William J. Zielinski[1], and **M. J. Mazurek**, USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, California 95521

Reproductive Characteristics of the Point Arena Mountain Beaver (*Aplodontia rufa nigra*)

Abstract

Little is known about the ecology and life history of the federally endangered Point Arena mountain beaver (*Aplodontia rufa nigra*). The distribution of this primitive burrowing rodent is disjunct from the balance of the species' range and occurs in a unique maritime environment of coastal grasslands and forests. Fundamental to protecting this taxon is knowledge of its breeding season and other reproductive characteristics. This information is necessary so that ground-disturbing activities near burrow systems can be scheduled to avoid the breeding season. We examined the reproductive status of 38 individuals, captured 150 times, from June 2004–July 2005 (excluding 01 February–01 May when we were prohibited from trapping). We used changes in vaginal cytology to monitor estrus and we evaluated male breeding readiness by determining whether testes were scrotal. The earliest onset of estrus occurred on 02 December and it was detected until the trapping prohibition period began on 01 February. The first males had scrotal testes somewhat earlier, in late November, and most males were still in this condition when trapping prohibition began. These data suggest an earlier onset of the breeding season than described for other subspecies. All females and a majority of males (70%) examined in December and January had evidence of reproductive condition. No evidence of pregnancy was observed during the study period, but based on allometric equations developed elsewhere, and applied to the weights of juveniles we captured, parturition was estimated to occur in early- to mid-April.

Keywords: mountain beaver, *Aplodontia*, Point Arena, reproduction, breeding, California

Introduction

The Point Arena mountain beaver (*Aplodontia rufa nigra)* is one of 7 subspecies of this archaic, burrowing rodent (Feldhamer et al. 2003). The Point Arena subspecies was listed in 1991 as "Endangered" under the federal Endangered Species Act but there have been no formal studies on its reproductive ecology or life history. Research attention has focused on the development of survey methods to detect and to monitor their abundance (e.g., Northen and Fitts 1998, Zielinski and Mazurek 2006, Zielinski et al. 2010), their phylogeography (Zielinski et al. 2013, Piaggio et al. 2013) and their distribution (Zielinski et al. 2015). There have also been recent descriptions of their den sites (Zielinski et al. 2010) and ectoparasites (Hunter et al. 2010). However, management of the taxon is handicapped by the lack of basic life history information necessary to develop standard protection measures and a comprehensive conservation strategy. Most of the data on reproductive chronology has been described for the more abundant populations in the northern portion of the species' range (Cramblet and Ridenhour 1956, Pfeiffer 1958), excluding data from the Point Arena subspecies. The disjunct nature of *A. r. nigra* and its southern, coastal location makes it likely to have evolved adaptations to the maritime climate and environment that affect its reproductive chronology. We sought to document the reproductive characteristics of the Point Arena subspecies, which may be unique to this taxon.

The absence of ecological information has made it difficult for land managers to evaluate the effects of proposed ground disturbing management activities on Point Arena mountain beavers. Estimates of the breeding season, gestation length and dates of parturition have been published for other subspecies (Pfeiffer 1956, 1958), but they vary and nothing is known about these reproductive characteristics in the geographically isolated Point Arena subspecies. We directed our research efforts towards understanding the chronology of

[1] Author to whom correspondence should be addressed. Email: bzielinski@fs.fed.us

the breeding season and time of parturition because without this information managers must be conservative in planning activities that may affect the subspecies during the breeding season. Nothing is currently known about the effects of disturbances such as vegetation management, operation of heavy equipment, and development of infrastructure on the Point Arena mountain beaver. Knowledge of the average dates of conception, parturition and weaning will allow officials to prescribe more specific guidelines about the time period during which these potential disturbances should be regulated. Current guidelines are focused primarily on protecting occupied habitat from disturbance (Hunter and Fitts 2005). There are no guidelines we are aware of for limiting the timing of disturbance, particularly during breeding and when females are pregnant or have dependent young.

