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Photo by Katherine Smith.

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Please direct correspondence to:
Armand Gonzales
Editor-in-Chief
California Fish and Game
Armand.Gonzales@wildlife.ca.gov

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Notes from the Editor

In this issue of *Fish and Game,* Trombley and Smith authored a paper on a male salt-marsh harvest mouse that was observed displaying an unusual behavior. In the last issue, Overton et al., described the predation of a Ridgeway rail by a peregrine falcon. The rail was vulnerable to predation due to high tides that inundated marsh habitats usually available as escape cover for rails and other species. Both species have the unfortunate distinction of being listed as endangered under the California and U.S. Endangered Species Acts. With the loss of nearly ninety percent of marsh habitats in the San Francisco Bay, and with the projected sea-level rise of 18-59 cm by 2050, the outlook for these species is concerning. Ongoing efforts to protect remaining marsh habitats and control invasive species are direct actions we can take to reduce the threats facing these species. This issues article from the archives provides an interesting comparison of current and historic thinking on salt licks. Laurent et al. (this issue) examines the chemical properties and classification of mineral licks used by deer and elk, while Bryant (1918) describes the creation of the Trinity Game Refuge and the benefits that natural salt licks provided for deer and other game. Interestingly, other actions described by Bryant to benefit game included placing salt bricks in the refuge and controlling predators (i.e. coyotes and mountain lions). Also in this issue, McClanahan et al., and Byron and Tupen document species occurrences in locations that would reasonably be considered suitable habitat for their respective specimens, but not previously recorded in the scientific literature. These types of baseline studies are important as species move and habitats change. I encourage all my fellow biologists and scientists to take the time to write-up your observations and submit a manuscript to *Fish and Game*. In a hundred years, it could be really important.

I've been asked several times about why the winter issue of *Fish and Game* came out in the middle of summer, the fall issue came out in the spring, the summer issue came out in the winter, and the spring issue came out in the fall. There are two explanations for this. The first and likely best explanation is that we're behind schedule and its really difficult to catch-up. The review process takes time, especially when the reviewers and Associate Editors are volunteering their time. So, while we have dozens of manuscripts under various stages of review, field seasons, class schedules, and family vacations can cause unexpected delays. The second but less likely explanation is climate change. Seriously, we will continue to publish as timely as possible and hopefully catch up by the end of this year.

Peter Kalvass, Associate Editor from the Marine Region has retired. Peter has been a valuable asset to *Fish and Game,* and will be missed. Thank you Peter for all your contributions. We wish you happy trails for a well-deserved retirement.

Armand Gonzales
Editor-in-Chief
California Fish and Game

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Documentation of mountain lion occurrence and reproduction in the Sacramento Valley of California

Kari A. McClanahan, Breanna N. Duplisea, Justin A. Dellinger*, and Marc W. Kenyon

California Department of Fish and Wildlife, Wildlife Investigations Lab, 1701 Nimbus Road, Rancho Cordova, CA 95670, USA (KAM, BND, JAD, MWK)

**Correspondent: justin.dellinger@wildlife.ca.gov*

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Little is currently known about mountain lion (*Puma concolor*) use of California's Sacramento Valley. Although mountain lions are occasionally reported adjacent to the floor of the Sacramento Valley at the base of the Sierra Nevada and Coast Ranges, habitat in this region has been considered unsuitable for mountain lion due to its extensive urban and agricultural development (Torres et al. 1996). However, relic riparian habitats persist in conjunction with restored and managed wetlands thanks to the efforts of local residents, waterfowl hunters, non-governmental organizations (NGOs) and State and Federal Agencies. These relic riparian and associated habitats provide essential habitat components for resident deer (*Odocoileus hemionus*). Thus with adequate prey, and sufficient habitat connectivity, these same areas might also allow for the presence of mountain lions.

The Butte Sink is a depression in the Sacramento Valley located immediately northwest of the Sutter Buttes, a small mountain range that rises out of the valley floor. The Butte Sink is approximately 24,500 ha containing a complex of riparian and wetland habitats at the conjunction of Butte, Colusa, Glenn, and Sutter counties east of the Sacramento River, north of the town of Colusa, California (Figure 1). Habitat types include valley riparian, seasonal emergent wetlands, permanent wetlands, and agricultural crops including rice, corn, walnuts, and olives. The Butte Sink regularly floods for several weeks at a time during winter months. Land ownership in the Butte Sink is composed of private commerical agricultural production interspersed with state and federal wildlife management areas, and private duck clubs which are managed for the benefit of the extensive numbers of waterfowl that seasonally inhabit the area.

