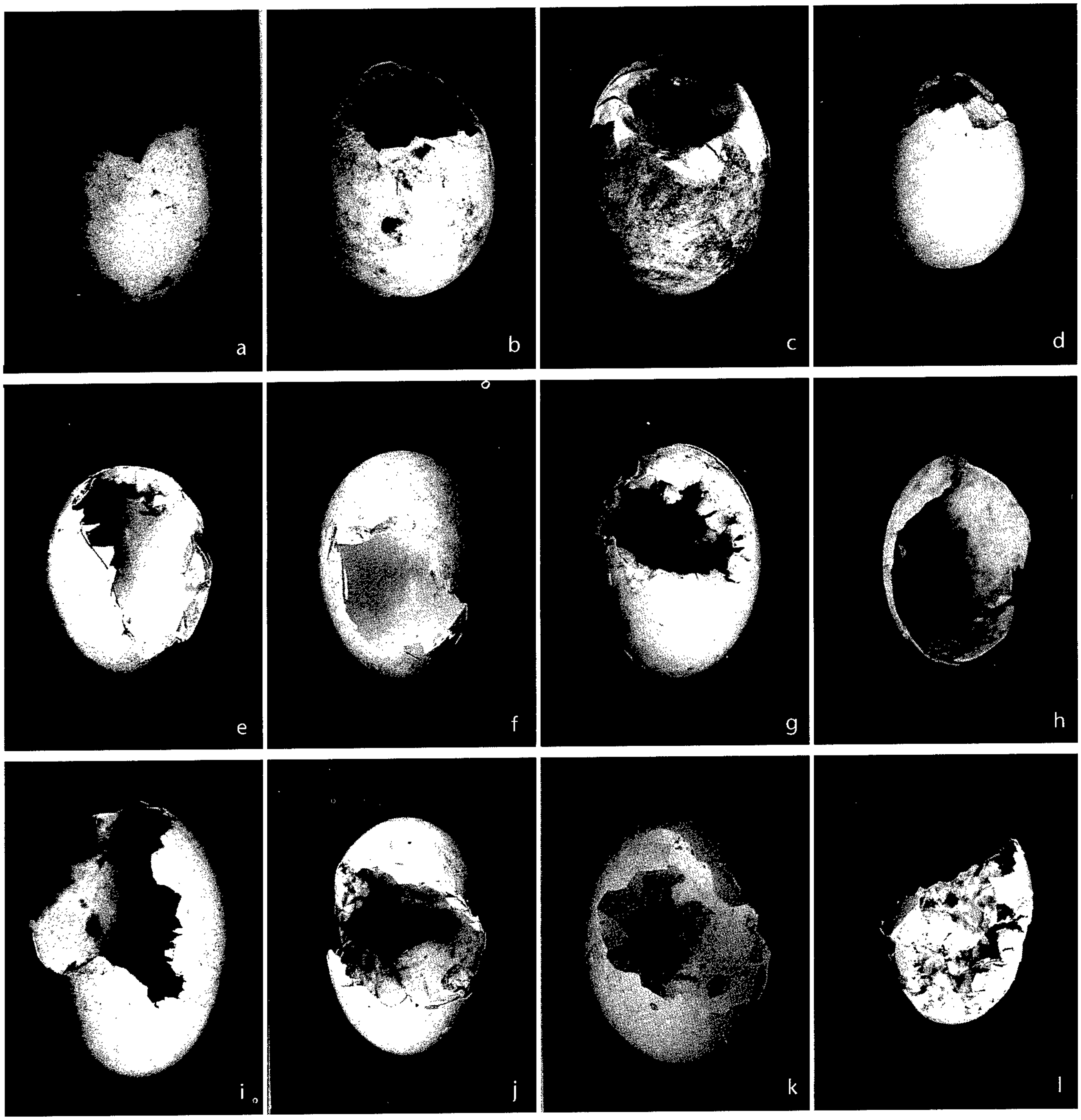
Appendix C, Figure 4. Eggshells of duck eggs depredated by striped skunks showing different types of destruction.



