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SANDHILL CRANE NESTING SUCCESS AND PRODUCTIVITY IN RELATION TO PREDATOR REMOVAL IN SOUTHEASTERN OREGON

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ABSTRACT.—I reviewed Greater Sandhill Crane (*Grus canadensis tabida*) reproductive success at Malheur National Wildlife Refuge in southeastern Oregon, 1966–1989, during which time predators were removed in 12 years and not removed in 12 years. Of 1,024 comparable crane nests found in those years, compared to those during nonremoval years, nests during years when some predators were removed had greater nesting success, more young fledged/100 pairs, lower mortality rates of young, and higher annual recruitment rates. The most important limiting factor for cranes at Malheur NWR was low annual recruitment resulting primarily from predation on eggs and prefledged young. Coyotes (*Canis latrans*) were the primary predator on eggs and young, but in some years Common Ravens (*Corvus corax*) and raccoons (*Procyon lotor*) took a large number of eggs. *Received 7 October 2002, accepted 08 March 2003.*

Across a wide range of habitats and geographical locations, nest predation has been recognized as the primary source of loss for many avian species, accounting for a mean of 80% of mortality (Martin 1993). This is particularly evident for species associated with wetland environments. For example, Mallard (*Anas platyrhynchos*) mortality rates in the Prairie Pothole Region of North America have ranged from 88–92% for clutches and 50–73% for prefledged young (Sargeant et al. 1993). The Sandhill Crane (*Grus canadensis*), another wetland species, frequently suffers substantial losses of nests and young in some regions of the western United States (Drewien et al. 1985, Littlefield 1995a). Although other mortality factors occur in western crane populations (especially those hunted), low annual recruitment generally is a major limiting factor (Drewien et al. 1995) and is due primarily to predation of eggs and prefledged young.

Malheur National Wildlife Refuge in southeastern Oregon hosts the greatest number of Greater Sandhill Cranes (*G. c. tabida*) breeding in the Pacific Coast states of North America (Littlefield et al. 1994). However, crane nesting and fledging success at Malheur NWR are limited by predation (Littlefield 1976, 1995a, 1995b). Coyotes (*Canis latrans*) are the primary predators of both eggs and prefledged young, but in some years raccoons (*Procyon lotor*) and Common Ravens (*Corvus corax*) take a large number of clutches (Littlefield 1976, 1995a). Other predators implicated in the mortality of young include mink (*Mustela vison*), Northern Harriers (*Circus cyaneus*), Golden Eagles (*Aquila chrysaetos*), and Great Horned Owls (*Bubo virginianus*; Littlefield and Lindstedt 1992, Ivey and Scheuering 1997). Although these four species kill some young, they generally are of little consequence when coyotes are at or above normal population levels (Littlefield and Lindstedt 1992).

Before 1972, predators were removed routinely from Malheur NWR by trapping, shooting, denning (removal of young), and chemical predicides. After 1972, predator removal was discontinued except during six years between 1982 and 1989; removal did not occur in 66% of the years between 1972 and 1989. The objective of this study was to examine the breeding records of cranes at Malheur NWR for the 24-year period, 1966–1989, to compare nesting success, mortality of young, and fledging success for years when at least some predators were lethally removed to those years when no predators were removed. Crane demographics, nesting habitat, and predator history at Malheur NWR were summarized elsewhere (Littlefield 1995a, 1995b; Littlefield and Thompson 1987).

STUDY AREA AND METHODS

Study area.—Malheur NWR (43° 16′ N, 118° 53′ W) encompasses approximately 75,000 ha of freshwater marshes, meadows,

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lakes, ponds, riparian systems, alkali sumps, and shrub-covered uplands within the lake system of the northwestern Great Basin. Mean annual precipitation is only 25.5 cm, but ample water usually is available from snow melt on adjoining mountain ranges. Silvies River and Silver Creek flow southward from the Blue Mountains and the Blitzen River flows northward from the Steens Mountain, and both drain into closed-basin Malheur Lake and Harney Lake (Silver Creek). The climate is characterized by hot, dry summers and cold winters; precipitation generally occurs as snow from late November through February and rain during May and June. The growing season is short and frost may occur during any month (Littlefield 1990).

