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# Sexual segregation and use of water by bighorn sheep: implications for conservation

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## Abstract

Males and females of most dimorphic ruminants segregate outside the mating season, which may necessitate that conservation efforts focus on differential resources used by the sexes. Dimorphic bighorn sheep *Ovis canadensis* are one of the rarest ungulates in North America with some populations listed as endangered. Water sources are important for the persistence of populations of bighorns, especially in a changing climate. Understanding whether the sexes use different water sources could influence the conservation of this species and the habitats they occupy; however, little research exists regarding this important topic. We tested hypotheses relating to use of water sources by reintroduced male and female bighorns in Utah, USA. We investigated whether use of this resource differed across seasons by sex, and if sexes used water more during drought compared with non-drought conditions. Bighorns used small, adjacent core areas during segregation, and males and females used different sources of water during that time. Males visited water sources used by females more during aggregation. Males and females used water sources more in summer, and males visited water sources more during rut than did females. Males and females did not use water sources more during drought compared with non-drought conditions; however, sexes visited water sources more during the season following drought than following non-drought conditions, indicating a time-lag in use of this resource. Our results highlight the importance of water sources used by sexes of bighorns, and indicate that the existing criterion for distance of bighorn reintroductions from water may be inadequate for successful establishment of populations. We recommend conservationists assess availability of water sources near habitat used by male and female ungulates before conserving and manipulating habitat, siting artificial sources of water and reintroducing animals.

## Introduction

Sexual segregation occurs widely among dimorphic ungulates and may influence use of habitat by the sexes (Kie & Bowyer, 1999; Barboza & Bowyer, 2000; Bowyer, 2004). Bighorn sheep *Ovis canadensis* are one of the rarest ungulates in North America (Valdez & Krausman, 1999), with some populations listed as endangered (Krausman, 2000; Rubin *et al*., 2002; Turner *et al*., 2004). These animals exhibit extreme sexual dimorphism (Bleich, Bowyer & Wehausen, 1997; Ruckstuhl, 1998; Weckerly, 1998), which leads to differences in allometry between sexes and to pronounced sexual segregation (Bleich *et al*., 1997; Barboza & Bowyer, 2000; Mooring *et al*., 2003). Bighorns are habitat specialists (Bleich *et al*., 1996) and are ecologically fragile because they occupy fragmented, limited habitats (Schwartz, Bleich & Bleich, 1986; Bleich, Wehausen & Holl, 1990; Singer, Papouchis & Symonds, 2000*b*). To conserve populations of these rare animals, consideration should be given to habitat requirements of males and females separately (Bowyer, Kie & Van Ballenberghe, 1996; Bleich *et al*., 1997; Bowyer, 2004) and how use of these resources varies by season.

Sources of water are a critical habitat component for most populations of bighorn sheep (Buechner, 1960; Bleich *et al*., 2006; Marshal *et al*., 2006*b*), although a few populations appear to occupy mountains with no known perennial sources of water (Alderman, Krausman & Leopold, 1989; Broyles & Cutler, 1999). Nonetheless, lack of perennial sources of water may enhance the probability of population declines (Douglas, 1988; Dolan, 2006), especially as the dependability of water sources decreases because of climate change (Epps *et al*., 2004; Brown & Thorpe, 2008). Indeed, populations of desert bighorn sheep *Ovis canadensis nelsoni* have been extirpated from areas that lacked perennial sources of water and that received <200 mm of precipitation annually (Epps *et al*., 2004). Sources of water are used differently by sexes of ungulates (Bowyer, 1984; Berger, 1986; Kie, Bowyer & Stewart, 2003). For bighorn sheep, females occupy areas that are closer to water compared with males (Leslie Jr & Douglas, 1979, 1980; Bleich *et al.*, 1997), and females may benefit more from artificial sources of water (i.e. guzzlers and horizontal wells) constructed in areas they use (Bleich, Coombes & Davis, 1982; Bleich *et al.*, 1997).

The location of water sources holds import for the conservation, manipulation and management of habitat used by male and female bighorns (Bleich *et al.*, 1997; Ruckstuhl, 1998; Mooring *et al.*, 2003). Indeed, conservation of these ungulates could be improved by better understanding how sexes use different sources of water year-round (Bleich *et al.*, 1997). Although water sources are important for bighorns, little research has occurred regarding differential use of this critical resource by males and females.