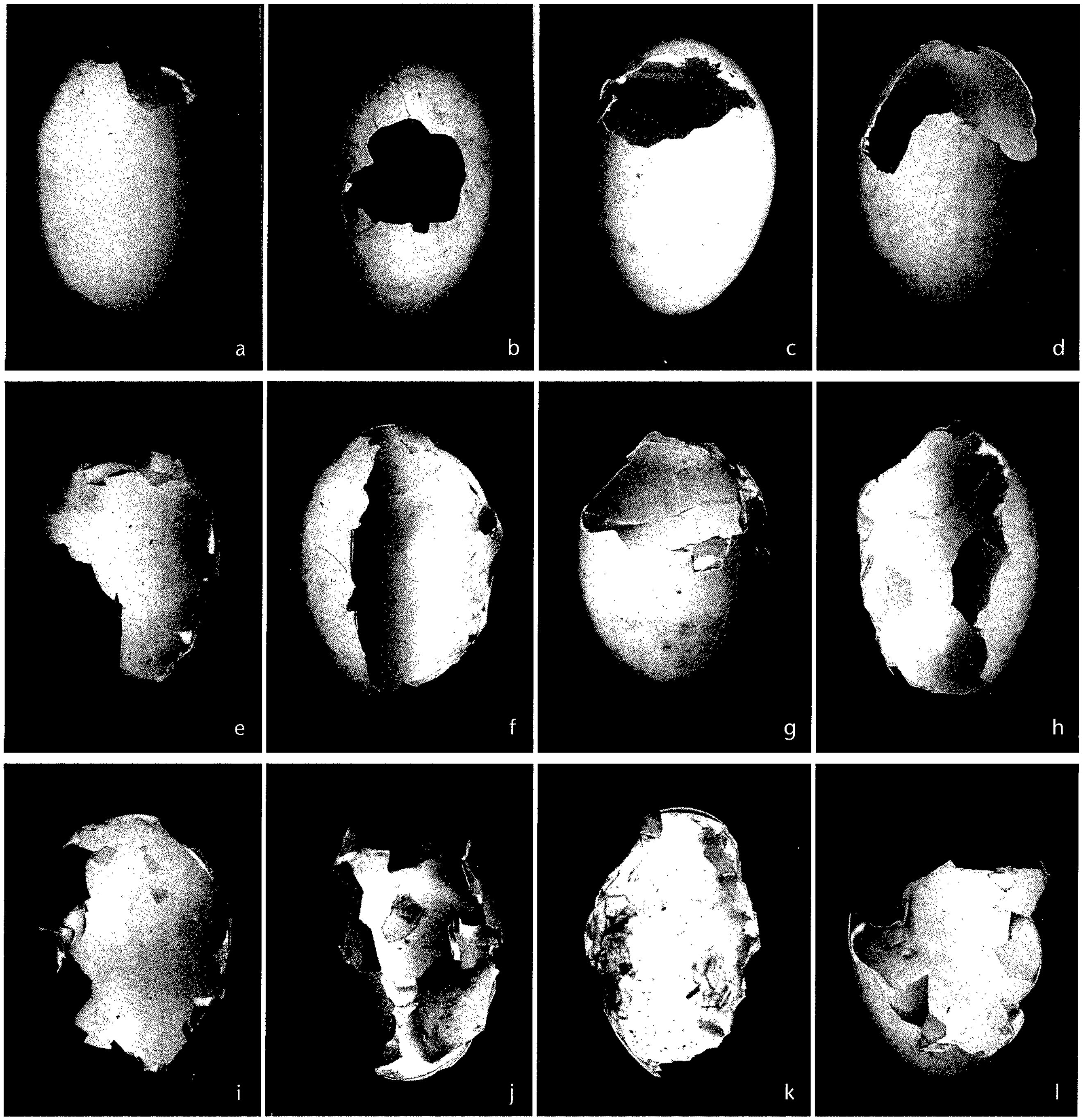
Appendix C, Figure 5. Eggshells of duck eggs depredated by American badgers showing different types of destruction.



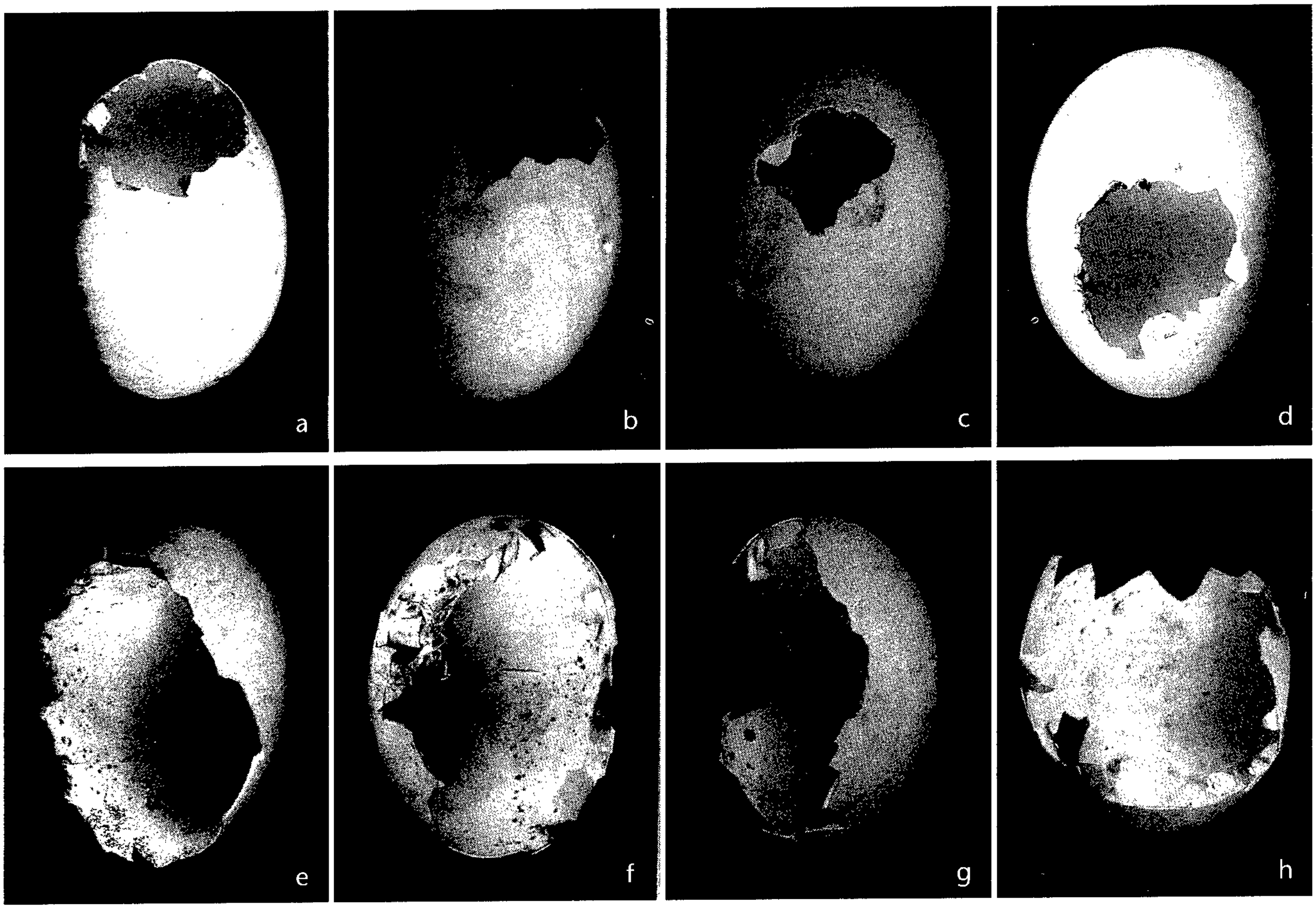
Appendix C, Figure 6. Eggshells of duck eggs depredated by minks showing different types of destruction.