Historic and recent information from bounty records, museum records, and depredation permits suggest that mountain lion occurrence in the area has been historically low since records began in 1907. Sutter County is the only county in the study area to be entirely contained in the Sacramento Valley, and accounted for only one depredation permit issued since the depredation program's inception in 1972. Similarly, Long and Sweitzer (2001) surveyed museums and found only four out of the 280 mountain lions collected in the state came from the California's Central Valley (composed of the Sacramento Valley and the much larger San Joaquin Valley). All four specimens were collected prior to

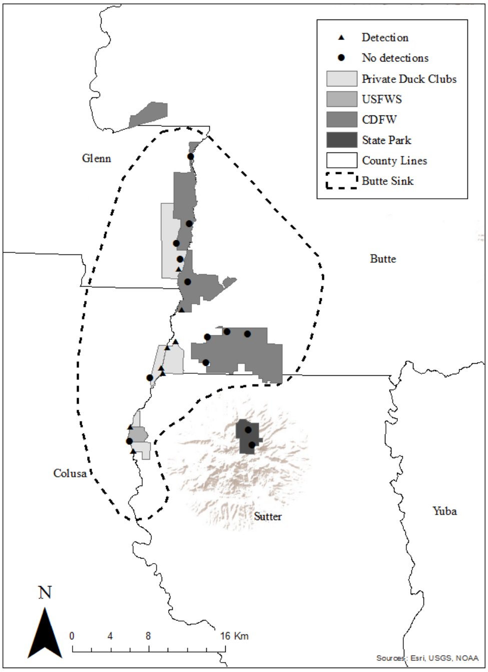

FIGURE 1.—Land ownership and camera-trap locations in the Butte Sink, Sacramento Valley, California. Cameras were deployed from March to November 2016.

1921. As part of an effort to document mountain lion populations across the state, and due to recent anecdotal reports by local residents of mountain lion presence in the Butte Sink, we wanted to document mountain lion presence in the Butte Sink and surrounding areas within the Sacramento Valley. Data gathered from this study was deposited into a statewide mountain lion habitat assessment and population estimate database.

We placed 20 un-baited Reconyx PC900 HyperFire Professional covert IR cameras throughout the Butte Sink and surrounding areas. Camera-traps were placed on private duck clubs, and state and federal lands (Figure 1). Potential locations were established either through the use of aerial imagery (Google Earth, accessed 15 February, 2016); or reliance on local knowledge of wildlife game trail occurrence. The final decision for selecting sites was based on on-the-ground evaluation of the physiognomic and topographical features that would naturally facilitate mountain lion movement in and around the Butte Sink. These included infrequently traveled dirt roads, levees, and game trails; particularly those with adequate vegetation for cover, which mountain lions select when moving through their home range (Dickson et al. 2005). Twenty cameras were placed opportunistically to meet our objective of documenting presence of mountain lions, rather than in a grid design used in modeling occupancy. We set camera-traps from 01 March 2016 through 10

November 2016, for a total of 5,165 camera-trap nights. We also received opportunistic images from cooperating individuals or land managers when mountain lions were detected on their cameras. Camera-traps were checked weekly at which time photos from the previous week were viewed on a portable tablet. We also replaced media storage cards and batteries as needed.

Mountain lions were detected on 15 occasions for a detection rate of 0.29 detections per 100 camera-trap nights. The first detection occurred on 12 April 2016, 39 days after deployment of the camera-traps. The mean occurrence interval of mountain lion detections was every 11 days over the period from receiving the first image to the last on 20 September 2016. The shortest inter-detection interval was 2.6 hrs on 15 April 2016, between two cameras spaced approximately 3,150 m apart. As only the rear of the lion was captured on the first camera, and only the head at the second location, we could not confirm whether or not it was the same animal. The longest inter-detection interval was 48 days from 10 June to 28 July 2016. Although mountain lion detection rates (number of detections per day) lessened during the summer months with a mean of 25 days between sightings from 27 April to 31 August 2016, we continued to detect them throughout the study period.

