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Abstract: Parasitic gapeworms (*Cyathostoma* sp.) caused 5.6% of mortalities of 219 radiomarked greater sandhill crane (*Grus canadensis tabida*) colts at Malheur National Wildlife Refuge (NWR) in Oregon from 1991–98. From 1993–98 we tested the efficacy of ivermectin, an antihelmenthic drug, as a means of increasing colt survival by reducing gapeworm infestations. We selected pairs of siblings for the study, injecting 1 colt with ivermectin and not the other. We found significantly shorter survival times for untreated birds compared to those treated with ivermectin ($P = 0.06$). We conclude that in areas with gapeworm infestations in young cranes, the use of ivermectin will increase the colts' chances for survival, however, the procedure may not be practical in some field situations. Additional studies are needed on the epidemiology of gapeworms and its effects on recruitment of sandhill cranes.

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Biologists first reported parasitic gapeworms from greater sandhill cranes in Florida (Forrester et al. 1974), where they found 1 to 4 in each of 7 wintering birds. Forrester et al. (1975) later reported 2 infected Florida sandhill cranes (*G. c. pratensis*); 1 had a single worm and the other had 2. Such minor infections were apparently having no ill effects. Spalding et al. (1996) found 1 individual of *C. variegatum* during a necropsy of a whooping crane (*G. americana*); this parasite has caused death from suffocation in captive sandhill and whooping cranes (Carpenter and Derrickson 1987, Spalding et al. 1996). In the wild, biologists first recorded mortality from a gapeworm infestation in a juvenile sandhill crane in 1983 (Littlefield and Lindstedt 1992) and reported 8 additional gapeworm-caused mortalities between 1991–95 (Ivey and Scheuering 1997); both occurrences were on Malheur NWR in southeast Oregon, a major breeding site for the Central Valley Population (CVP) of greater sandhill cranes.

Adult gapeworms produce eggs within the trachea of the infected bird which are then coughed up, swallowed, and expelled in the excrement. The larvae may then enter invertebrate hosts and can remain infective for up to 3½ years (Cole 1999). Birds become infected by ingesting gapeworm eggs, larvae, or parasitized invertebrates (Olsen 1962). Wild birds which feed extensively on earthworms (*Lumbricius terrestris*) are particularly vulnerable to infestations (Wehr 1971), and earthworms likely provide a major vector for infection since they are a common food for young cranes. After ingested eggs hatch, the larvae penetrate various organs and migrate to the lungs via the circulatory system. Rapidly growing larvae can reach the lungs within 6 hrs of ingestion (Cole 1999). The parasites then infect the trachea (and less frequently the bronchi) and may obstruct the trachea of young cranes through irritation and formation of mucus plugs, leading to death (Olsen et al. 1996). Advanced stages of infection may also cause birds to be lethargic, have respiratory distress, stop feeding, and sometimes die from emaciation (Wehr 1971, Ruff 1991). Young cranes are particularly vulnerable to gapeworm-caused morality because of the small size of their trachea. Littlefield and Lindstedt (1992) suggested that gapeworms may predispose colts to predation.

Biologists initiated telemetry studies at Malheur NWR to determine the causes of colt mortality because low recruitment led to a decline in the number of breeding pairs of cranes (Littlefield 1995). They conducted studies from 1983–84 (Littlefield and Lindstedt 1992) and from 1991–98 (Ivey and Scheuering 1997, G. L. Ivey unpublished data). In 1992, 6 colts sent to the National Wildlife Health Center (NWHC) for necropsy were heavily infested with gapeworms which led to their death. Each of these colts contained 20 to 30 gapeworms in their tracheas; 3 other colts had ≤10. Based on the percentage of losses to gapeworms from the radio-marked sample, we estimate that 72 refuge colts died of gapeworm infestations that year. Consequently, in conjunction with the telemetry study, we initiated a gapeworm treatment program using the drug ivermectin in 1993. Ivermectin is used to treat parasites in mammals and birds by

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inhabiting transmission at neuro-muscular junctions, paralyzing the parasite and thereby killing it.