The principle crane breeding areas at Malheur NWR are (1) adjacent to Silver Creek west and northwest of Harney Lake, (2) the shallows around Malheur Lake, and (3) the Blitzen Valley. Most pairs nest in Blitzen Valley, which extends southward from Malheur Lake for about 56 km. An interspersion of emergent vegetated marshes, open irrigated meadows, and uplands dominated by big sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus* spp.), black greasewood (*Sarcobatus vermiculatus*), and/or Great Basin wildrye (*Elymus cinereus*) provide crane nesting and brood rearing habitats. Shrub-covered expanses and long stretches of rimrocks adjoin Malheur NWR on the eastern, southern, and western boundaries. These cattle-grazed public ranges provide habitat for coyotes, and rimrocks support breeding ravens. Raccoons were first recorded at Malheur NWR in 1950 (Littlefield 1995b), and are now found throughout the wetlands; coyotes and ravens also hunt wetland habitats extensively.

Most (>90%) cranes at Malheur NWR nest among course emergents, particularly broadfruited burreed (*Sparganium eurycarpum*) and hardstem bulrush (*Scirpus acutus*); common cattail (*Typha latifolia*) is used less frequently (Littlefield 1968, 1995b, 2001). These emergent stands usually are near meadows and subirrigated interfaces between wetlands and uplands, and also are principal foraging sites.

Data collection.—Nests usually were found by ground searching, but were occasionally located from fixed-winged aircraft or rarely from a helicopter. Nests were sampled throughout Malheur NWR, with most in the Blitzen Valley. From early April to late May, a sample of nests was assessed annually except during 1968, 1972, 1975, 1979, and 1988. Because Sandhill Cranes are philopatric (Walkinshaw 1949, Littlefield 1968, Drewien 1973), known breeding territories were searched until either an active or inactive nest was located. Thus, the traditional method, or apparent estimator for nest success (*sensu* Sargeant and Raveling 1992), was used in data analysis. For active nests, incubation stage was estimated using the flotation method (Westerskov 1950), and sites were marked with a lath placed at least 15 m from the nest. Nests were revisited after the estimated hatching dates to assess fates. Clutches abandoned, flooded, or infertile ($n = 72$) were not used in nesting success analyses. I compared nesting success during predator removal and nonremoval years using a 2×2 contingency test with Yates correction for continuity (Zar 1974).

Fledged cranes were counted at the grainfields of Malheur NWR during September. At one location where grain was not available and ground access poor, young were counted from a fixed-winged aircraft or helicopter. Because of the disturbance created by helicopters, all aerial counts eventually were made from fixed-wing aircraft. It was difficult to classify young using a noisy and rapidly moving plane (a Cessna 182 or 185). It was determined that cranes could be observed easily and little disturbed from a Piper Super Cub, which was used after 1984.

With the number of breeding pairs known, I calculated recruitment at Malheur NWR as (number of fledged young/fledged young + breeding adults) $\times$ 100. The recruitment rate estimates presented here were specifically for pairs breeding at Malheur NWR (see U.S. Fish and Wildlife Service 1978); for methods assessing recruitment for other populations see Drewien et al. (1995). I compared mortality of young and annual recruitment rate during years with and without predator removal by one-tailed *t*-tests (Zar 1974).

RESULTS

Nesting success.—No data were available on the number of coyotes removed during 1946–1971 when compound 1080 (sodium

TABLE 1. Predators removed from Malheur National Wildlife Refuge, southeastern Oregon, 1986–1989.

Species	1986	1987	1988	1989	Total
Coyote	166	460	226	226	1,078
Common Raven	44	124	102	43	313
Raccoon	11	16	12	28	67
Total	221	600	340	297	1,458

fluoroacetate) bait stations were used extensively at Malheur NWR and adjoining areas. Other predators no doubt were killed indirectly during the 26-year program. Crane nesting success was assessed for five years (1966–1971) before compound 1080 and other predicides were banned on public lands. Although few coyotes were noted during these years, those present had little difficulty locating crane nests, as most wetlands at Malheur NWR were severely degraded by chronic winter livestock grazing (Littlefield and Thompson 1987). Of 357 sampled crane clutches, 173 (48%) hatched, 168 (47%) were lost to predators (65 to ravens, 52 to coyotes, and 51 to raccoons), and 16 (4%) were lost for other reasons. Predator control ceased in February 1972, and coyotes became the most common egg predator at Malheur NWR after 1976.

Ten years later predator control was reinstituted. During 1982 and 1983, Common Ravens were removed from a 8,153-ha site, and both ravens and coyotes from a 7,976-ha site. The number of ravens removed was unknown, but the local population was substantially reduced (pers. obs.); 214 coyotes were dispatched. Overall, crane nesting success for 142 sampled nests was 69% and 70% in 1982 and 1983, respectively, up from 46% for 317 nests assessed during 1973–1981. Nesting success during 1983 was 80% at the site where both coyotes and ravens were removed; no increase occurred where only ravens were removed (Littlefield and Cornely 1997).