At least two distinct adults were identified in our images: a male who was distinguished by a missing right front foot (Figure 2), and a female who was accompanied by three kittens (Figure 3A). We also detected an adult with no kittens or foot abnormalities, but it is unclear if this is a third individual or the mother without her kittens. In addition to these five known unique mountain lions detected during this study period, we were given images of a female and litter taken in 2012 (Figure 3B) at a duck club in the study area. We cannot however determine whether this is the same female we detected in 2016.

The presence of multiple litters observed in the area indicates the Butte Sink is suitable for foraging reproductive females. A female with kittens requires substantially more calories than a non-reproductive adult mountain lion. Energetic models have demonstrated that over the length of time required to carry, birth, and raise dependent young to independence, females with dependent young require at least twice the amount of deer compared to a lone individual (Laundrè 2005). This time period of increased caloric need is generally 21-24 months long with 3 months for gestation and 18-21 months for raising young (Logan and Sweanor 2001).

Although the majority of the Sacramento Valley is either open agriculture or urban development, our study area may represent a pocket of suitable mountain lion habitat within the Sacramento Valley. Mountain lions have been documented preferentially selecting riparian habitat and avoiding agriculture and urban areas in Southern California (Dickson and Beier 2002) and Arizona (Nicholson et al. 2014). Furthermore, mountain lions living in landscapes dominated by human disturbance appeared less sensitive to anthropogenic features, suggesting that some may differentially select habitats (Wilmers et al. 2013) and may become accustomed to more regular human activity (Benson et al. 2016). However, animals living in closer proximity to human activity are at greater risk of mortality (Burdett et al. 2010).

It is conceivable that mountain lions living in riparian islands like the Butte Sink would likely have adequate prey throughout the year. In mountainous areas, mountain lions generally follow seasonal ungulate movement patterns (Robinson et al. 2002), but mountain lions in general are known to have very flexible foraging patterns (Smith et al. 2016).

FIGURE 2.—Camera-trap image of an adult male mountain lion with a missing right front foot (date 12 April, 2016). The camera-trap was located adjacent to a tributary of Butte Creek within the Butte Sink study area.

FIGURE 3A.—Camera-trap image of an adult female mountain lion with two kittens (date 19 April 2016).

FIGURE 3B.—Camera trap image of an adult female mountain lion with two kittens (date 6 November 2012). Image courtesy of JP Stover and Wild Goose Club.

In addtion to the deer detected on nearly every camera-trap each week, the Butte Sink is also known to support dense populations of American beavers (*Castor candensis*), turkeys (*Meleagris gallopavo*), lagomorphs (*Sylvilagus* spp.), striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), and various species of waterfowl (e.g., *Areidae* and *Anatidae*), and fish (e.g., *Cyprinidae*; CDFW 2015), all potential mountain lion prey (Iriarte et al. 1990; Murphy and Ruth 2009). Further, deer are likely year-round residents because of the extensive agricultural development that now surrounds, and is a part of, the Butte Sink (Ingles 1965; Loft and Bleich 2014). The combination of resident deer and the diversity of secondary prey available lead us to believe that mountain lions likely persist year-round in the Butte Sink. However, further study is needed to determine mountain lion movements during large-scale flood events, which can inundate the Butte Sink area for multiple weeks at a time.

The Butte Sink is a remnant of native habitats that once covered much of the Sacramento Valley. Using California GAP vegetation data (Davis et al. 1995) we attempted to visually identify additional aggregate blocks of relic riparian habitat that remained in the Central Valley (Figure 4). These aggregate blocks were identified by selecting riparian habitat ≥1,500 ha in size and ≤2 km from similar habitat of greater than or equal size. These thresholds were derived from research on mountain lions in the Santa Monica National Recreation Area and surrounding areas wherein some animals were found to inhabit, at least temporarily, habitat blocks ≥1,500 ha in size and ≤2 km from similar habitat (Benson