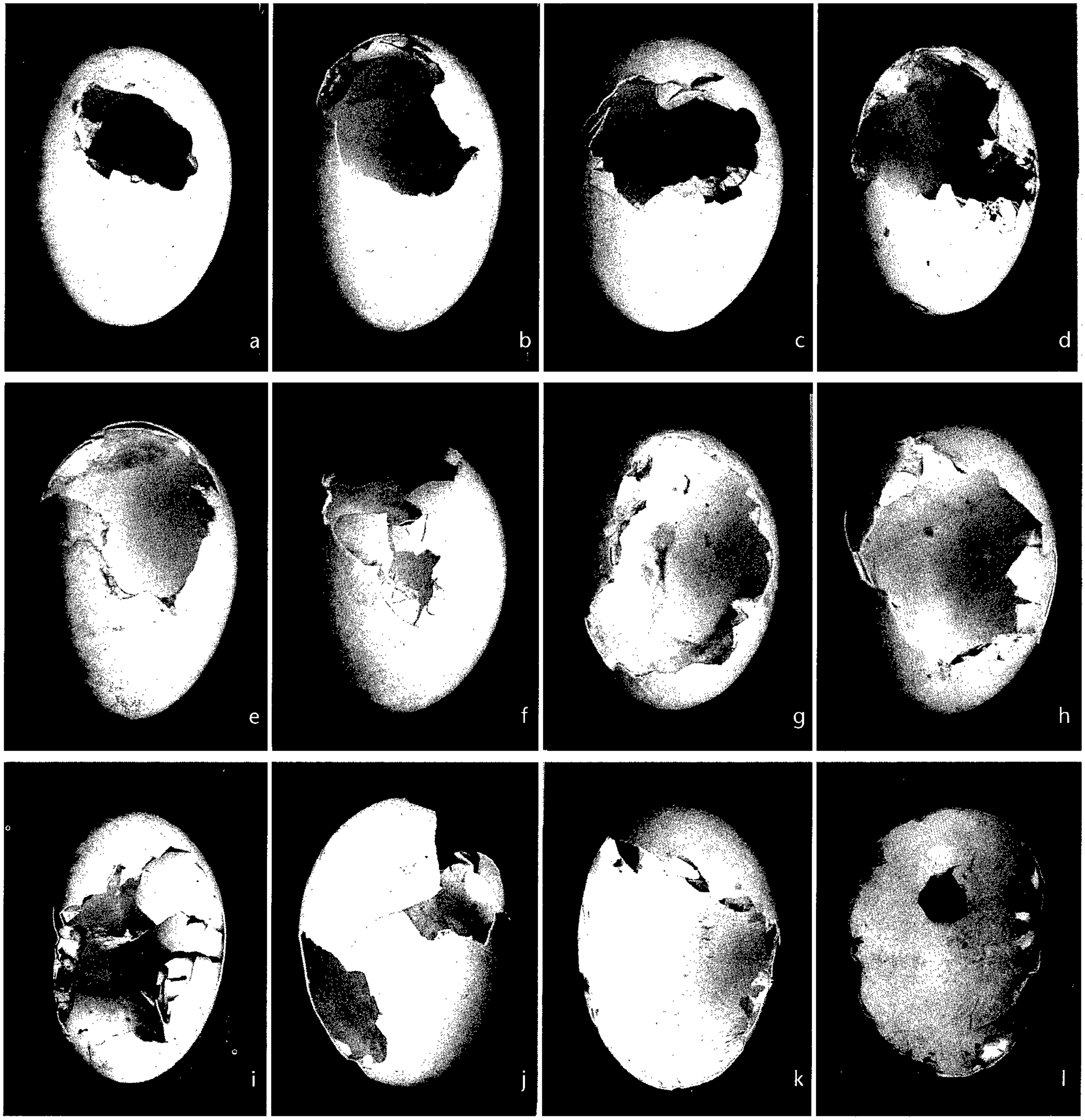
Appendix C, Figure 7. Eggshells of duck eggs depredated by weasels showing different types of destruction.