The work is authorized under permit issued by the US Fish and Wildlife Service (TE-080774-1) and by Memorandum of Understanding with the California Department of Fish and Wildlife. We followed the National Wildlife Research Center Standard Operating Procedures for trapping and handling mountain beavers (FP/WA 001.00, FP/WA 003.00; see Appendix A). Our protocol for the care and handling of animals was reviewed by the US Fish and Wildlife Service and adheres to the guidelines specified by the American Society of Mammalogists (Sikes et al. 2011).

Methods

The study was conducted at Manchester State Park (the Park), five miles north of the town of Point Arena, California and the majority of work occurred at four focal study sites referred to as Kinney Beach (KB), the Environmental Trail (ET), Camp/Dunes (CD) and Alder Creek (AC) (Figure 1). The distribution and occurrence of mountain beavers in these areas was established from previous surveys (Fitts et al. 2002). The Park is located on an alluvial plain formed by the Garcia River where the topography is comprised of low hills formed by stabilized sand dunes and coastal terraces. The research study was conducted in the central and northern portion of the Park where the vegetation is coastal scrub with limited surface water. The

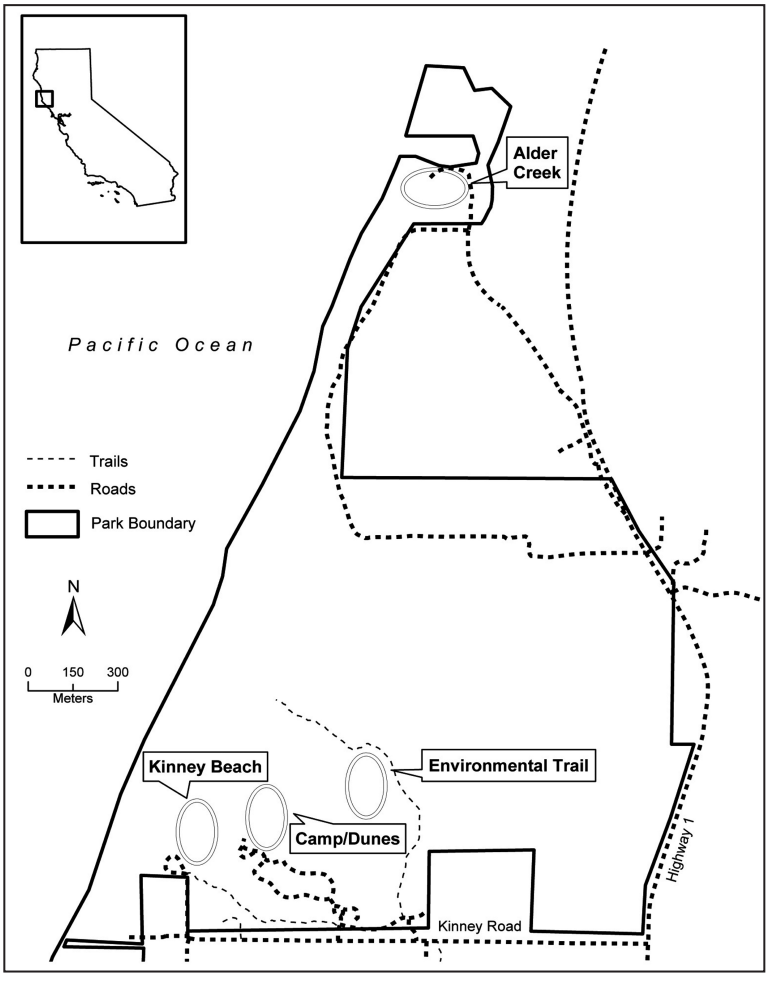

Figure 1. Point Arena mountain beaver study sites (Alder Creek, Kinney Beach, Camp/Dunes, Environmental Trail) within Manchester State Park, Mendocino County, California 2004–2005.

climate is Mediterranean maritime, with relatively cool summers (average July maximum is 18.4 °C and minimum is 9.9 °C). Winters are wet with only occasional freezing temperature.

Candidate trap locations were evaluated by first determining mountain beaver occupancy using the method of fern removal (Engeman et al. 1991). Ferns are used as food and bedding by mountain beavers, and rarely by other species (Engeman et al. 1991). Thus, the removal of fronds placed at a burrow entrance is considered an indication of the burrow's occupancy. We placed sword and bracken fern (*Pteridium aquilinum*) at 90 burrow openings at the ET site, at 34 openings at the KB site, and at 101 openings at the AC site. We returned approximately every 2–3 days to evaluate the presence or absence of the fern bundle and placed traps at sites where the bundle was removed. Using this method we placed approximately 30–40 traps per site.

