FACTORS AFFECTING SURVIVAL OF COLUMBIAN WHITE-TAILED DEER FAWNS IN THE LOWER COLUMBIA RIVER

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ABSTRACT The federally endangered lower Columbia River population of Columbian white-tailed deer (*Odocoileus virginianus leucurus*) numbers only a few hundred individuals. The population has not increased despite more than 40 years of legal protection and the establishment of a national wildlife refuge dedicated to its preservation. High fawn mortality has been identified as a limiting factor for the population. We studied the causes of fawn mortality during 10 individual years by fitting fawns (n = 131) with radiocollars and monitoring their fate for the first 150 days of age each year. Only 23% of the fawns survived. Predation by coyotes accounted for 69% of mortalities. Other causes of mortality were disease, starvation and unknown. We recommend that the refuge reduce coyote numbers during the period of maximum fawn vulnerability (June through September) when necessary to achieve population goals for the deer.

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INTRODUCTION

The Columbian white-tailed deer (CWTD) is the westernmost of the 38 subspecies of *O. virginianus* inhabiting North America (Baker 1984). The CWTD likely was abundant within its historic range, which encompassed floodplain and riparian habitats in the lowlands from southwestern Oregon (present day Douglas County) to possibly as far north as southern Puget Sound in Washington (Bailey 1936, Smith 1985). In 1806, Lewis and Clark observed and harvested white-tailed deer along the Columbia River from approximately the Dalles, Oregon to Astoria, Oregon (Thwaites 1905). David Douglas reported white-tails along the Columbia, Cowlitz and Willamette Rivers in Washington and Oregon in 1829 (Douglas 1914). By the early 1900s, CWTD had been extirpated throughout much of their historic range (Jewett 1914, Bailey 1936), presumably as a result of habitat loss and degradation associated with agricultural development and logging, as well as possible overhunting (Gavin 1978, US Fish and Wildlife Service 1983). The CWTD was federally listed as endangered under the Endangered Species Preservation Act (Pubic Law 89-669, 80 Stat. 926) in 1968 when only a small population (300-400 deer) was known to exist along the lower Columbia River. The population was divided into five subpopulations in southwestern Washington and northwestern Oregon (US Fish and Wildlife Service 1983). In 1978, a population of approximately 2,000-2,500 white-tails in southwestern Oregon (Douglas County), approximately 320 km south of the lower Columbia River, was recognized as being CWTD.

Because the two populations are geographically isolated, the federal recovery plan for CWTD addresses them separately (US Fish and Wildlife Service 1983). In Douglas County Oregon, land-use planning and zoning ordinances were implemented along with other conservation actions specified in the recovery plan. This population, which was growing even before it was classified as CWTD (Smith 1981), increased to more than 6,000 deer and it was delisted in 2003. In the lower Columbia River area, conservation activities focused on securing and managing lowland habitats, including establishment of the Julia Butler Hansen National Wildlife Refuge for the Columbian White-tailed Deer (herein referred to as Refuge). The Mainland and Tenasillahe Island units on the Refuge provide secure habitat for two subpopulations of CWTD in the lower Columbia River. As described in the recovery plan, secure habitat is free from adverse human activities such as clearing woody plants and unregulated heavy grazing by domestic animals. The criteria for recovery of the lower Columbia River population are the maintenance of a minimum of 400 deer in ≥ 3 viable subpopulations in suitable, secure habitat. The recovery plan defines a viable subpopulation as one containing at least 50 deer during the fall of the year.

In contrast with the Douglas County Oregon population, the lower Columbia River population has experienced considerable fluctuations in numbers. The total estimated population has ranged from about 400 in 1983 to 900 in 1988 to 515 in 2006. On the Refuge, the CWTD population has ranged from 575 (1988) to <200 (1996). The latter number was the result of substantial mortality associated with river flooding in late winter, 1996. In December 2005, there were an estimated 250 CWTD on the Refuge and 315 animals off refuge lands (US Fish and Wildlife Service, unpublished data). Severe flooding on the Mainland Unit during November 2006 resulted in numbers on the Refuge declining to an estimated 210 during December. From 1988 to through 2006, the CWTD populations in the lower Columbia and on the Refuge exhibited declines of 44 and 67%, respectively.