We tested hypotheses regarding use of water sources by male and female bighorns. More specifically, we predicted that males and females would visit and spend more time at separate water sources during the period of sexual segregation compared with when sexes aggregated, and that males would visit and spend more time at water sources used by females when the sexes were aggregated (sensu Bleich *et al.*, 1997). We also predicted that males would use water sources more often during rut, because of increased exertion during mating activities (Rubin *et al.*, 2002; Turner *et al.*, 2004), whereas females would use water sources more during summer to meet the needs of giving birth and especially lactation (Bleich *et al.*, 1997; Rubin *et al.*, 2002; Turner *et al.*, 2004). Finally, we predicted that the sexes would visit and spend more time at water sources during drought compared with non-drought conditions, because of lack of available water. Answers to these questions are critical for conservation and restoration of bighorn sheep, as well as other ungulates, because this information may influence manipulation and conservation of habitat, selection of areas for siting artificial sources of water, and assessment of release areas before reintroducing animals.

## Materials and methods

### Study area

We quantified use of natural water sources by bighorn sheep on Antelope Island State Park (40°57′N, 112°13′W) in Utah, USA (Fig. 1). The study area comprises 11 300 ha, and is 24 km long and 8.3 km wide, with the highest peak at 2134 m. During the study legal hunting for bighorns was prohibited on the island, and the average size of the population was 162 animals (Whiting, Bowyer & Flinders, 2009*a*). We defined seasons according to birthing and mating behaviors of bighorns on the island as follows: spring was 1 April to 30 June, summer consisted of 1 July to 30 September and rut occurred from 1 October to 30 November (Whiting *et al.*, 2009*a*). In our analyses, we did not include winter (1 December to 31 March), because bighorns rarely visited water sources during that time (Whiting *et al.*, 2009*a*). We defined segregation as 1 April to 30 September and aggregation as 1 October to 30 November based on mating behaviors of these bighorns (Whiting *et al.*, 2009*a*).

Mean annual temperature for our study area was 17.5 °C. Since 1948, the mean total precipitation in summer was 78 mm. During our study, summer 2005 received much less precipitation (22 mm) compared with historical amounts and with summer 2006 (122 mm). Spring 2005 received 280 mm of precipitation compared with 133 mm in spring 2006. Total rainfall during rut 2005 was 82 mm, and 97 mm fell during rut 2006 (Whiting *et al.*, 2009*a*). Human use of this area is restricted to hiking, biking and horseback riding on limited, designated trails (Fairbanks & Tullous, 2002). Greater detail regarding the flora and fauna of this area is available elsewhere (Fairbanks & Tullous, 2002; Rogerson, Fairbanks & Cornicelli, 2008; Whiting *et al.*, 2009*a*).

We deployed Reconyx$^{TM}$ motion-sensor cameras (Reconyx, LLP, La Crosse, WI, USA) at seven natural sources of water (Fig. 1). These springs were the only known perennial sources of water in proximity to habitat of bighorn sheep and ranged in elevation from 1290 to 1680 m (Rogerson *et al.*, 2008; Whiting *et al.*, 2009*a*; Whiting, Bowyer & Flinders, 2009*b*). Cameras were set at the same general location throughout the study, and within 15 m of the head waters of each spring (Whiting *et al.*, 2009*a,b*). Flow from these springs was reduced seasonally with marked reduction during drought conditions; therefore, when setting cameras we selected areas at the head waters of each spring that had demonstrated use by ungulates. We used multiresponse permutation procedures (MRPP), employing the EXACT command for small sample sizes, to determine if spatial distribution of water sources used by male and female bighorns differed (Cade & Richards, 2005). This method is a powerful tool for detecting spatial differences (Pierce, Bleich & Bowyer, 2000; Stewart *et al.*, 2006). Initially, we randomly placed five cameras at the seven water sources; however, by November 2005, we set cameras at all seven springs. Cameras were located at any particular water source on average 66% (range = 58–73%) of the total number of days in which these devices could have been deployed. Pictures were taken every 20 s so long as animals were in the field of view of the sensor of the camera. We considered a lapse of 25 min between a bighorn activating a camera as a new visit (Whiting *et al.*, 2009*a,b*). With this criterion, the median number of hours between successive visits to a water source was 13 (upper and lower quartile distances = 2–25 h).