We placed a single-door live trap (Model 102, 16 x 5 x 5 inch, Tomahawk Live Trap Co., Tomahawk, Wisconsin) at burrow entrances, which required no excavation (Ransome 2003). In the few locations ($n = 3$) where a runway was accessible via a collapsed burrow ceiling we placed a double-door trap (6 x 6 x 24 inch) directly in the burrow. Traps were pre-baited with part of an apple, wired open and placed for 24 hours prior to being engaged. After the pre-baiting period, traps were opened and baited with part of an apple and commercial rodent chow. The traps were covered with plastic and a protective cover of cardboard. When traps were set in late afternoon or early evening they were checked within 2 hours of sunrise the following day. Traps set in early morning were checked approximately every 4 hours.

Captured animals were transferred to a burlap bag, weighed to the nearest 0.5 gram, and sexed (presence or absence of a baculum). The baculum was also measured to the nearest millimeter, because of the possibility that this characteristic may distinguish age classes. Animals were initially placed in three age classes based on weight: juveniles(< 700 g), sub-adults or yearlings (700–900 g), and adults (> 900 g). The use of weight alone is an unreliable method of aging (Lovejoy and Black 1974) so as we became more familiar with a larger number of animals we also used sexual and pelage characteristics to aid in our estimates of age. Animals with lower weight, glossy black fur, and elastic skin were generally considered subadults. Adult fur was both black and brown, the skin was often taut, scaly, and scarred. Although various characteristics were assumed to be associated with age, we had no unambiguous measure of age so we considered any individual > 900 g as an adult. Captured animals were physically restrained for marking. We placed numbered metal ear tags (#1005 size 1 Monel) in each ear and Passive Implantable Transponders (PIT) tags were inserted subcutaneously adjacent to the spine above the right rear flank.

Examining trapped animals was the primary method to assess reproductive condition. With the knowledge that late winter/early spring was the period that most likely included the breeding season (Cramblet and Ridenhour 1956, Pfeiffer 1958), trapping was focused in the period from mid-November 2004 and concluding 01 February, 2005. Animals were captured outside this period as well, but these occasions did not occur with the same regular periodicity. Our federal permit did not allow us to trap during the months of February–April, to avoid potential harm to pregnant and post-partum females and their young. This prohibition made calculating the timing of the breeding season a challenge. Assessment of the timing of reproductive events was reconstructed from data gathered from animals captured prior to and after the period of time when trapping was prohibited.

Males were considered sexually active when the testes were scrotal and inactive when the testes where abdominal (Pfeiffer 1956). Female reproductive status was determined primarily by examining vaginal cytology after lavage (Pfeiffer 1958). Lavage was conducted by flushing the vagina with a small amount of distilled water using an eye dropper. Cells were later viewed microscopically and estrous was confirmed by the presence of cornified epithelial cells (Pfeiffer 1958). We also observed the condition of the vulvae of females which, when swollen is also an indication of estrus (Pfeiffer 1958).

TABLE 1. Summary of Point Arena mountain beavers captured, their sex and age-class, and their dates of first and last capture at 4 trapping sites within Manchester State Park 2004 and 2005. Abbreviations in age class refer to adults (A), subadults (S) and juveniles (J), based on weight at initial capture.