STUDY AREA

Malheur NWR, in southeast Oregon, contains 75,386 ha and lies within the northern Great Basin. This region is characterized by an arid climate, shrub-steppe uplands, fault block mountain ranges, and internal drainage basins. The refuge is a wetland oasis within a desert environment with 24,406 ha of freshwater marshes, 10,440 ha of flood-irrigated meadows, and the remainder consisting of uplands, alkali lakes, and playas. Most of the cranes rely on irrigated meadows and marshes for nesting. Malheur NWR supports the highest density of breeding CVP cranes, with 245 pairs in 1999 (Ivey and Herziger 2000).

METHODS

We located sandhill crane nests annually in April and May and floated eggs to estimate hatch date (Westerskov 1950). Shortly after the predicted hatch date, we revisited nests to assess the fates and to transmitter-equip colts. Older colts were captured by hand as they were encountered throughout the brood rearing period. Ivey and Scheuering (1997) described telemetry methodology.

For this study, we radio-equipped 34 pairs of crane siblings, with 1 colt in each brood randomly selected to receive ivermectin (IVOMEC®, MSD AGVET, Rahway, New Jersey, USA). We planned to treat individuals with 2 doses; the first at 10–14 days old and a second at 4–5 weeks, calculated at 0.2 ml per 100 g of body weight at 10 mg/ml (F. J. Dein, NWHC, personal communication). Each bird to be medicated was weighed to determine dosage and given an injection subcutaneously in the axilla. We monitored colts daily and necropsied dead chicks to determine the cause of death and assess gapeworm infestation levels. The NWHC staff analyzed remains from 1993–96; the senior author necropsied chicks from 1997–98.

We used the Weibull survival model (SAS Institute 1989) to assess the relationship between survival times and ivermectin treatment and report the exact P value for the result of this analysis. Colts with gapeworms may have died directly from the disease or indirectly through reduced fitness, consequently, we analyzed the data by considering all mortalities, regardless of assigned causes of death. Because the survival analysis had a significant P value for the ivermectin covariate, we quantified the relative difference in survival times between treated and untreated colts using the exponential value of the parameter estimate from the model (Allison 1995).

RESULTS

An analysis of colts monitored with radio telemetry from 1991–98 showed that of 219 mortalities, gapeworms caused 10 (5.6%) of 178 deaths where causes were known (G. L. Ivey unpublished data). Ages at death from gapeworms ranged from 23 to 60 days, and each colt hosted from 22 to 39 parasites. Most NWHC diagnostic reports only identified the parasite to genus (*Cyathostoma*); *C. bronchialis* was identified from 6 birds. Total mortality was high, complicating interpretation of the results of the ivermectin trials: predators accounted for 41 deaths (60.3% of 68 colts), with only 9 colts surviving to fledge. Only 1 colt died directly from a gapeworm infestation, an untreated bird which died at 31 days of age. Table 1 summarizes the fate of both treated and untreated colts.

Of the 68 colts, only 12 treated and 11 untreated birds were available for necropsy; 25 others were partially consumed by predators, 9 fledged, and 11 others could not be necropsied because either the transmitter (but not the bird) was recovered (3 colts), contact was lost (6), or the remains were too damaged to necropsy (1 was very decomposed and another was mutilated by a hay mower). Although only 12 treated birds survived long enough to receive a second dose of ivermectin, necropsy results, based on the sample of 23 colts, revealed that ivermectin did reduce gapeworm infections. For untreated colts, 63.6% of those necropsied had gapeworms,

Table 1. Fate of 34 ivermectin-treated greater sandhill crane colts and 34 untreated colts, Malheur National Wildlife Refuge, Oregon, 1993–98.

Fate	Treated		Untreated	
	n	%	*n*	%
Drown	1	2.9	1	2.9
Gapeworm	0	0	1	2.9
Hay mower	1	2.9	0	0
Intraspecific	2	5.9	1	2.9
Lost contact	2	5.9	4	11.8
Predation	21	61.8	20	58.8
Starvation	1	2.9	1	2.9
Total mortality	28	82.4	28	82.4
Fledge	5	14.7	4	11.8
Unknown	1	2.9	2	5.9

whereas for treated colts only 1 (which received only 1 injection) was infected with gapeworms (8.3%).