For each visit, we tallied the total number of bighorns and categorized groups as male, female or mixed-sex. We subdivided males into size categories: Class I (2.5–3.4 years old), Class II (3.5–6 years old), Class III (6–8 years old) and Class IV (8–16 years old) as described in Geist (1968). Male groups included ≥1 male of any age. Female groups consisted of ≥1 adult female, including neonates, yearlings and Class I males, because these young males change from female groups to male groups across these ages (Festa-Bianchet, 1991; Ruckstuhl, 1998, 1999). Mixed-sex groups were composed of ≥1 adult female and ≥1 Class II, III or IV males, but also included young, yearlings or Class I males (Bleich *et al.*, 1997).

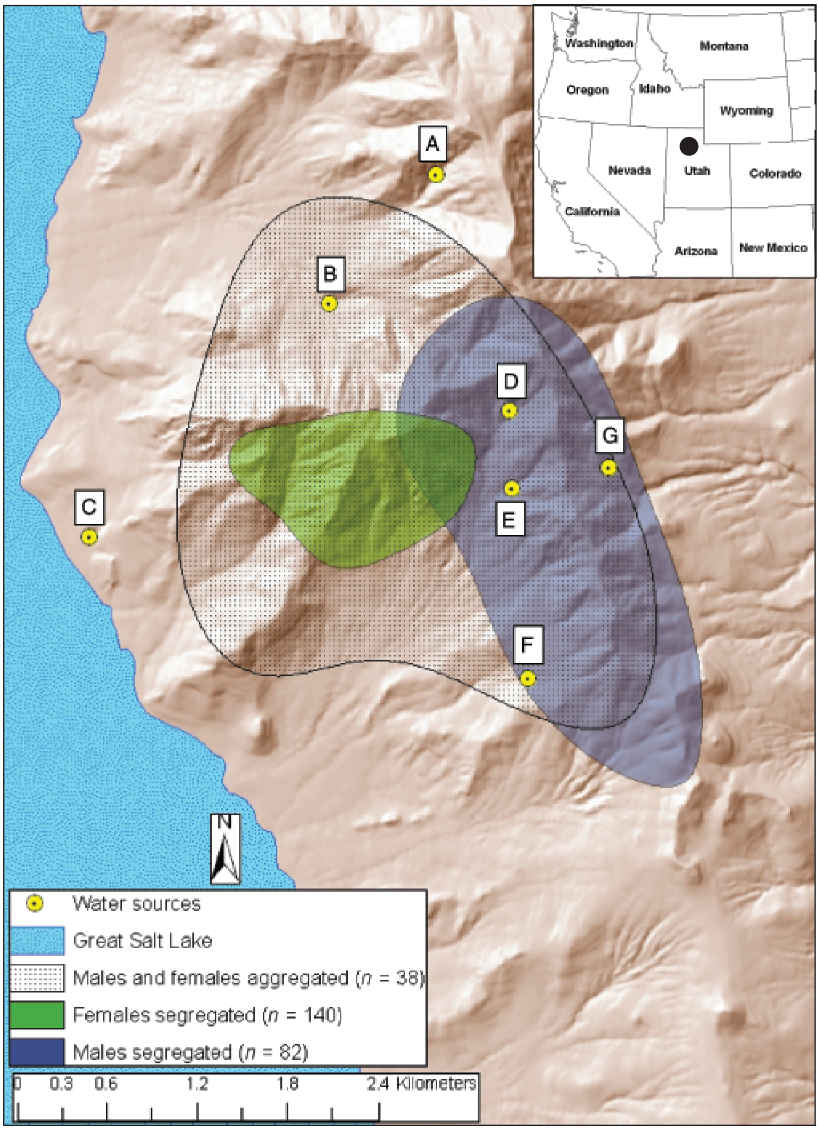


**Figure 1** Utilization distributions (50% core areas), and number of sightings used to produce polygons, in relation to sources of water (designated A–G) for male and female bighorn sheep *Ovis canadensis* during segregation and aggregation on Antelope Island State Park, Utah, USA from July 2005 to December 2006.