Individual	Sex	Age Class	No. Captures	Date first capture	Date last capture
Alder Creek					
019	M	A	2	14 Aug 2004	17 Aug 2004
020	F	S	10	14 Aug 2004	26 Jan 2005
021	M	A	10	14 Aug 2004	25 June 2005
028	M	S	8	13 Nov 2004	25 June 2005
034	F	S	6	18 Dec 2004	6 May 2005
035	M	A	4	31 Dec 2004	25 Jun 2005
Camp/Dunes					
033	M	A	7	18 Dec 2004	26 Jun 2005
038	F	J	2	20 June 2005	26 June 2005
Kinney Beach					
001	F	A	1	21 Jun 2004	21 Jun 2004
002	M	A	5	21 Jun 2004	13 Jul 2004
003	M	J	1	21 Jun 2004	21 Jun 2004
004	F	A	1	21 Jun 2004	21 Jun 2004
005	M	A	5	21 Jun 2004	13 Jul 2004
006	F	S	7	23 Jun 2004	19 Aug 2004
007	F	A	5	23 Jun 2004	10 Oct 2004
008	F	S	5	23 Jun 2004	19 Aug 2004
009	M	S	5	29 Jun 2004	27 Jul 2004
010	F	J	1	01 Jul 2004	01 Jul 2004
014	F	A	3	26 Jul 2004	12 Aug 2004
015	F	A	3	28 Jul 2004	16 Aug 2004
016	M	A	1	28 Jul 2004	28 Jul 2004
017	F	S	1	12 Aug 2004	12 Aug 2004
018	F	S	1	12 Aug 2004	12 Aug 2004
023	F	S	1	19 Aug 2004	19 Aug 2004
024	M	S	1	19 Aug 2004	19 Aug 2004
025	F	A	1	19 Aug 2004	19 Aug 2004
026	M	A	1	19 Aug 2004	19 Aug 2004
027	M	S	1	18 Nov 2004	18 Nov 2004
030	M	A	4	02 Dec 2004	24 Jun 2005
031	M	S	10	16 Dec 2004	23 Jun 2005
032	M	S	10	16 Dec 2004	06 Jul 2005
036	M	A	9	02 Jan 2005	23 Jun 2005
Environmental Trail					
011	F	A	2	09 Jul 2004	09 Oct 2004
012	M	A	2	11 Jul 2004	24 Jul 2004
013	F	A	7	11 Jul 2004	02 Dec 2004
022	M	A	1	18 Aug 2004	18 Aug 2004
029	F	S	4	19 Nov 2004	09 May 2005
Stoneboro					
037	M	S	2	03 Jan 2004	15 Jan 2005

Results

During the course of the entire study, from 20 June 2004–08 July 2005, we captured 38 individuals on 150 occasions during 1895 trap periods (Table 1, Figure 2). Prior to our initial trapping episode, in the spring of 2004, the occupancy status of 225 burrows was determined using fern removal. Fern was removed at 111 (49%) of these burrows and traps set at these locations captured the first 22 mountain beavers (on 41 occasions). Subsequent