Small, isolated populations may be vulnerable to extirpation from a variety of factors (Shaffer 1981, Roelke et al. 1993). Vehicular collisions, predation, drowning, nutritional stress (starvation), disease (including necrobacillosis [foot rot]), and poaching were identified as proximate causes of mortality for CWTD (Gavin et al. 1984); however, the effects of each of these mortality factors on population levels in the lower Columbia River area was unknown (US Fish and Wildlife Service 1983). The objective of our study was to determine the survival and causes of mortalities for CWTD fawns on the Refuge.

STUDY AREA

The Refuge (initially known as the Columbia White Tailed Deer Sanctuary) was first established (342 ha) during December 1971 for preservation and management of the CWTD. Currently, the Refuge encompasses 2,510 hectars of Columbia River bottomlands. It is located within the *Picea Sitchensis* zone (Franklin and Dyrness 1988), although most of the Sitka spruce forest was cleared for agriculture during the first half of the 20th century. Principal vegetation types include Sitka spruce swamp, black cottonwood (*Populus balsamifera trichocarpa*) swamp, riparian mixed forest (principal species include Sitka spruce, black cottonwood, red alder (*Alnus rubra*), western red cedar (*Thuja plicata*) and big-leaf maple (*Acer macrophyllum*), managed grass and legume fields, old fields, and emergent wetlands. Levees protect about 1,600 hectares from the tidal flooding of the Columbia River.

Our study was conducted on the Refuge's 826-ha Mainland Unit. This unit supports what has historically been one of the largest subpopulations of CWTD in the lower Columbian River area. The recovery plan for the CWTD classified the subpopulation on the Mainland Unit as being both viable (with a herd size of 150-200 deer in 1981) and in secure habitat; however, numbers declined to an estimated at 60 individuals during 2006 due to flooding mortality and low fawn survival (US Fish and Wildlife Service, unpublished data). The Mainland Unit is former tideland "reclaimed" by levee construction during the 1920s and 1930s. Previous studies have found that CWTD forage extensively in fields dominated by short grasses and legumes that are in close proximity to woody vegetation (Suring 1974, Suring and Vohs 1979, Gavin et al. 1984). Management practices include seasonal cattle grazing, mowing and seeding to provide palatable grasses and legumes in managed fields; planting native trees and shrubs to increase the amount and distribution of woody vegetation; restoring emergent wetlands to provide a diversity of herbaceous vegetation; restricting public access to minimize disturbance to CWTD; and controlling competing and predatory wildlife such as Roosevelt elk and coyotes. The Mainland Unit is separated from the CWTD subpopulation on the 788-ha Tenasillahe Island Unit by a 1.6 km-wide channel of the Columbia River.

The Refuge is within the marine west coast climate zone. Mean annual precipitation for the past 30 years was 165 cm (US Fish and Wildlife Service, unpublished data). Most precipitation occurs during late fall and winter; summers are relatively dry. Temperatures range from a mean monthly minimum of 3°C during January to a mean monthly maximum of 20°C during August. Snowfall is uncommon and rarely covers the ground.

METHODS

We captured neonatal (≤14 days old) CWTD on the Mainland Unit of the Refuge during late May and June in 1978 (n = 19), 1979 (n = 15), 1980 (n = 7), 1981 (n = 19), 1982 (n = 4), 1996 (n = 13), 1997 (n = 18), 1998 (n = 20), 1999 (n = 8), and 2000 (n = 14). We located fawns by searching with volunteer crews areas frequented by does and by observing doe behavior to pinpoint fawn locations (Huegel et al. 1985). We fitted each fawn with breakaway radio-collars equipped with a 4-hr mortality sensor (Telonics, Mesa, AZ, USA). We recorded sex and estimated birth date for all radio-marked fawns. We estimated age of the fawns by evaluating the pelage, hoof condition, and condition of the umbilical cord (Haugen and Speake 1958).The collars dropped free from surviving fawns after 4-8 months.

Radio-marked fawns were monitored daily for survival during the first 30 days and ≥4 times per week thereafter until breakaway collars fell off. Survival of radio-marked fawns was periodically confirmed with visual observations. Dead fawns were recovered as quickly as possible after receipt of a mortality signal. Relatively intact carcasses were shipped to the National Wildlife Health Center (Madison, Wisconsin, USA) for necropsy. Partial carcasses were necropsied by the principal investigator. We determined cause of mortality using necropsy results in combination with evidence collected at mortality sites.