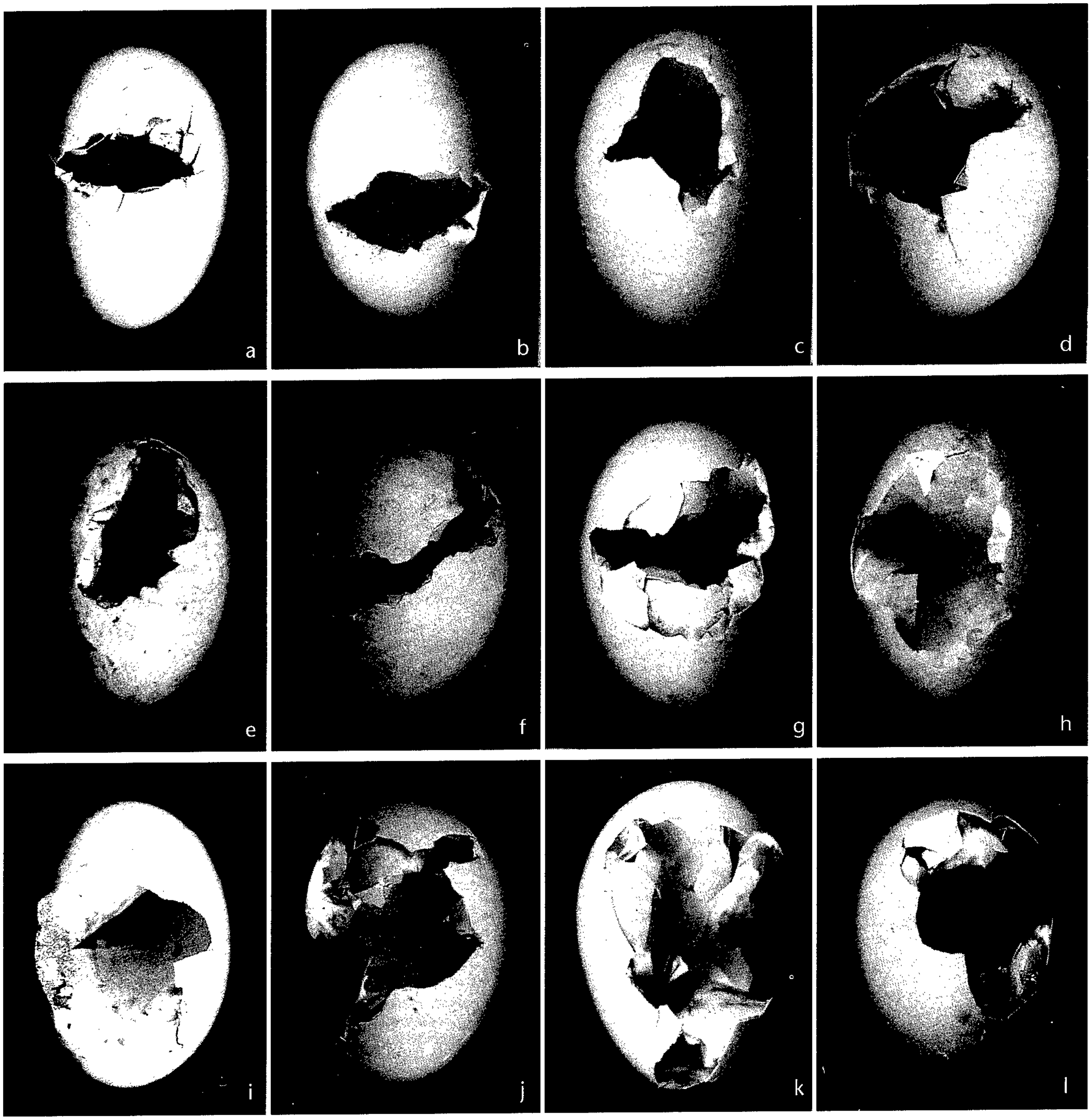
Appendix C, Figure 8. Eggshells of duck eggs depredated by Franklin's ground squirrels showing different types of destruction.



Appendix C, Figure 9. Eggshells of duck eggs depredated by black-billed magpies showing different types of destruction.



Appendix C, Figure 10. Eggshells of duck eggs depredated by American crows showing different types of destruction.



Appendix C, Figure 11. Eggshells of duck eggs depredated by ring-billed gulls and California gulls showing different types of destruction.

Appendix D: Format for Quantifying Evidence of Depredation of Duck Nests

We developed a format (Appendix D, Fig. 1) for quantifying evidence of depredation of duck nests in the Prairie Pothole Region. The nest depredation record was designed for use with nests being monitored for fate with information recorded on a nest record (Klett et. al 1986). Thus, for each completed nest depredation record, other information exists to help identify potential offending predators (e.g., history of missing eggs) or restrict analyses to nests meeting certain criteria (e.g., nest destroyed during incubation, clutch of ≥6 eggs when nest destroyed).