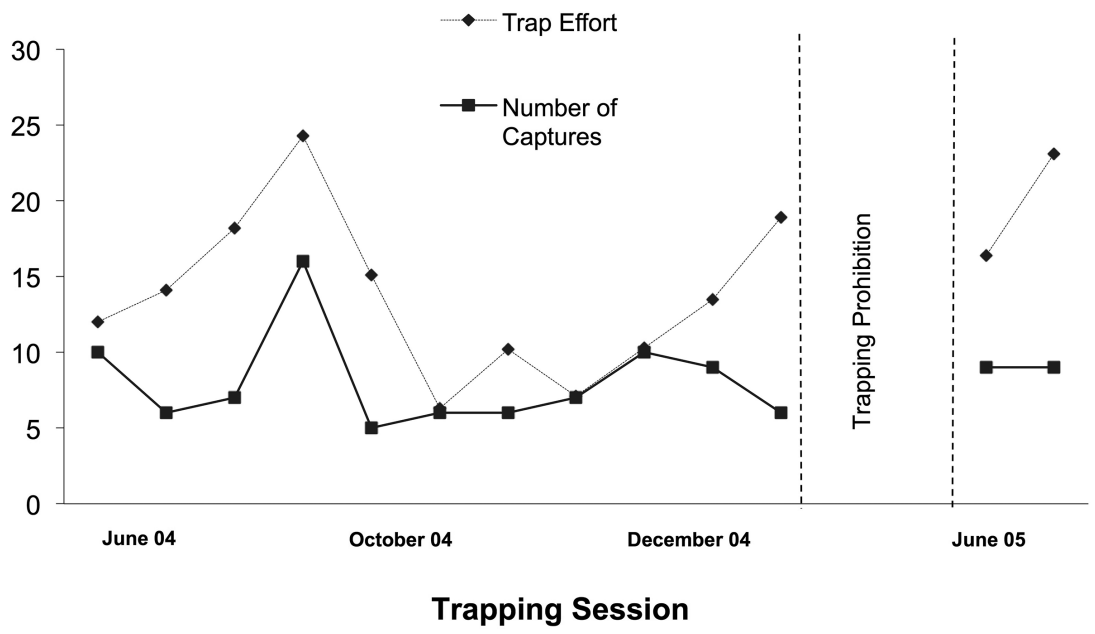

Figure 2. Trapping effort (number of trapping periods /10, to adjust scale) related to number of captures of Point Arena mountain beavers. Data drawn from trapping in all sites in Manchester State Park, Mendocino County, California, 2004–2005. Our federal permit prohibited trapping from 01 February–01 May.

trapping episodes did not include pre-baiting with fern. Recaptures were common (Table 1) with 9 individuals captured between 7 and 10 times. Only 3 juveniles were captured; a male on 21 June 2004 weighing 608 g, a female on 01 July 2004 weighing 535 g and another female on 20 June 2005 weighing 643 g. Mean baculum lengths were larger for adult males (29.9 mm, SD = 3.5) than for subadult males (25.4 mm, SD = 4.2; t = 1.497, P = 0.153).

Reproductive Chronology

Females—The earliest a female was observed with cornified vaginal cells was on 02 December 2004, and cornified cells were observed until the end of January 2005 (Figure 3). During this period there were 13 captures of 4 females, all of which had cornified cells during at least one of those captures. There appeared to be a decline in the quantity of cornified cells observed per sample toward the end of January. The pattern of vulvae swelling generally followed the chronology indicated by vaginal cytology (Figure 3). None of the 17 females captured on 26 occasions between 01 May–30 November had evidence of estrus. We did not detect any embryos in any females.

The prohibition on trapping in late winter and early spring prevented us from estimating parturition dates with accuracy. If pregnancy occurred early in the winter, we would have captured noticeably pregnant females by the end of the January, but we did not. The sex ratio of captured animals became extremely male biased during December and January, which made it very difficult to examine a sufficient number of females at the time of year when pregnancy could be verified. Instead, we back-dated the time of parturition using growth curve data from another subspecies (*A. r. pacifica*; Lovejoy et al. 1978) and applied it to the weights of juveniles when they were first captured in the spring. The weights of the 3 juveniles, which were all caught between 20 June and 01 July, were between 53 and 64% of the mean adult weight for their sex. Converting the growth curve to percent of adult weight allowed us to estimate that our juveniles