We classified mortalities as predation, disease, starvation, or unknown. Predation was identified primarily based upon the condition of remains including bite marks, wounds, and copious bleeding (White 1973, Garner et al. 1976, Stiegers and Flinders 1980). Identification of predator species followed O'Gara (1978) as well as Wade and Bowns (1984). Where necropsy revealed no evidence of trauma, trained pathologists at the National Wildlife Health Center diagnosed disease by presence of lesions, bacteria or parasites. Emaciated carcasses with empty stomachs were classified as starvation mortalities. Fawn mortalities with insufficient pathological information from the necropsy and lack of evidence at the recovery site were classified as unknown. Fawns were classified as fate unknown where collars were dropped early or there were no remains or sign to analyze.

Survival rates during the study period (June to November) on the Mainland Unit were calculated for the following year groupings: 1978-82, 1996+1999+2000, and 1997-98. The 1978-82 and 1996+1999+2000 periods represented years with no coyote control. In contrast, 1997-98 were years with coyote control (trapping and shooting) from January to May that ended before the start of fawning on the Refuge. Survival (*S*) rates of radio-marked neonates were determined using the Kaplan-Meier estimator modified for staggered entry (Pollock et al. 1989, White and Garrott 1990). Fawns surviving to the end of the fawning season were treated as right-censored for survival rate analyses (Pollock et al. 1989). Survival curves indicated morality rates decreased with age. We used the LIFETEST procedure in SAS (SAS Institute 1989) to plot log{-log[S(time)]} against log(time) that was generally linear indicating data fit a Weibull distribution.

The logrank (Mantel-Cox) test was used to compare survival distributions between select year groupings (1978-82 vs. 1996+1999+2000, 1997-98 vs. 1996+1999+2000) for all mortality factors combined. The logrank test also was used to compare survival rates for recent year groupings with and without coyote control (1997-98 vs. 1996+1999+2000) for cause-specific mortality factors (predation, disease, starvation, and unknown).

Mortality rates for cause-specific mortality factors at 60-, 90-, and 150-day intervals were determined for the three previous identified year groupings. Mortality rates were derived as 1-*S*. We calculated importance of each mortality factor by dividing each mortality rate by the sum of all mortality rates. This procedure is described as competing risks by Allison (1997). SAS (SAS Institute 1989) was used to compute survival rates as well as logrank statistics using $\alpha = 0.05$.

RESULTS

We captured and radio-marked 131 fawns during our 10-year study (Table 1). Mean age at capture was 4.5 days (SE = 0.43). Sixteen fawns were censored from the study because of premature collar drop or lost radio signals, leaving 115 for analysis.

Only 27 (23%) of these radio-marked animals were known to survive beyond 150 days of age. There were 89 fawn mortalities during our study period (Table 1).

Predation was the primary mortality factor, where 69% of the deaths were attributed to coyotes. In addition, some of the 14 mortalities from unknown causes likely were caused by coyotes, but there was insufficient evidence to definitively classify them as predation. In contrast, disease and starvation (combined) caused only 16% of the deaths during the study period. The mean age of fawns killed by coyotes was 40 days. About 95% of predation mortalities occurred during June, July and August. Of 28 fawns monitored beyond 150 days of age (range = 153 to 1,000 days, mean = 264 days), only 2 (7%) were killed by coyotes and 3 (11%) died of other causes.

The survival rates (95% confidence intervals in parenthesis) to 150 days of age for all mortality factors combined were 0.11 (0.01-0.21), 0.22 (0.12-0.32), and 0.53 (0.35-0.72) for 1996+1999+2000, 1978-82, and 1997-98, respectively (Fig. 1). The survival rate (all mortality factors combined) was significantly higher (χ^2=11.06, P=0.0009) for recent years with coyote control (1997-98) compared to recent years without coyote control (1996+1999+2000). Although slightly greater, there was no significant difference (χ^2=3.26, P=0.0711) between survival rates for recent and past year groupings without coyote control.

Coyote predation was the only mortality-specific factor where the survival rate was significantly higher (χ^2=8.35, P=0.0039) for recent years with coyote control compared to recent years without coyote control. For the other cause-specific mortality factors (starvation, disease, and unknown causes), there were no differences ($\chi^2 \leq$3.48, P≥0.0.0622) between recent years with coyote control compared to recent years without coyote control.