Low nest success again occurred in 1984 and 1985 when predators were not controlled. Of 117 clutches assessed, 47 (40%) hatched, 59 (50%) were lost to predators (38 to coyotes, 15 to ravens, and 6 to raccoons), and 11 (9%) were lost for other reasons. An intensive predator removal program was initiated in 1986 after crane pairs had declined from 236 in 1977 to 181 in 1986, with a major decline beginning in 1984 (Littlefield 1995a). The predators that were removed are listed in Table 1. A total of 163 crane clutches was sampled, of which 100 (61%) hatched, 51 (31%) were predated (33 by coyotes, 9 by ravens, and 9 by raccoons), and 12 (7%) clutches were lost for other reasons.

Nest success data were available for 10 years when predators were controlled and 9 years when they were not. For the 1,096 crane nests assessed during the study, 662 were in predator removal years (Table 2) and 434 in nonremoval years (Table 3). Excluding 72 clutches abandoned, flooded, or infertile, 1,024 were available for comparison, and

TABLE 2. Greater Sandhill Crane nesting success during predator removal years at Malheur National Wildlife Refuge, southeastern Oregon.

Year	Total clutches[a]	Hatched		Predated	
		n	%	*n*	%
1966	51	18	35	26	51
1967	59	25	42	33	56
1969	88	52	59	32	36
1970	76	34	45	38	50
1971	83	44	53	39	47
1982	81	54	67	24	30
1983	61	38	62	16	26
1986	60	40	67	16	27
1987	61	35	51	21	34
1989	42	25	60	14	53
Total	662	365	55	259	39

[a] Includes clutches lost to abandonment, flooding, and infertility.

TABLE 3. Greater Sandhill Crane nesting success during years in which predators were not removed at Malheur National Wildlife Refuge, southeastern Oregon.

Year	Total clutches[a]	Hatched		Predated	
		n	%	*n*	%
1973	49	10	20	37	76
1974	50	18	36	30	60
1976	52	35	67	16	31
1977	50	23	46	26	52
1978	55	19	34	24	44
1980	30	16	53	11	37
1981	31	15	48	14	45
1984	67	23	34	34	51
1985	50	24	48	25	50
Total	434	183	42	217	50

[a] Includes clutches also lost to abandonment, flooding, and infertility.

TABLE 4. Greater Sandhill Crane productivity during predator removal years at Malheur National Wildlife Refuge, southeastern Oregon.

Year	Number of breeding pairs	Mortality of young (%)	Recruitment (%)	Number of young fledged per 100 pairs
1970[a]	235	66.5	12.6	28.9
1971	(235)	80.7	8.9	19.6
1982[a]	214	90.1	5.5	11.7
1983	(214)	84.8	8.4	18.2
1986[a]	181	77.6	12.1	27.6
1987	(181)	78.4	10.6	23.7
1988	(181)	—	1.6	3.1
1989[a]	168	74.7	12.7	25.0
Mean	201	78.9	9.1	19.7
SD	26.6	7.5	3.9	8.1

[a] Years when crane pairs were counted; number of breeding pairs in the years following a count was estimated to be the same and is presented in parentheses.

nesting success was greater in years when predators were removed ($\chi^2 = 15.84$, df = 1, $P < 0.010$). With predator removal, coyotes still destroyed 17% ($n = 108$) of the clutches, compared to 27% ($n = 106$) during nonremoval years. Common Ravens destroyed 6% fewer clutches (14% versus 20%) in removal years, whereas raccoons took a slightly greater percentage (11% versus 8%). Fewer raccoons seemed present at Malheur NWR when coyotes were abundant (Littlefield 1995b).

Fledging success.—With or without predator removal, the mortality rate of young cranes was high, ranging from 66.5% in 1970 to 98.8% in 1974 (mean = 84.4%, SD = 9.4). The mortality rate of young was significantly lower in years when predators were removed ($t = -3.38$, df = 6, $P < 0.010$), and recruitment rates were significantly higher ($t = 2.90$, df = 7, $P < 0.025$). With removal, excluding the extreme drought year of 1988 when recruitment was only 1.6%, rates ranged from 5.5% in 1982 to 12.7% in 1989 (mean = 9.1%, SD = 3.9; Table 4). However, without removal, the lowest rates were 0.4% in 1973 and 1974, and the highest was 9.1% in 1976 (mean = 5.1%, SD = 3.3; Table 5). With predator removal, the number of young fledged/100 pairs ranged from 3.1 in 1988 to 28.9 in 1970 (mean = 19.7, SD = 8.1; Table

TABLE 5. Greater Sandhill Crane productivity during years in which predators were not removed at Malheur National Wildlife Refuge, southeastern Oregon.