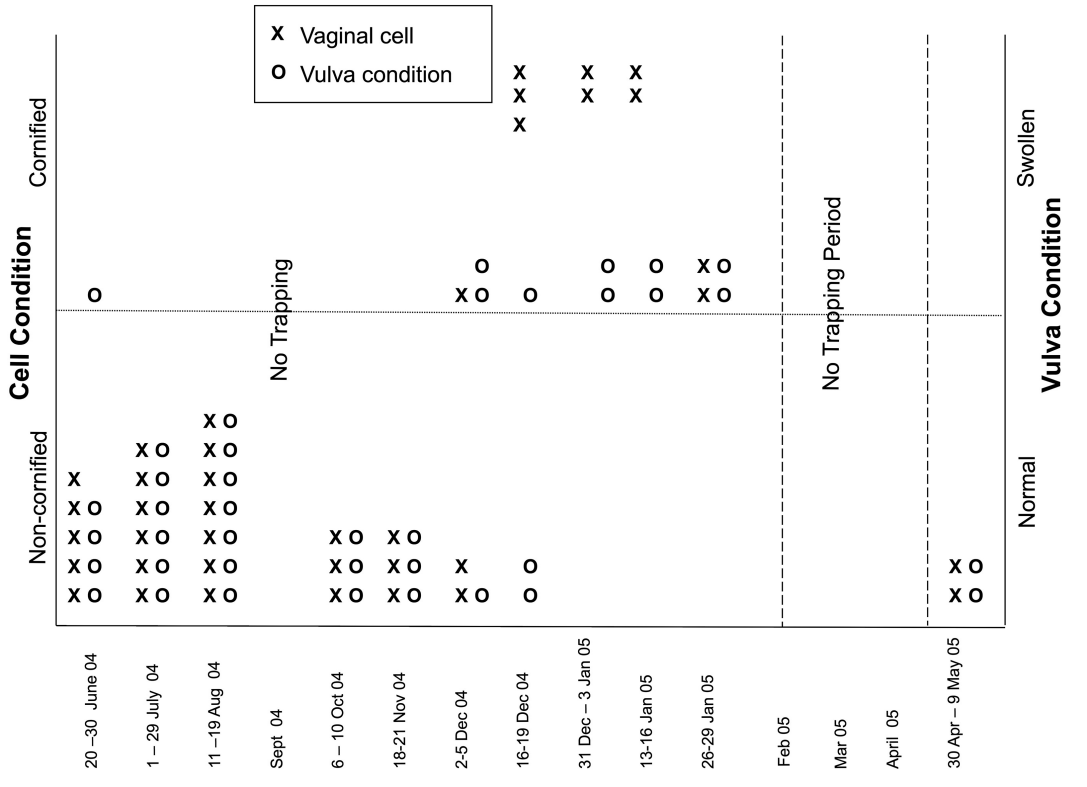

Figure 3. Female reproductive chronology at Manchester State Park, Mendocino County, California 20 June 2004–09 May 2005. Data came from 16 different individuals examined on 38 occasions. Four individual females contributed to the data during the period from 01 December–31 January and 16 individual females from the period 01 May–30 November. The captures of two juveniles are not recorded. Symbols that fall above the horizontal line indicate either vaginal cell condition (X) or vulva condition (O) consistent with reproductive condition, symbols below the horizontal line indicate captures of females lacking this condition (i.e., without cornified vaginal cells or vulva swelling). When symbols for vaginal cell and vulva condition appear as a pair, the results were derived from the same individual. Our federal permit prohibited trapping from 01 February–29 April.

were probably 9–11 weeks of age in late June. This approach resulted in estimated dates of parturition from early to mid-April. The true estimate may be closer to the latter part of this range because *A. r. pacifica*, whose growth rates were used to back-calculate date of parturition, is a smaller subspecies than *A. r. nigra* and thus and may have resulted in positive bias in our estimate.

Males—The first evidence of scrotal testes occurred in a male examined on 18 November, and from this time until 30 January the majority of the males ($n = 8$; 73.7%) showed signs of reproductive readiness (Figure 4). Testes were abdominal from 01 May–October. Five males were recaptured frequently ($n > 3$ occasions) during the period from mid November through the end of January and their testes were scrotal during each occasion. Exceptions included two subadult males that were recaptured during this period but whose testes were abdominal and one adult whose testes regressed in late January.

Discussion

The Point Arena mountain beaver appears to have a single breeding season that spans the period from late-November to at least the beginning of February (when the seasonal trapping prohibition began). Our permit did not allow us to trap to inspect animals from 01 February–01 May, and thus we were not able to estimate the latest date