Lack of independence potentially occurred as groups of bighorn sheep visited multiple water sources during a particular day (Jaeger, Wehausen & Bleich, 1991). To help ameliorate this problem and to test for differences in the number of visits by bighorns to water, we considered each day a sampling unit (Whiting *et al.*, 2009*a*). This procedure provided a binomial-response variable (visit or no visit) for any particular day, which is a conservative estimate of visits to water sources, and permits sampling with replacement (Zar, 1999; Whiting *et al.*, 2009*a*). We calculated the proportion of days in which bighorns visited water sources by dividing the number of days that bighorns visited water by the number of days cameras were deployed during that season (Whiting *et al.*, 2009*a*). We then calculated 95% confidence intervals for the proportion of days in which bighorns visited water sources (Bowden, Anderson & Medin, 1984; Bowyer, 1991; Whiting *et al.*, 2009*a*), recognizing that this procedure overestimates the standard error (Bowden *et al.*, 1984; Bowyer, 1991).

To quantify duration of a visit at a water source, we multiplied the highest count of bighorn sheep for each cohort in a visit by the duration (min) of that visit (Whiting *et al.*, 2009*a*). We recognized that the number of bighorns in female groups was most likely more than in male groups (Bleich *et al.*, 1997). Further, we likely underestimated the total number of animals during visits of large groups (Jaeger *et al.*, 1991), because of the restricted view of the camera frame. This dilemma was alleviated somewhat by our calculation of duration of a visit, because larger groups ostensibly spent more time at water sources and thus had a greater duration (Whiting *et al.*, 2009*a*). Data for duration of visits were rank transformed (Conover & Iman, 1981), and we used two- and three-way ANOVAs to investigate relationships of duration of visit by group composition, season, year, water source and important interactions of these variables according to our predictions. We investigated pairwise, *post hoc* comparisons using a Tukey–Kramer test ($T$). Additionally, we arbitrarily adjusted $\alpha$ to 0.02 to help reduce the potential problem of lack of independence for groups of bighorns visiting multiple water sources in a day (Bowyer *et al.*, 2007; Whiting *et al.*, 2009*a*).

We observed bighorn sheep an average of three times each month from April to November 2005 and 2006. We conducted ground observations during daylight in areas used by these animals (Rogerson *et al.*, 2008; Whiting *et al.*, 2009*a*; Olson *et al.*, 2008). We observed bighorns from designated trails and from game trails leading to sources of water in bighorn habitat. When we observed groups of bighorns, we noted sex of individuals and group size and composition. We considered undisturbed animals to be a part of the same group if they were $\leq 50$ m from one another, or if they appeared to be aware of the presence of other sheep and moved as a cohesive unit (Bleich *et al.*, 1997). If we were unsure if a bighorn was part of a particular group, we watched animals until they joined other groups or moved away (Bowyer, McCullough & Belovsky, 2001). Each location was mapped on a United States Geological Survey topographical map with a scale of 1:24 000, and we calculated 50% core areas (Oehler, Bowyer & Bleich, 2003) using the reference bandwidth for males and females during segregation and aggregation using the Home Range Tools extension for ArcGIS 9.2 (Rodgers *et al.*, 2007). We quantified overlapping space use between sexes by calculating a utilization distribution overlap index (UDOI; Fieberg & Kochanny, 2005) between 50% core areas of males and females.

## Results

Cameras were set for 258 days when sexes of bighorn sheep segregated and 122 days when they aggregated. During segregation, males visited water sources A through D on 39 occasions and E–G on 205 occasions, whereas females visited springs A through D on 329 occasions and E–G on 46 occasions (Fig. 2). Consequently, we considered water sources E through G as those used mostly by males, and springs A through D as those used predominantly by females during sexual segregation (Fig. 2). Even with a small sample size, MRPP indicated that differences in the spatial distribution of water sources used by males (E through G) and females (A through D) during segregation approached significance ($P = 0.057$), while not statistically significant this difference is likely biologically important. During aggregation, males visited water sources A through D on 77 occasions and E–G on 17 instances, whereas females visited springs A through D on 30 occasions and E–G on only seven instances (Fig. 2).