Year	Number of breeding pairs	Mortality of young (%)	Recruitment (%)	Number of young fledged per 100 pairs
1972	(235)	—	8.4	18.3
1973	(235)	98.0	0.4	0.8
1974	(235)	98.8	0.4	0.8
1975[a]	236	—	3.5	7.2
1976	(236)	84.6	9.1	19.9
1977[a]	219	85.5	5.4	11.4
1978	(219)	70.1	8.9	19.6
1979	(219)	—	8.2	17.8
1980[a]	221	84.9	7.1	15.5
1981	(221)	88.7	5.0	10.5
1984	(214)	93.9	1.8	3.7
1985[a]	186	92.6	2.4	4.8
Mean	224	88.6	5.1	10.9
SD	15	8.8	3.3	7.3

[a] Years when crane pairs were counted; number of breeding pairs in the years following a count was estimated to be the same and is presented in parentheses.

4). When predator numbers were not reduced, the range was 0.8 in 1973 and 1974 to 19.9 in 1976 (mean = 10.9, SD = 7.3; Table 5).

DISCUSSION

From 1966–1989, during 12 years when predator numbers were reduced, a mean of 55% of Sandhill Crane clutches hatched at least one egg, compared to 42% in years lacking predator removal. For 19 years when nesting success was assessed, coyotes were the most important predator, taking 214 (22%) of 1,024 clutches, although raccoons were the major egg predator in 1967 and 1969. There was little evidence that raccoons were eruptive (*sensu* Fritzell 1982), and increased raccoon predation rates corresponded with years when coyote numbers were below normal (Littlefield 1995b). High coyote density may impact raccoon density (Greenwood and Sovada 1996) or activity. Common Ravens were responsible for taking the greatest number of clutches during 1970, 1971, and 1973. Except for 1973, more raccoon and raven predation occurred when coyotes were being intensively controlled throughout the western United States with the predicide compound 1080.

Unlike other wetland birds, cranes differ in brood-rearing behavior and brood habitat use. Pairs generally nest in aquatic situations, but move their young to nearby uplands, meadows, and moist ecotones for rearing. These sites also are the principal foraging areas for most mammalian predators. Greater Sandhill Crane young require 66–75 days to fledge and are highly vulnerable to predation. Telemetry studies at Malheur NWR during the mid-1980s found 68% of 25 monitored flightless young were lost to predators; coyotes consumed 52% with one or two known losses attributed each to raccoons, domestic dogs, or Great Horned Owls (Littlefield and Lindstedt 1992). Ravens, however, have not been observed preying on young cranes at Malheur NWR.

Two of the most important predators, ravens and coyotes, have increased substantially since the early 1970s. Throughout North America there was significant raven population growth between 1965 and 1979, particularly in the California foothills and Rocky Mountain states (Robbins et al. 1986). During 1980–1994, ravens increased at annual rates of 5.8% in Oregon and 6.8% in Washington (Sharp 1996). After predicide restrictions on public lands in 1972, coyote populations markedly increased in the Pacific Northwest, especially in the shrub-steppe region of southeastern Oregon (Willis et al. 1993). Coyote population growth was not restricted to the Pacific Northwest, e.g., increases also were noted in southeastern Idaho (Drewien et al. 1985), northeastern California, and on the southern High Plains of northwestern Texas (pers. obs.). Since the 1970s, the species also has been expanding and reoccupying former ranges in the Prairie Pothole Region of the northern Great Plains (Sovada et al. 1995), suggesting widespread population growth throughout western North America.

The gray wolf (*C. lupus*), which generally excludes or preys upon coyotes (Carbyn 1982), has been eradicated over most of its historical western range, and the coyote has become and will perhaps continue to be the top carnivore. Public sentiment likely will limit wolf reintroductions and restrict coyote control methods. Commercial fur harvest may be the only means available for coyote population management. With modification of harvest regulations, coyote numbers probably will continue to increase in the Prairie Pothole Region and, along with subsequent interspecific canid exclusion, reduce red fox (*Vulpes vulpes*) populations; foxes in the northern prairies currently are an important predator of breeding adult waterfowl and their nests (Sovada et al. 1995). Few cranes breed in the prairie region, except in northwestern Minnesota, but if coyote numbers substantially increase, management will be warranted to ensure the species does not become overly abundant. It will be important to evaluate the entire avian community of an area before decisions are made on which canid predator is to be encouraged, managed, or protected. Otherwise, more problems may arise than are resolved, especially if coyotes become as abundant and destructive on nesting cranes as they presently are in some regions of the Rocky Mountains and Great Basin. This will be particularly important for the few wetlands in the northern prairies which support breeding Sandhill Cranes.

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