Ivermectin treatment also increased survival times of colts. We found significantly shorter survival times for untreated birds compared with those treated with ivermectin ($P = 0.06$), and the ivermectin covariate from the Weibull model had an estimated parameter of 0.448. Consequently, the expected survival time after capture was 1.6 times greater ($e^{0.668} = 1.6$ where 0.448 is the absolute value of the parameter estimate) for treated colts compared with those untreated.

DISCUSSION

Ivermectin treatment reduced gapeworm infestations in crane colts, resulting in a 60% increase in survival time. Longer survival presumably resulted from treated colts being healthier and more fit to find food, escape predators, and cope with sibling aggression. However, because of high mortality in both groups, we found no statistically significant differences in fledging success; 5 treated colts fledged, compared to 4 untreated.

It seems likely that gapeworms are contributing to low crane recruitment at Malheur NWR. Drewien et al. (1995) reported recruitment rates of populations of the greater subspecies and found that the CVP had the second lowest rate (5.6–6.1%), with the Lower Colorado River Valley Population (which breeds primarily in northeast Nevada) having the lowest (averaging 4.8%). Malheur NWR recruitment rates have been even lower in recent years, averaging only 1.6% between 1995–98 (Ivey and Herziger 2000). Considering that 63.6% of the untreated colts were found infected with gapeworms, this parasite is likely causing serious problems on Malheur NWR. This high infection rate likely contributes to elevated morality of colts. Although no data has been collected, it is likely that adult cranes on the refuge are also infected and possibly are carriers of the parasite, perhaps perpetuating the gapeworm cycle.

The low rate of infection in the treated birds in this study leads us to conclude that providing even 1 dose of ivermectin may be a practical approach to treatment; of 8 necropsied birds which received 1 injection, only 1 (12.5%) was infected with gapeworms, while 4 colts which received 2 injections each had none. Olsen and Langenberg (1996) recommended that 2 doses of ivermectin be given to infected crane 7–10 days apart, however, our data indicates that it may be unnecessary to recapture colts for second injections.

MANAGEMENT IMPLICATIONS

We recommend that biologists conduct further investigations to determine the extent of gapeworm infestations at other breeding sites. Necropsies should be performed on dead cranes (chicks and adults) to check for gapeworm parasites. Detection of gapeworms is difficult in living cranes because birds can be seriously infected but not show overt signs of the disease; infection rates can only be accurately determined by fecal analysis or physical examination of the trachea. However, birds noted coughing, head shaking, or exhibiting difficult breathing are likely infected, although these symptoms are also indicative of several other respiratory ailments, including mite infections, aspergillosis, and wet pox (Cole 1999).

If biologists find cranes to be infected with the parasite, managers should consider ivermectin treatment of colts, but they should determine the practicality of dosing in the field before attempting such a program. If they initiate a treatment program, we recommend the following:

1. Conduct the program in an experimental approach to better assess the efficacy of treatment.
2. Locate colts and give injections opportunistically, but the colts need to be about 10 days old before the first dose and should be marked to prevent the possibility of overdosing.
3. Minimize stress to colts by using 2 experienced personnel. Although a trained person can perform the treatment alone, performance efficiency is increased with 2 people. While the colt is captured and weighed by 1 person, the other prepares the medication. The person that weighs the colt then restrains it as the second person administers the medication, thus minimizing handling time. Treatment time should take <3 min.

We conclude that in areas with gapeworm infestations, ivermectin treatment can increase survival, however, the procedure would only be practical on intensively managed areas or for endangered cranes where survival of every individual is critical. Although this parasite is apparently not common in wild birds in the United States, there is a high infection rate of wild birds in the United Kingdom, suggesting it could potentially become a serious problem (Cole 1999). Additional field studies are needed on gapeworm epidemiology in sandhill cranes and its subsequent effects on population recruitment.

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