To calculate 50% core areas, we observed groups of males on 82 occasions and females 140 instances during segregation, and groups of males and females on 38 occasions during aggregation. During segregation, the 50% core area used by males (3.9 $km^2$) was three times as large as the core area used by females (1.2 $km^2$), and the size of the 50% core area used by sexes during aggregation was 8.1 $km^2$ (Fig. 1). During segregation, three water sources were outside of the core area used by males, and all sources of water were outside the core area used by females (Fig. 1). During aggregation, two sources of water were outside the core area used by both sexes (Fig. 1). The UDOI was 0.023, indicating a small degree of overlap in volume of 50% core areas of males and females.

Visits to water sources differed by sex and during segregation and aggregation. When bighorn sheep segregated, males visited water sources used by females substantially less often than did females (Fig. 3); however, males visited water sources in areas used by males three times more than did females (Fig. 3). During aggregation, males visited sources of water used by females twice as often as females (Fig. 3), and males visited water sources located in areas used by males as often as females (Fig. 3). Further, males visited water sources used by females almost three times more during aggregation compared with segregation (Fig. 3). Also, duration at water sources differed by sex during segregation. During segregation, males spent less time at all sources of water compared with females ($F = 35.0$, d.f. $= 1, 615$, $P < 0.001$; Fig. 4). A significant interaction occurred between duration at water sources

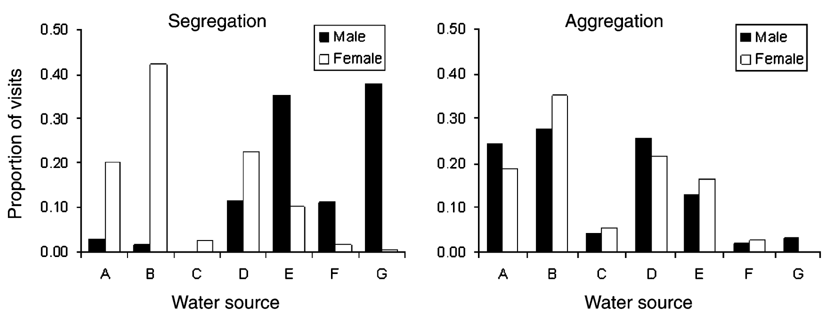


**Figure 2** Proportion of visits to seven water sources, labeled A–G, by male and female bighorn sheep *Ovis canadensis* during segregation and aggregation on Antelope Island State Park, Utah, USA from April to November 2005 and 2006.

 

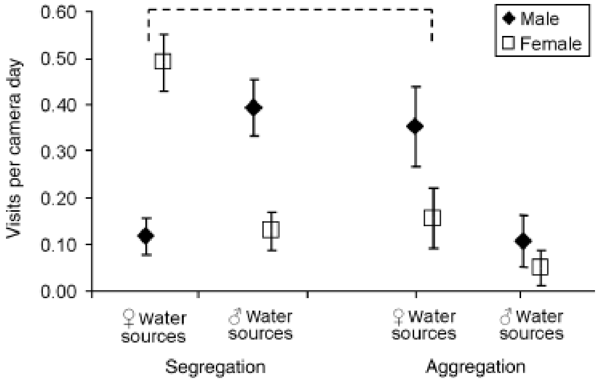


**Figure 3** Number of visits divided by the number of days in which cameras were set (±95% CI) at water sources located in areas used by sexes of bighorn sheep *Ovis canadensis* on Antelope Island State Park, Utah, USA during 2005 and 2006. Males visited water sources used by females almost three times more often during aggregation compared with when bighorns were segregated (dashed line highlights relationship).