In developing the nest depredation record, we focused on 3 attributes of duck nests: (1) eggs and eggshells, (2) ground surface, and (3) nest material. We limited the area of collection of evidence to a 3-m radius around the nest. This helped insure that all reported data pertained to the subject nest, and kept the searched area small (necessary because most duck nests are in dense vegetation).

Critical factors in selection of variables for attributes and in development of descriptors for each variable were that no special expertise would be required of investigators to collect information, and prior visits by investigators to nests would not confound quality of the data. For these reasons, we avoided requesting information about tracks, hairs, odors, and tooth marks in eggs. Also, we abandoned attempts to quantify predator disturbance of vegetation (e.g., trails or matted areas). This decision was made because investigators had difficulty differentiating human disturbance of vegetation, trails made by attendant hens, and predator disturbance. Nevertheless, we encourage experienced investigators to record these and other supplementary evidence believed useful in identifying offending predators.

Before completing a nest depredation record, investigators must decide if any eggs hatched. No record is required if ≥1 egg hatched (Cowardin *et al.* 1985, Klett *et al.* 1986). An exception to this rule is for nests depredated when eggs were hatching and ≥1 dead duckling was found. Investigators may wish to fill out a record for such nests to insure that the mortality is documented.

Determination of whether an egg hatched requires careful examination of eggshells and shell fragments. Embryonic ducklings break the encircling shell by rotating their head in the air cell, and pecking a narrow slit around the blunt end of the egg (Terres 1980). This action separates the shell into a large intact piece with a round hole in the end, through which the duckling exits, and the end fragment (Appendix D, Fig. 2a, b). These weakened brittle eggshell pieces are often trampled by the hen and ducklings. Eggshell membranes may become separated from the shell and intermingled with shell fragments in the nest. Presence of a detached compressed membrane (Appendix D, Fig. 2c, d) is evidence of a hatched egg (Girard 1941, Klett *et al.* 1986).

The nest depredation record should be completed only for nests destroyed by predators, and nests abandoned by ducks because of predators (e.g., dead hen at nest but no eggs depredated). The record contains boxes for recording data control information, codes, counts, and measurements that describe depredation evidence found at nests.

Confusion can occur in recording values for some descriptors. Troublesome values are: (1) none (or zero), (2) not applicable, (3) undetermined, (4) no data, or (5) invalid data (extraneous conditions have influenced nest fate [e.g., nest site was cultivated, flooded, or trampled by cattle]). We recommend adhering to the following conventions when recording those values. If the value is none (or zero), record a zero. If the value is not applicable, undetermined, no data, or invalid data, draw a horizontal line through all boxes for the descriptor. Thus, there will be an entry in ≥1 box for every descriptor on completed records.

Instructions for Completing the Nest Depredation Record

Data Control and Merge

Variables comprising Boxes 1-16 identify data sets and link nest depredation records to nest records (Klett *et al.* 1986).

Box 1: Record a code to indicate this is a nest depredation record.

Boxes 2-16: Response codes recorded in these boxes must be the same as on the corresponding nest record for the final (termination) visit to the nest.

Boxes 17-20: Record the month and day when the nest was terminated by the investigator.

Boxes 21-22: Record the first and last initials of the observer.

Nest Material Displacement

Predators may displace nest material when destroying a nest. Material may be pulled from the nest and left on the ground and/or scattered aerially around the nest in tufts that become entangled on vegetation. The following questions pertain to percentages of total nest material that was pulled from the nest and left on the ground and total nest material scattered aerially around the nest. The percentage of nest material displaced on the ground, plus that displaced aerially, equals 100%. Nest material >5 cm from the original edge of the nest (before nest was destroyed) is classified as displaced, but it need not be disjunct from the nest. Nest material ≤5 cm from the edge of the nest or nest material rearranged or matted in the nest (e.g., from predator eating eggs in the nest) is not considered displaced.

For each variable, select the best response code from the 7 listed choices: 0 = none, 1 = trace, 2 = 1-5%, 3 = 6-10%, 4 = 11-25%, 5 = 26-50%, 6 = 51-75%, and 7 = 76-100%.

Box 23: Record the code that best describes the estimated percentage of the total nest material that was pulled, or otherwise displaced, from the nest and left on the ground, such as at the edge of the nest, in a trail, or where the predator ate eggs.

Boxes 24-26: Record the code that best describes the estimated percentage of the displaced nest material on the ground that is in each of 3 distance intervals: ≤20 cm from edge of nest, >20 cm - 1 m from edge of nest, and >1 m - 3 m from edge of nest.

Box 27: Record the code that best describes the estimated percentage of the total nest material that was scattered aerially around the nest (i.e., tossed in tufts or carried in feet, bills, or mouths) and became entangled on vegetation.

Boxes 28-30: Record the code that best describes the estimated percentage of aerially displaced nest material that is in each of 3 distance intervals: ≤20 cm from edge of nest, >20 cm - 1 m from edge of nest, and >1 m - 3 m from edge of nest.