The mortality rates from coyote predation were higher compared with rates associated with other causes of death throughout the study period (Table 2). Mortality rates associated with coyote predation ranged from 0.28 to 0.78, where they were generally lower for years with coyote control. Predation by coyotes was the primary source (most important) of mortality during all study years. After predation, disease and starvation varied in importance as mortality factors depending upon the year grouping.

Restricted coyote removals (February to mid-April) on the Refuge's Mainland Unit resulted in higher fawn survival as indicated by fawn:doe (F:D) ratios of 43:100 and 61:100 during 1997 and 1998, respectively, with coyote control compared with an average of 10:100 for 3 years before removals (Table 2). Similarly, an average F:D ratio for three years pre-control (2001-2003) on the Refuge's Tenasillahe Unit was 6:100 compared with an average of 36:100 for four years (2004-2007) with restricted coyote removal during February to mid-April (US Fish and Wildlife Service, unpublished data).

DISCUSSION

We found low survival for CWTD neonates on the Mainland Unit of the Refuge. The apparent survival rate for radio-marked fawns throughout our study was 23% (27 of

116 deer). We found survival rates of 24-52% and 15-34% during the first 60 and 90 days of age, respectively, for fawns during study years without coyote control.

CWTD fawns were apparently healthy on the Refuge during our study. We found only 7% and 5% of the radio-marked fawns died of disease and starvation, respectively. Similarly, Gavin et al. (1984) found 4% of the mortalities for CWTD during 1974-1977 were disease caused, where all deaths were attributable to Necrobacillosis. They also found no fawns died from nutritional stress. A health assessment conducted on CWTD (n=20) from the Refuge during February 1998 found no indication of infectious diseases (BVD, bovine coronavirus, IBR, bovine enterovirus, and Pasteurella multocida) and low parasite loads (Creekmore and Glaser 1999). All deer had serum selenium (Se) values below the reference range and 17% had vitamin E levels that were deficient. However, the overall evaluation found CWTD on the Refuge were healthy despite the Se-vitamin E deficiency.

Coyote predation was the most important mortality factor impacting survival of CWTD fawns on the Refuge, responsible for 69% of neonatal mortalities during our study. This percentage likely was higher because some deaths from unknown causes (14 of 89 [16%]) probably were coyote predation but conclusive evidence was lacking. In contrast, Gavin et al. (1984) found only 17% of the fawn mortalities on the Refuge during 1974-1977 were attributable to coyotes; however, 74% (40 of 54) of fawn deaths in their study were attributed to unknown causes that likely included coyote predation. High losses of white-tailed deer fawns to coyotes also were reported by Cook et al. (1971), Beasom (1974), Garner et al. (1976), and Bartush and Lewis (1981). Although coyotes were the only predator identified for CWTD fawns on the Refuge, other mammalian predators (bobcat, domestic dogs, and fox) killed neonatal Columbian white-tailed deer in the southwestern Oregon population (Ricca et al. 2002).

Coyote predation, the primary cause of fawn mortality, may be limiting deer recruitment on the Refuge. The mean (F:D) ratio during November on the Mainland Unit was 26:100 (ranged from 1:100 to 61:100) from 1986-2000, where the highest ratios occurred during years with coyote control (1997-98). Potential fawn survival is considerably greater because F:D ratios >60:100 have been recorded on the Refuge (1990 and 1992 on the Tenasillahe Island Unit) since the 1980s (US Fish and Wildlife Service, unpublished data). The highest F:D ratio recorded for any CWDT subpopulation in the Lower Columbia River was 70:100. F:D ratios of ≥100:100 are commonly observed for white-tailed deer (McCullough 1984). Gavin (1979) concluded that fawn mortality was controlling recruitment rate and the subpopulation size on the Refuge Mainland Unit.

Predator control has the potential to increase recruitment on the refuge. Stout (1982) found that fawn:doe ratios at Fort Sill, Oklahoma, increased from 37:100 to 94:100 following coyote control. Predator control has resulted in increased fawn survival in other areas as well (Beasom 1974, Guthery and Beasom 1977). Ballard et al. (2001) reviewed the effects of predation and predator control on deer populations in North America. They concluded that predator control could be effective in increasing deer populations provided that:

1) deer populations are below carrying capacity,

2) predation is a limiting factor for the populations in question,

3) control efforts are effective in substantially reducing predator numbers,

4) control efforts are timed to be most effective (just prior to predator or prey reproduction), and

5) control occurs at a focused scale (generally less than 259 mi^2.