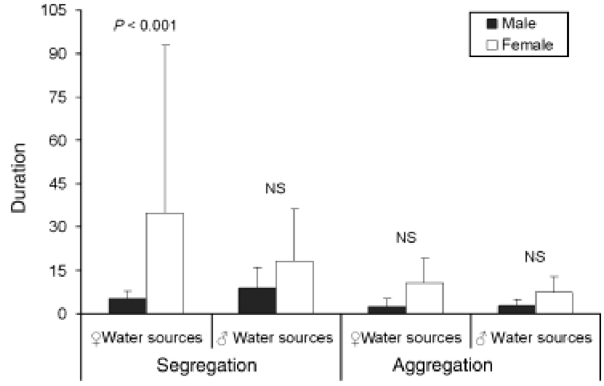


**Figure 4** Median duration (min) of visits at water sources located in areas used by sexes of bighorn sheep *Ovis canadensis* on Antelope Island State Park, Utah, USA during 2005 and 2006. Bars represent 1/4 interquartile distances. ANOVA with ranked data was used to test differences for duration at water sources by season and sex.

located in male or female areas and group composition ($F = 8.87$, d.f. $= 1, 615$, $P = 0.003$; Fig. 4), indicating that males spent less time at female water sources compared with use of those sources by females during segregation ($T = -6.53$, $P < 0.001$). Males, however, did not spend more time at male water sources than females during segregation ($T = -2.12$, $P = 0.15$; Fig. 4). During aggregation, males and females spent similar time at water sources regardless of the location of the water source ($F = 4.03$, d.f. $= 1, 127$, $P = 0.05$; Fig. 4), and no significant differences existed for the interaction between duration at water sources located in male or female areas and group composition ($F = 0.04$, d.f. $= 1, 127$, $P = 0.84$; Fig. 4).

Male and female bighorn sheep visited sources of water more in summer compared with spring and rut (Table 1). Males visited water sources more during rut than females; however, females did not visit water sources more in spring or summer compared with males (Table 1). Across all seasons, males spent less time at water sources compared with females ($F = 34.8$, d.f. $= 1, 744$, $P < 0.001$); the interaction between group composition and season was not significant ($F = 0.39$, d.f. $= 2, 744$, $P = 0.68$).

Cameras were set at water sources for 74 days in summer 2005, 92 days in summer 2006 and 61 days during both rut 2005 and rut 2006. Male and female bighorn sheep did not visit sources of water more during drought conditions (summer 2005) compared with non-drought conditions (summer 2006; Fig. 5). Conversely, males and females visited water sources more during the season following drought (rut 2005) compared with the season following non-drought conditions (rut 2006). Furthermore, during the season following drought (rut 2005), males visited water sources twice as often as females (Fig. 5). Duration at water sources was higher for males ($F = 19.44$, d.f. $= 1, 294$, $P < 0.001$) and females ($F = 9.82$, d.f. $= 1, 347$, $P = 0.002$) during summer compared with rut. No significant differences, however, existed for the interaction of year by season for males ($F = 0.48$, d.f. $= 1, 294$, $P = 0.49$) or females ($F = 0.84$, d.f. $= 1, 347$, $P = 0.84$), indicating that sexes did not spend more time at water sources during drought conditions compared with the season of non-drought conditions.

## Discussion

When segregated, male and female bighorn sheep used different sources of water on Antelope Island. During aggregation, males visited water sources used by females almost three times more often than when sexes segregated, and sexes of bighorns used water sources more during summer compared with other seasons. Female bighorns usually occur in steeper terrain closer to water (Bleich *et al.*, 1997; Mooring *et al.*, 2003) and occupy smaller, limited areas than do males; however, males move to areas used by females during rut (Geist, 1971; Bleich *et al.*, 1997; DeCesare & Pletscher, 2006), similar to the behavior we observed. Furthermore, some ungulates segregate on a relatively fine scale (Bowyer *et al.*, 1996; Kie & Bowyer, 1999; Bowyer & Kie, 2006). Bighorn habitat on Antelope Island is limited (Olson *et al.*, 2008), and although these animals used small, adjacent core areas during segregation, sexes still visited different sources of water, and females moved from core areas to access water. These results indicate that even at a relatively fine scale conservation and management of habitat for bighorns should include areas containing water sources that will benefit males and females during segregation. Additionally, the construction of artificial sources of water (i.e. guzzlers and horizontal wells) is important for the conservation of populations of bighorns (Rosenstock, Ballard & Devos Jr, 1999; Bleich *et al.*, 2006; Marshal *et al.*, 2006*a*). We recommend construction of these devices in habitats that would benefit males and females during segregation, when use of water was the highest for those animals.