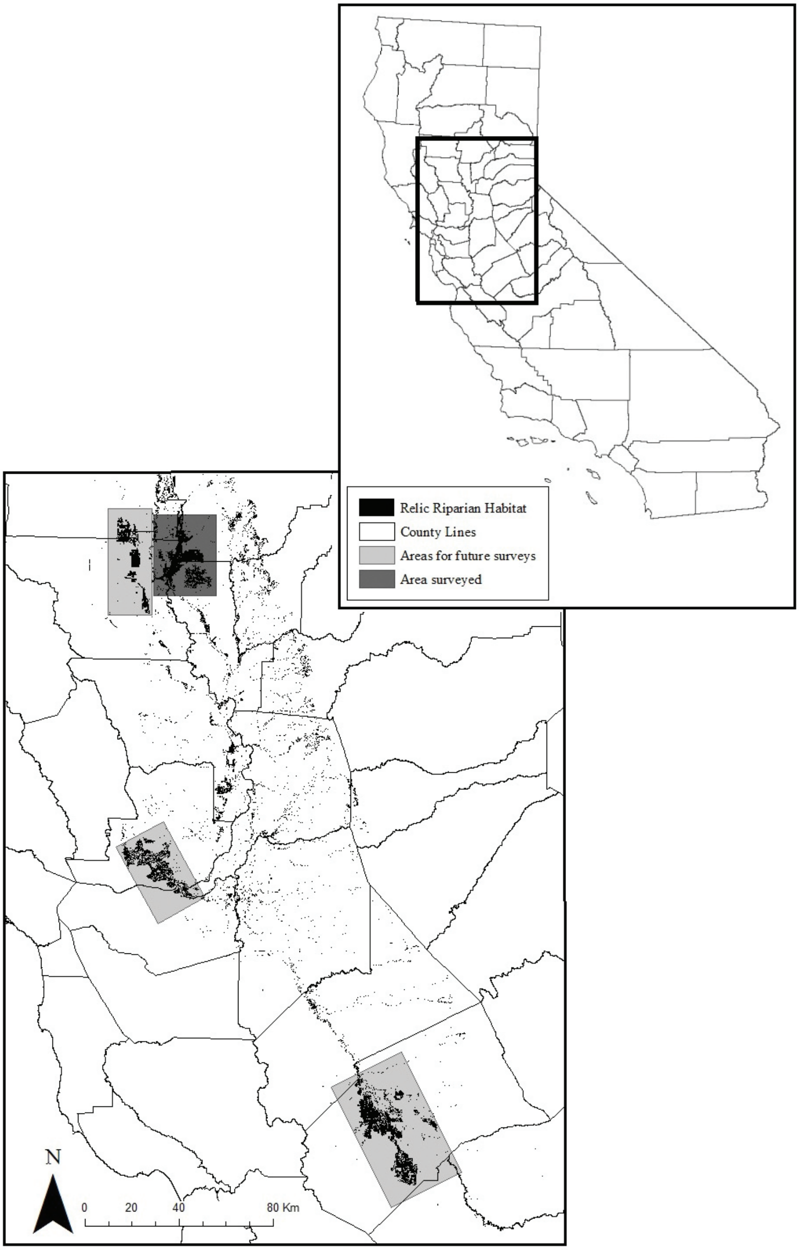

FIGURE 4.—Location of Butte Sink survey area relative to the locations of additional areas of relic riparian habitat in the Central Valley of California. These areas could be surveyed for mountain lion activity.

et al. 2016). Based on this analysis, we found that blocks of relic riparian habitat occur in and around the Sacramento River National Wildlife Refuge Complex (~11,800 ha), Grizzly Island Wildlife Area (~17,200 ha), and San Luis National Wildlife Refuge (~31,900 ha). It is possible that mountain lions are present, at least periodically, in these additional blocks of relic riparian habitat. Future camera work in these areas might help increase our understanding of mountain lion distribution in the Central Valley of California.

We suggest that mountain lions are occupying and reproducing within the Sacramento Valley's Butte Sink, an area heavily impacted by humans, and are capable of utilizing habitat islands within agricultural lands that have adequate connectivity with larger habitat blocks. Such information should be carefully considered when designating suitable habitat for mountain lions in California, in that some habitat of this type may not have been considered viable for mountain lions in the past. However, adequate connectivity between remnant islands of habitat and larger habitat areas is critical if these remnants are to remain viable over time.

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We would like to thank Bird Haven, White Mallard Duck Club, Wild Goose Club, Colusa Shooting Club, El Anzar Duck Club, California State Parks, and the U. S. Fish and Wildlife Service for granting us access to their properties and for their input on camera locations. Thank you to Tim Hermansen, Laura Cockrell and Shannon Rich of CDFW for checking our cameras on the Upper Butte Basin Wildlife Area, and to Dave VanBaren of CDFW for checking the cameras on Gray Lodge Wildlife Area.