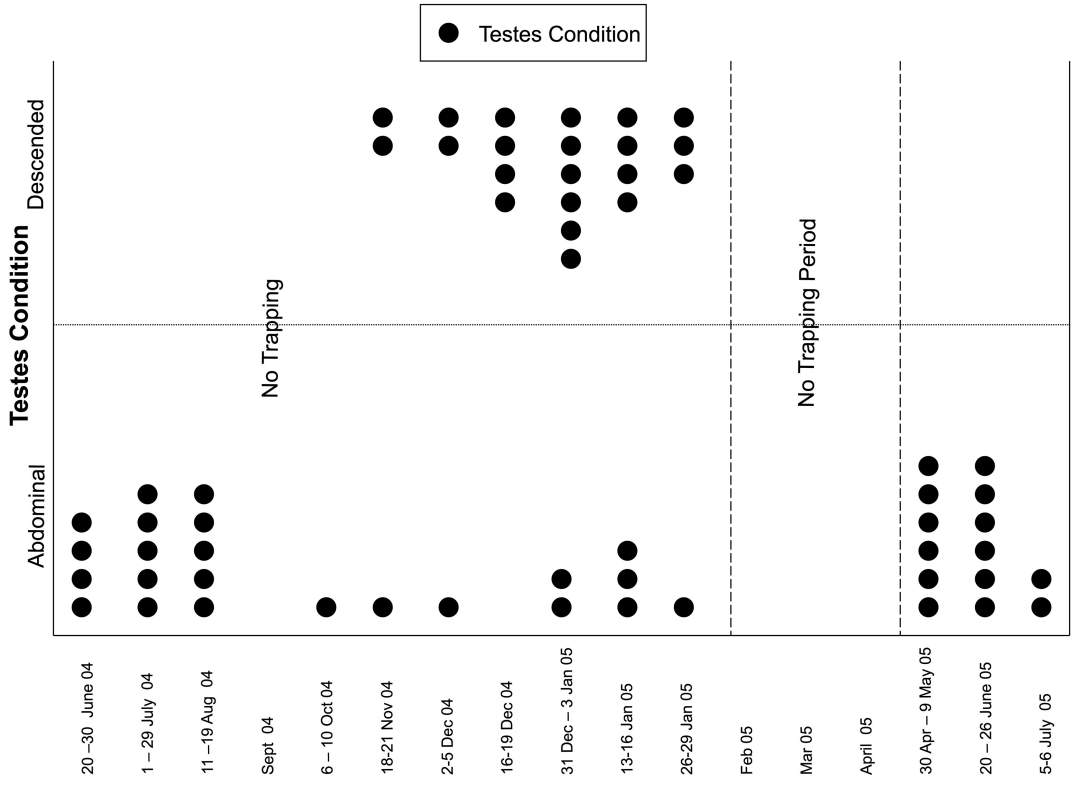

Figure 4. Male reproductive chronology at Manchester State Park, Mendocino County, California, 20 June 2004–6 July 2005 (n =20 individuals examined on 57 capture occasions). Black dot symbols that fall above the horizontal line indicate individuals that had descended testes, those below the line had undescended testes. Our federal permit prohibited trapping from 01 February–29 April.

that cornified epithelial cells were detected, but this condition appeared to decrease in frequency toward the end of January. Interestingly, there were a few occasions when a female was examined during the eight week period from 01 December through 30 January and she did not have either cornified vaginal epithelia or swelling of the vulva. There were also a few cases where a female had cornified cells but no swelling of the vulva. However, all females examined did exhibit the signs of estrus during at least one occasion during this period. Pfeiffer (1958) estimated that estrus in *Aplodontia* lasted 5–7 weeks and that there was a single period of estrus each year. Thus, it seems unlikely that females will illustrate intermittent estrus during the period we examined them. It is possible that we overlooked cornified cells on the few occasions where they were not discovered in females that were examined during December and January. We also would have a better understanding of the estrous cycle had we trapped more than four females during winter. It is possible that females in breeding condition, or pregnant, may be less likely to enter traps.

The temporal pattern of scrotal testes followed closely the pattern of female reproductive condition, perhaps anticipating it by a few weeks, indicating that males were in reproductive condition from mid-November through at least the end of January. We did not attempt, however, to estimate the period of active spermatogenesis. Unlike other males, two individuals were captured on several occasions during November–January with undescended testes. Based on weights, they were assumed to be subadults that were most likely incapable of breeding. Mountain beavers studied elsewhere are unlikely to be capable of breeding until their 2nd or 3rd fall (Pfeiffer 1958). However,

using morphological evidence of reproductive condition can be confusing, especially for pre-reproductive females which can exhibit signs of estrus in the late fall, and teat maturation in the spring, despite their low probability of becoming pregnant (Pfeiffer 1955, 1958).