**Table 1** Number of days cameras were set and proportion of visits during those days at seven water sources used by reintroduced bighorn sheep *Ovis canadensis* on Antelope Island State Park, Utah, USA from April to November during 2005 and 2006

| | | Males | | Females | |
|---|---|---|---|---|---|
| Season | Days cameras were set | Proportion of visits | 95% CI | Proportion of visits | 95% CI |
| Spring | 91 | 0.22 | 0.13–0.31 | 0.23 | 0.14–0.32 |
| Summer | 166 | 0.59 | 0.52–0.66 | 0.67 | 0.60–0.74 |
| Rut | 122 | 0.39 | 0.30–0.48 | 0.16 | 0.09–0.23 |

CI, confidence interval.

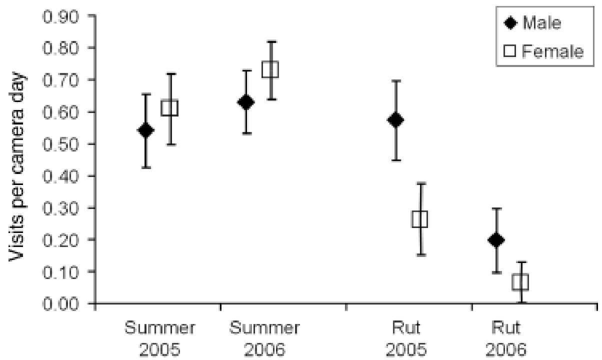


**Figure 5** Number of visits divided by the number of days in which cameras were set (±95% CI) at seven water sources used by bighorn sheep *Ovis canadensis* on Antelope Island State Park, Utah, USA. Males and females did not visit water sources more during drought (summer 2005) than during non-drought conditions (summer 2006); however, sexes visited sources of water more during the season following drought (rut 2005) compared with the season following non-drought conditions (rut 2006).

Reintroductions of ungulates are a vital strategy for the conservation of these animals (Griffith *et al.*, 1989; Seddon, Armstrong & Maloney, 2007). Differential use of water sources by males and females may affect successful reintroductions and conservation of ungulates, especially in arid regions. For bighorn sheep, reintroductions are the primary way in which biologists reestablish populations (Bleich *et al.*, 1990; Krausman, 2000); however, reintroductions historically have experienced low success (Smith, Flinders & Winn, 1991; Singer *et al.*, 2000*b*; Rominger *et al.*, 2004). Indeed, much can be done to improve the success of reintroductions (Smith *et al.*, 1991; Krausman, 2000; Krausman & Bowyer, 2003). Proximity of water sources to areas of release can influence the success of ungulate reintroductions (Wallach *et al.*, 2007). Protocol for reintroducing bighorn sheep indicates that all animals should be released into areas with sources of water $\leq 3.2$ km from escape terrain (Smith *et al.*, 1991; Singer, Bleich & Gudorf, 2000*a*). In our study, all sources of water were well within 3.2 km of 50% core areas used by either sex of bighorn (Fig. 1); however, use of this resource differed according to the proximity of water to habitats used by males and females, and some sources of water were used rarely by the sexes during particular seasons (Fig. 2). We recommend conservationists assess the availability of water sources near habitats that are important for both males and females before reintroducing animals (Bleich *et al.*, 1997; Mooring *et al.*, 2003; Wallach *et al.*, 2007).

Climate change will affect the future quantity and quality of water for wildlife around the world (Brown & Thorpe, 2008; Chambers & Pellant, 2008), which will likely hinder conservation efforts for bighorn populations (Epps *et al.*, 2004; Cain *et al.*, 2006; Dolan, 2006). Our study provided a unique test of use of water sources by bighorns during drought. Use of this resource did not increase for either sex during a pronounced summer drought (2005) compared with a summer of non-drought (2006); however, visits to sources of water were higher for both sexes during the season following drought (rut 2005), which possibly occurred because of a time-lag in the use of this resource (Whiting *et al.*, 2009*a*). Moreover, our data indicated that drought conditions may affect sexes differently, because males visited water sources twice as often as females during the season following drought, possibly because of increased exertion during rut (Rubin *et al.*, 2002; Turner *et al.*, 2004). Our results indicate that a need exists to assess the availability of water sources near habitat used by males and females before conserving and manipulating habitat, siting artificial sources of water and reintroducing animals.

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