Cached Eggs

Some predators cache eggs in soil or debris at nests, or cover eggs in nests with soil and/or debris. To find cached eggs, probe disturbed areas of soil or debris with your fingers. Predators may retrieve and eat cached eggs before investigators discover depredation. Treat eggshells at entrances to holes where eggs were cached and subsequently retrieved by predators as cached eggs. Treat holes that held a cached egg (e.g., impression of egg in bottom of hole), but for which no eggshell is found, as cached eggs.

Boxes 31-32: Record number of eggs in the nest that were covered with soil and/or debris by a predator (do not include eggs covered with nest material by a duck). Record a zero if there are none.

Boxes 33-34: Record number of cached eggs (including eggs cached but retrieved by predators) outside the nest. Record a zero if you find none.

Box 35: Record code that best describes depth (cm) of soil and/or debris covering top of the egg that was cached deepest outside the nest. If there is evidence that an egg was cached and subsequently exhumed by a predator (hole in soil with impression of egg in bottom), estimate depth of the soil and/or debris that covered top of the cached egg. Record zero if the predator left exposed any part of the deepest cached egg. Response codes are: 0 = none, 1 = ≤1 cm, 2 = >1 cm - 3 cm, and 3 = >3 cm.

Dug Areas

Some predators dig at nests. Dug areas can be holes that were dug but then filled with soil and/or debris (e.g., hole dug to cache egg), or areas where soil was piled.

Boxes 36-37: Record number of dug areas. Record zero if there are none. Record 99 if there is >1 dug area but you are uncertain of the number.

Box 38: Record code that best describes width (cm) of widest dug area. Response codes are: 1 = 1 cm - 5 cm, 2 = 6 cm - 10 cm, 3 = 11 cm -20 cm, and 4 = >20 cm.

Whole Eggs

Predators may leave ≥1 whole egg at a nest with a destroyed clutch. Whole eggs include undamaged eggs, eggs with cracks and/or indentations but no visible contents, pipped or hatching eggs, and cached eggs. Record zero for each descriptor for which there are none.

Boxes 39-40: Record number of whole eggs in nest.

Boxes 41-42: Record number of whole eggs outside the nest and ≤3 m from the nest.

Instructions Based on Types of Shells Found

Amount of shell fragments and types of eggshells at nests with destroyed clutches can range from a single tiny fragment to many eggshells. Data recorded in Boxes 43-76 relate to eggshells or shell fragments.

Box 43: Record code of response that best describes amount of shell fragments and types of eggshell(s) found, and complete remainder of record according to the instructions. Response codes are: 0 = no eggshell or shell fragment is found (draw a horizontal line through Boxes 44-76 but complete Boxes 77-80), 1 = only fragments (includes 1 tiny chip) of shell are found (draw a horizontal line through Boxes 44-53 and Boxes 55-76 but complete Box 54 and Boxes 77-80), 2 = ≥1 eggshell of any type listed for Boxes 44-53 are found (complete all remaining boxes of the record).

Number of Shells by Type and Amount of Shell Fragments

Predators eat eggs at nests and leave eggshells with various types of damage as well as shell fragments. These variables pertain to number of eggshells of each specified type and amount of shell fragments found.

Boxes 44-45: Record number of eggshells with a small hole. Record a zero if there are none.

Boxes 46-47: Record number of eggshells with a large hole. Record a zero if there are none.

Boxes 48-49: Record number of fractured eggshells. Record a zero if there are none.

Boxes 50-51: Record number of trampled eggshells. Record a zero if there are none.

Boxes 52-53: Record number of crushed eggshells. Record a zero if there are none.

Box 54: Record code that best describes estimated total amount of shell fragments found. Response codes are: 0 = none, 1 = trace (1-5 tiny chips), 2 = total amount is less than that of 1 egg, 3 = total amount equals that of 1-3 eggs, and 4 = total amount exceeds that of 3 eggs.

Location of Openings in Eggshells

This variable pertains only to eggshells that have small or large holes. Predators generally open eggs by making small holes, then enlarge them to remove contents. Location of final opening (or openings) may be in the side and/or an end. All openings in eggshells are to be considered. For example, if an eggshell had an opening in the side and another in an end, recorded location would be side-end. Total number of eggshells recorded in Boxes 55-60 is to equal the total number of eggshells recorded in Boxes 44-47. Record a zero for each category when there are none.

Boxes 55-56: Record for combined eggshells with small or large holes the number that have the opening in the side. Record a zero if there are none.

Boxes 57-58: Record for combined eggshells with small or large holes the number that have the opening in an end. Record a zero if there are none.

Boxes 59-60: Record for combined eggshells with small or large holes the number that have the opening in a side-end. Record a zero if there are none.

Eggshells With Multiple Openings

This variable pertains only to eggshells that have a small or large hole. Predators may make ≥1 opening in an eggshell. Openings can range in size from a single small peck or canine puncture that breaks through the shell and underlying membrane to large holes that destroy much of the original shape of the egg. Openings must be separated by >1 cm of intact shell (intact shell can have cracks) to be considered distinct.