The refuge meets these criteria in that the deer population is low, there is strong evidence that predation is the major limiting factor for recruitment, and the land area is relatively small (9.7 mi^2). However, while past control efforts on the refuge were generally effective in removing coyotes, they may not have been timed well. Control was conducted during winter and early spring, ending by April 15 each year. Fawn survival was higher during control years, but not as high as it could have been. Fawning begins in early June and fawns are highly vulnerable to coyote predation until about September. Thus, there is a window of time for coyotes to repopulate the refuge between the cessation of control and the end of the period of maximum fawn vulnerability. Coyotes have apparently utilized that window, with the result being that control has not been as effective as it might have been. For maximum effectiveness, control should be timed as close as possible to the anticipated risk (in the present instance, the period of fawn vulnerability) (Knowlton et al. 1999). More effective control would reduce the frequency of need for control.

MANAGEMENT RECOMMENDATIONS

As demonstrated through our study, neonatal CWTD are highly susceptible to coyote predation throughout the fawning season (June to November) on the Refuge.

Because previous coyote control on the Refuge ceased before pup whelping (mid-April), there likely was a time period for coyotes to repopulate before the end of the fawning season. To maximize fawn survival and potential recruitment, coyote control should be timed to coincide with the period of maximum fawn vulnerability. At a minimum, we recommend that the annual timing of coyote control be extended throughout the period of maximum fawn vulnerability (June through September) for CWTD in the lower Columbia River area, when it is deemed necessary to maintain the viability of individual subpopulations.

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Table 1. Fates of radiomarked Columbian white-tailed deer fawns during June–November at the Julia Butler Hansen Refuge for the Columbian white-tailed deer, southwest Washington, 1978–1982 and 1996–2000.

				Mortalities			
Year	n	Censored[a]	Survived	Coyote	Disease	Starvation	Other[b]
1978	19	0	2	9	4	0	4
1979	15	3	2	6	1	1	2
1980	7	1	0	3	0	0	3
1981	19	4	3	8	1	1	2
1982	4	2	1	1	0	0	0
1996	13	1	0	9	1	1	1
1997[c]	18	2	12	3	0	1	0
1998[c]	14	3	2	8	1	0	0
1999	8	0	0	6	0	1	1
2000	14	0	5	8	0	1	0
Total	131	15	27	61	8	6	14

[a] Unknown fate, lost telemetry signal.

[b] Unknown or miscellaneous cause of death.

[c] Years with coyote control preceding the fawning season on Mainland Unit: 12 and 1 coyotes were removed in 1997 and 1998, respectively.

Table 2. Cause-specific mortality rates[a] for radio-marked Columbian white-tailed deer fawns at Julia Butler Hansen Refuge for the Columbian White-Tailed Deer, southwestern Washington, 1978 - 2000.

	1978-82 NCC[b]			1996+1999+2000 NCC			1997-98 CC[b]		
Cause of Death	60d	90d	150d	60d	90d	150d	60d	90d	150d
Predation	0.28(48)[c]	0.50(59)	0.55(48)	0.65(66)	0.78(70)	0.81(62)	0.30(73)	0.38(78)	0.42(79)
Disease	0.13(22)	0.13(15)	0.13(11)	0.04(4)	0.04(4)	0.04(1)	0.07(17)	0.07(14)	0.07(14)
Starvation	0.09(16)	0.09(11)	0.09(8)	0.26(26)	0.26(23)	0.26(20)	0.04(10)	0.04(8)	0.04(8)
Exposure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown	0.08(14)	0.13(15)	0.38(33)	0.04(4)	0.04(4)	0.20(15)	0.00	0/00	0.00

[a]Mortality rates at 60, 90, and 150 days were calculated using survival rates (*S*) from the Kaplan-Meier estimator modified for staggered entry (Pollock et al. 1989, White and Garrott 1990). Mortality rates were derived as 1-*S*.

[b]NCC and CC represent years with no coyote control and coyote control, respectively.

[c]Relative importance (%) of a mortality factor for each year-day combination.

Fig.1. Survival rates of radio-marked, neonatal Columbian white-tailed deer from birth to 150 days of age at Julia Butler Hansen Refuge for the Columbian White-Tailed Deer, southwestern Washington, 1978 - 2000. CC and NCC represent years with and without coyote control on the Refuge.