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Potential evidence of communal nesting, mate guarding, or biparental care in the salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*)

Sadie Trombley And Katherine R. Smith*

California Department of Fish and Wildlife, Suisun Marsh Unit, 2109 Arch Airport Rd Suite #100, Stockton, CA 95206, USA (KRS)

University of California, Davis, Department of Wildlife, Fish and Conservation Biology, One Shields Avenue, University of California, Davis, CA 95616, USA (ST)

**Correspondent: katie.smith@wildlife.ca.gov*

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The salt marsh harvest mouse (*Reithrodontomys raviventris*) is endemic to the saline and brackish marshes surrounding the San Francisco Estuary (Fisler 1965). There are two subspecies of salt marsh harvest mouse; the northern subspecies (*R. r. halicoetes*), which occurs primarily around San Pablo, Suisun and Grizzly bays, and the southern subspecies (*R. r. raviventris*), which occurs primarily around the South San Francisco Bay (Fisler 1965). Due to the loss of over 90% historic tidal marsh habitat in the San Francisco Estuary, both subspecies were listed as endangered by the U.S. Fish and Wildlife Service in 1970 and the California Department of Fish and Game in 1971 (U.S. Fish and Wildlife Service 2013). Very little research has directly addressed the behaviors of salt marsh harvest mice, and virtually none has investigated intraspecific interactions. Understanding animal behavior can improve conservation efforts (Berger-Tal et al. 2011), but until very recently, the only observations of social behaviors of the salt marsh harvest mouse (e.g., breeding behaviors) occurred *ex situ* (Fisler 1961).

Beginning in 2013, researchers from the California Department of Fish and Wildlife (CDFW), and University of California, Davis performed radiotelemetry seasonally as part of a three-year demographic and habitat use study on the northern subspecies. Once per season, at three study blocks consisting of paired tidal and diked managed wetlands, adult male and female salt marsh harvest mice were radiocollared and monitored for habitat use and other behaviors. Monitoring activities were concentrated during nocturnal hours but also encompassed some daylight hours. Researchers tracked and located mice throughout shifts with at least 30 minutes between sequential locations for individuals. Using this technique we were able to make observations of habitat use, feeding behavior, interactions between individual mice, and more.

During three years of radiotelemetry work, tracking hundreds of individual salt marsh harvest mice, we rarely observed mice remaining in one location for extended periods during nocturnal hours. However, on 30 August 2016 at CDFW's Goodyear Slough Unit in Benicia, California, between the hours of 0300 and 0600, we tracked a radiocollared adult male salt marsh harvest mouse to the same nest four times. The nest, made of harvested annual grasses (Figure 1), was located in pickleweed (*Salicornia pacifica*) about 0.5 m above the ground, and about 10 cm above standing water on a recently flooded diked managed wetland. At 0645 hrs, to confirm that the mouse was present and that the radiocollar had not slipped off, we uncovered the top of the nest. Upon pulling back the nesting material, we observed the adult male mouse and three well-haired juvenile mice huddled together in the nest. The juveniles were beneath the adult male's body (Figure 2). The mice did not flee and we replaced the nesting material promptly to minimize disturbance. The weather at the time was mild; the temperature was about 17.0° C, average wind speed was 2.6 miles per hour, and cloud cover was about 50% with no precipitation. Later that day, between 1900 hrs and 2300 hrs, we recorded the radiocollared male mouse moving about, presumably foraging. During this period the weather remained mild; the temperature dropped from about 28.5° C to 20.0° C, wind speed decreased from 2.5 to 1.0 mile per hour, and cloud cover increased from about 30% to 80% with no precipitation.

The following morning between 0300 hrs and 0600 hrs we tracked the mouse to the same nest three times. At 0640 hrs, we again checked on the mouse, pulling away the top nesting material to reveal the adult male and the three juvenile mice. This time

FIGURE 1.—Nest built out of dry annual grass in the upper branches of a pickleweed bush (*Sarcocornia pacifica*).

FIGURE 2.—A radiocollared adult male salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*) in a nest with three juveniles.

one juvenile was tucked under the adult's abdomen, while the other two lay on top of him. We removed the adult mouse from the nest and verified that the radiocollar was in place and was not restricting his movement. At this point we confirmed him to be a scrotal male and placed him back in the nest. The juvenile mice did not flee as we removed and replaced the male (Figure 3). The temperature was about 16° C, average wind speed was 2.4 miles per hour, and cloud cover was <5%. Monitoring during the following nights revealed that the radiocollared adult and juvenile mice were not using the nest.