Boxes 61-62: Record for combined eggshells that have small or large holes the number that have ≥2 openings. Record a zero if no eggshell has multiple openings.

Eggshells With Egg Contents

This variable pertains only to eggshells that have a small or large hole. Predators may not completely eat all contents of an egg. Albumen left in eggs may dry and be inconspicuous, but yoke and/or embryos are usually conspicuous. Eggshells of eggs with contents completely eaten can be discolored on the inside but have no caked or "runny" residue. Record number found even if ≥1 eggshell with a small or large hole is not suitable for evaluation (e.g., eggshell is in water).

Boxes 63-64: Record for combined eggshells with small or large holes the number that are clean. Record a zero if there are none.

Boxes 65-66: Record for combined eggshells with small or large holes the number that have conspicuous yolk residue but <25% of original contents of the egg.

Boxes 67-68: Record for combined eggshells with small or large holes the number that have conspicuous yolk residue and ≥25% of original contents of the egg.

Eggshell Locations

This variable pertains to eggshells of all types but excludes shell fragments. Predators may leave eggshells in nests and/or at various distances from nests. The combined total of eggshells recorded in Boxes 69-76 is to equal the combined total of eggshells recorded in Boxes 44-53.

Boxes 69-70: Record number of eggshells in the nest. Record a zero if there are none.

Boxes 71-72: Record number of eggshells between the edge of the nest and ≤20 cm from the nest. Record a zero if there are none.

Boxes 73-74: Record number of eggshells >20 cm - 1 m from the nest. Record a zero if there are none.

Boxes 75-76: Record the number of eggshells >1 m - 3 m from the nest. Record a zero if there are none.

Dead Hens or Ducklings

Evidence may be found that indicates the hen and/or ducklings were killed by a predator or died from other causes. Evidence of a dead hen may range from a few feathers or blood to a whole carcass. A carcass is whole if no parts are missing, although it may be decomposed or largely consumed by insects. Evidence of a dead duckling consists of carcass parts or an entire duckling. A dead duckling must be detached from an eggshell to be considered a carcass; otherwise, it is egg contents. Assume that a dead hen or dead duckling(s) at a nest are from that nest unless the species differs from that of the eggs. Answer questions exclusively from evidence ≤3 m from the nest. Carcass or carcass parts found >3 m from the nest may warrant listing under comments in Box 80.

Box 77: Record code of the response that best describes fate of the hen. Response codes are: 0 = no physical evidence indicating dead hen, 1 = loose feathers or blood indicate dead hen, 2 = carcass part(s) with head attached to body are present, 3 = carcass parts with head missing or detached from body are present, and 4 = whole carcass is present.

Box 78: Record number of dead ducklings found using the following responses:
0 = none, 1-8 = record actual number if 1-8, and 9 = ≥9.

Predator Species Identification

Occasionally, predators that destroyed the nest are positively known. Describe under comments any details.

Box 79: Record a Y (Y= yes) if the predator species that destroyed the nest is positively known and write its name in the space provided.

General Comments

Sometimes it is desirable to provide written comments or even drawings to help explain evidence of depredation found at a nest.

Box 80: Record a 1 if comments are provided. Write comments on the record.

NEST DEPREDATION RECORD

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

1 DATA CONTROL; 2 3 4 5 COOPERATOR

6 7 8 STUDY AREA; 9 10 11 FIELD; 12 13 YEAR; 14 15 16 NEST NUMBER; 17 18 MONTH; 19 20 DAY; 21 22 OBSERVER

NEST MATERIAL DISPLACEMENT

% OF NEST MATERIAL — PULLED OUT ON GROUND: 23; AERIALLY DISPLACED: 27

% BY DISTANCE FROM NEST — GROUND DISPLACED: 24 25 26; AERIALLY DISPLACED: 28 29 30 (≤20 CM; >20 CM - 1 M; >1 - 3 M)

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%

CACHED EGGS

IN NEST: 31 32; OUTSIDE NEST: 33 34; GIVE NUMBER; ENTER (0) IF NONE

35 SOIL DEPTH OVER DEEPEST EGG OUTSIDE NEST: (0) NONE (1) ≤1 CM (2) >1 - 3 CM (3) >3 CM

DUG AREAS

NUMBER: 36 37 — (0) NONE (99) UNCERTAIN BUT ≥1

WIDTH OF WIDEST: 38 — (1) 1-5 CM (2) 6-10 CM (3) 11-20 CM (4) >20 CM

WHOLE EGGS

IN NEST: 39 40; OUTSIDE NEST: 41 42; NUMBER FOUND; ENTER (0) IF NONE

INSTRUCTIONS BASED ON SHELL TYPES FOUND

TYPE OF EGGSHELLS FOUND: 43

(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

NUMBER OF SHELLS BY TYPE

44 45 NUMBER WITH SMALL HOLES — >3/4 SHAPE INTACT
46 47 NUMBER WITH LARGE HOLES — >1/2 - 3/4 SHAPE INTACT
48 49 NUMBER FRACTURED — CONNECTED PIECES >1/2 EGG BUT ONLY 1/4 -1/2 SHAPE INTACT
50 51 NUMBER TRAMPLED — CONNECTED PIECES >1/2 EGG ON FLATTENED MEMBRANE; <1/4 SHAPE INTACT
52 53 NUMBER CRUSHED — CONNECTED PIECES >1/2 EGG WADDED IN SPHERE; <1/4 SHAPE INTACT