Previous reports on the reproduction of the mountain beaver suggest that it is a spontaneous ovulator with a single annual estrous cycle (Pfeiffer 1958). Testes of males have been reported to descend as early as late December and females have been reported to enter estrus from mid-February to as late as early May (Pfeiffer 1958, Lovejoy et al. 1978). Parturition dates have been estimated for mountain beaver populations from Washington to as far south as Marin County, California (Cramblet and Ridenhour 1956, Pfeiffer 1958), but these reports exclude data from the Point Arena subspecies. The estimated dates of parturition appeared earliest for *A. r. phaea* samples in Marin County (mid-February), but a strong relationship between parturition date and latitude is not apparent (Pfeiffer 1958). The date at which males were captured with descended testes, and the dates of first estrus as indicated by vaginal cytology, both indicate that *A. r. nigra* may initiate breeding somewhat earlier than reported for other subspecies.

Despite the apparently earlier onset of breeding condition in *A. r. nigra*, our limited data do not suggest a correspondingly earlier estimated date of parturition. Our estimate of early- to mid-April appear to fall in the modal range for the species (Pfeiffer 1958); this is considerably later than parturition dates estimated for *A. r. phaea*, approximately 120 km south of our study area, in Marin County, California and perhaps even later than reported by Pfeiffer for some individuals in populations in Oregon, Washington and the Sierra Nevada of California. These inferences must be interpreted with caution, however, because although Pfeiffer (1958) believed that breeding is fairly synchronous there appears to be a relatively broad time period over which any one female in a population will enter estrus. A small sample of individuals from any one population may not be representative. For example, by chance alone females that were captured or examined for signs of breeding may have been disproportionately represented by individuals that entered estrus either early or late.

Sampling effect may, indeed, help explain a paradox in our data on reproductive chronology. If adult females in our study population are capable of becoming pregnant in early December, and most do, then our estimates of parturition dates (given an approximately 30 day gestation; Pfeiffer 1958) should center closer to January–February than the April period we estimated by back-calculating based on juvenile weights. Apparently, either our sample of juveniles was biased and derived from females that happened to become pregnant late (rather than early) in the breeding season or our estimates of parturition dates from juvenile weights was flawed, perhaps because the duration of gestation is longer than reported, or trapping prohibition prevented us from capturing juveniles that were independent much earlier in the spring. However, if parturition occurred in January or February, we should have captured juveniles in May, rather than in June and July, supporting the April parturition estimate. It is also possible that there are a subset of females that demonstrate signs of estrus in early December that do not become pregnant until significantly later in the winter. Indeed, we did not confirm pregnancy in two apparently subadult females that exhibited cornified epithelial cells in December and January, suggesting that not all females that cycle become pregnant. Interestingly, our data on reproductive chronology in males suggest that they enter a period of reproductive readiness in advance of the females (as inferred also for other subspecies; Lovejoy et al. 1978, Feldhamer et al. 2003) and, like the females, appear to do so earlier than for other subspecies. In sum, we believe that *A. r. nigra* may have an earlier onset of the breeding season than most other mountain beaver populations, with the possible exception of *A. r. phaea* in Marin County, California.

Our study area was a state park where managers are responsible for minimizing the effects of disturbance or infrastructure development on the federally endangered Point Arena mountain

beaver. The implications of our data on breeding chronology on the management of ground-disturbing activities in mountain beaver habitat are unclear. The US Fish and Wildlife Service (US Fish and Wildlife Service 2009) recognizes that human-caused disturbance is a threat that may disrupt significant behaviors, such as breeding, feeding, or dispersal. Typical disturbances include vegetation clearing or mowing near campgrounds, excavation related to structural improvements, and the noise and vibration from vehicles. Most conservation measures focus on protecting habitat and excluding disturbance activities from mountain beaver habitat (Hunter and Fitts 2005, US Fish and Wildlife Service 2009). There is little information, however, about limiting ground disturbing activities near burrows during the time of year when breeding, gestation and parturition occurs. Our data may be helpful in this regard. If preventing disturbance during the breeding season is desired, our data suggest that precautions may need to be instituted as early as late November. And, if these precautions need to be in place until juveniles are independent, they may need to be in place through at least mid-July; perhaps later. We do not know, however, what types, frequency or intensity of disturbances may be perceived by mountain beavers as the most threatening nor do we know what stage of the breeding season (e.g., estrous cycling, gestation, immediately post-natal) that females may be most vulnerable to ground-disturbing activities.

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