SHELL FRAGMENTS

54 AMOUNT OF FRAGMENTS: (0) NONE (1) TRACE (2) <1 EGG (3) 1-3 EGGS (4) >3 EGGS

INDIVIDUAL OR CONNECTED PIECES ≤1/2 EGG

FOR SHELLS WITH SMALL AND LARGE HOLES ONLY

LOCATION OF OPENINGS IN EGGSHELLS: 55 56 SIDE; 57 58 END; 59 60 SIDE-END — NUMBER OF EACH TYPE; ENTER (0) IF NONE

SHELLS WITH MULTIPLE OPENINGS: 61 62 NUMBER OF SHELLS WITH ≥2 OPENINGS; ENTER (0) IF NONE

SHELLS WITH CONTENTS: 63 64 CLEAN; 65 66 CONSPICUOUS YOLK BUT <1/4 CONTENTS PRESENT; 67 68 CONSPICUOUS YOLK AND ≥1/4 CONTENTS PRESENT — GIVE NUMBER; ENTER (0) IF NONE

FOR ALL SHELLS EXCEPT FRAGMENTS AND WHOLE EGGS

SHELL LOCATIONS: 69 70 IN NEST; 71 72 EDGE - 20 CM FROM NEST; 73 74 >20 CM - 1 M FROM NEST; 75 76 >1 - 3 M FROM NEST — NUMBER IN EACH CATEGORY; ENTER (0) IF NONE

DEAD HEN OR DUCKLING(S)

77 HEN: (0) NO EVIDENCE OF DEATH (1) LOOSE FEATHERS OR BLOOD (2) CARCASS PARTS WITH HEAD ATTACHED (3) CARCASS PARTS WITH HEAD DETACHED (4) WHOLE CARCASS

78 DUCKLINGS: NUMBER FOUND DEAD (0) NONE (1-8) NUMBER (9) ≥9

PREDATOR SPECIES

79 (Y) IF POSITIVELY KNOWN

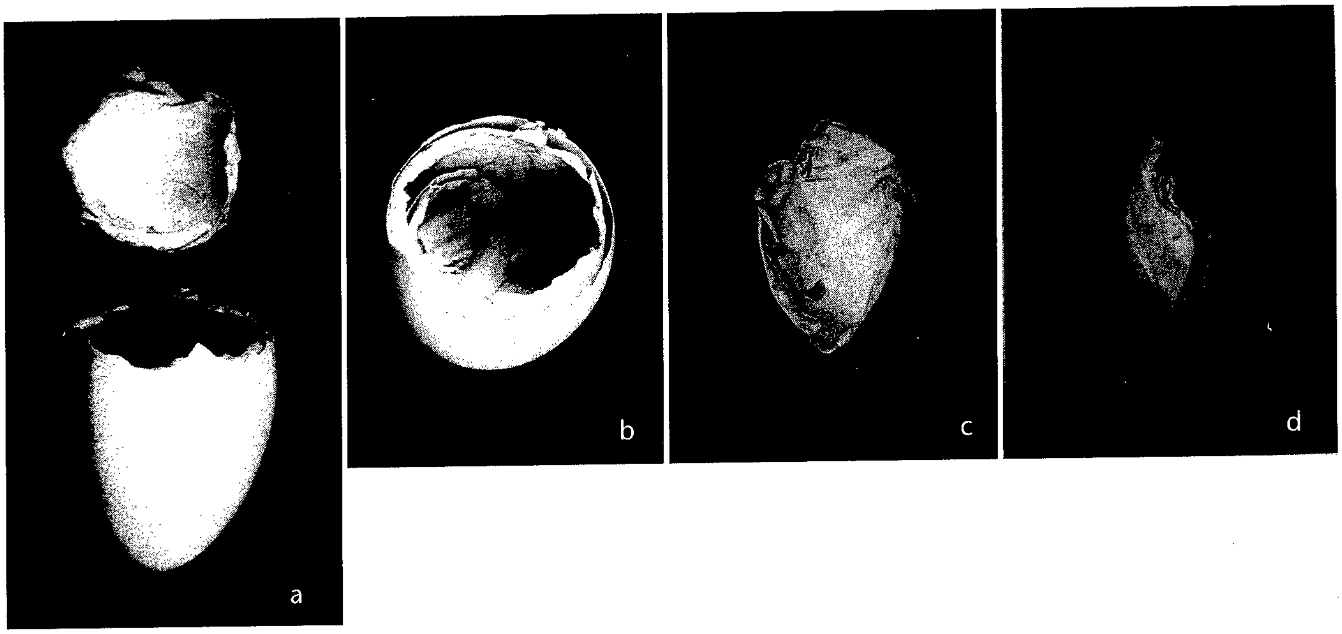
SPECIES ____________

COMMENTS

80 (1) IMPORTANT COMMENTS PROVIDED

REV. 5-96

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



Appendix D, Figure 2. Shells of hatched duck eggs showing large exit hole (a, b), end cap (a), and detached membrane (c, d).