This is the first time an adult male salt marsh harvest mouse has been observed nesting with juveniles in the wild, and we generated several potential explanations for the behavior. One possibility is that the radiocollared male was simply looking for a warm, dry place to rest and did not perceive any threat from the juvenile mice. Since the pond was recently flooded, the mice were forced into closer proximity with fewer resources. Flooding diked managed ponds for duck hunting can reduce the available habitat for salt marsh harvest mice and they may be forced to move vertically into emergent vegetation (Smith et al. 2014). However, this was during a relatively warm and dry period, so huddling for warmth was likely unnecessary.

FIGURE 3.—Three juvenile salt marsh harvest mice (*Reithrodontomys raviventris halicoetes*) huddling calmly in a nest after researchers removed an adult radiocollared male from the nest.

A second possible explanation is that the radiocollared male was mate guarding (Getz et al. 2003). There is some debate as to whether salt marsh harvest mice breed into August (Padgett-Flohr and Isakson 2003, Bias and Morrison 2006); however, we have observed reproductive females of the northern subspecies year-round during years of low precipitation. Female salt marsh harvest mice are capable of entering postpartum and/or lactation estrus (Gilbert 1984, Shellhammer et al. 1988) and we commonly capture pregnant females who are still lactating (suggesting post-partum estrus), so there is a strong possibility that the male was remaining near the juveniles to gain access to the mother for mating. Alternatively, the male could have been mate guarding the juveniles. While there are no published estimates of age to sexual maturity for female salt marsh harvest mice, female western harvest mice (*R. megalotis*) can reach sexual maturity in less than six weeks (Richins et al. 1974). Additionally, male western harvest mice are significantly more likely to be captured in traps with reproductively receptive females than pregnant or postpartum females (Blaustein and Rothstein 1978). We commonly observe this when sampling salt marsh harvest mice as well, often trapping older adult males and very young females together in the same trap. Unfortunately, to minimize disturbance, we did not remove the juveniles from the nest to determine their sex or take measurements for age estimation. However, since there were three individuals, it is likely that at least one of the juveniles was a female; hence, it is possible that this adult male was associating with these young mice as a means of guarding a female to ensure he was the first to breed her.

Our final possible explanation is that the radiocollared adult and three juvenile mice may have been genetically related. Northern salt marsh harvest mice have an average litter size of 4.21 (Fisler 1965), so this was potentially a litter of siblings. It is possible that the young were the male's offspring and he was participating in biparental care; he generally may have foraged for the first half of the night, and cared for the young during the latter half of the night while his mate foraged. The huddled position and nest guarding, which is typical of paternal care in mice (Gubernick and Teferi 2000), supports this possible explanation. Unfortunately, since the mice did not use the nest on subsequent nights, we were unable to collect hair samples to determine their genetic relationship.

Biparental care is rare among mammals, but relatively common in rodents (e.g., Silva et al. 2008; Schradin and Pillay 2003), where paternal care can significantly increase pup survival (e.g., Ophir et al. 2008; Gubernick and Teferi 2000). We observed radiocollared females in nests with young on a number of occasions, but this is the only observation we made of a male in a nest with young. However, we commonly tracked radiocollared adult males and females to the same location where they may have been sharing a nest. We were only able to confirm this visually with one pair because we did not regularly uncover nests unless radiocollars were stationary for extended periods or we were trying to capture mice for collar removal.

These observations have important implications for the conservation and management of the salt marsh harvest mouse. Understanding breeding behaviors such as communal nesting and biparental care can assist managers in conserving this endangered species by more accurately assessing habitat needs, demography, and densities. These types of data can also improve timing of habitat management activities to reduce negative effects on mice during peak breeding seasons. Observations of behaviors related to the life history of endangered species should be recorded when feasible, as they may prove valuable tools for conservation. Finally, collecting genetic samples from adult and juvenile salt marsh harvest mice captured in the same trap during routine surveys will improve our understanding of parental care and breeding behaviors for this critically endangered species.

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Mussels of the Upper Klamath River, Oregon and California

Earl Byron* and Jeff Tupen

CH2M, 2485 Natomas Park Drive, Ste. 600, Sacramento, CA 95834 (EB-retired, JT)

**Correspondent: earlbyron4@gmail.com*

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The purpose of this study was to provide baseline information that may assist in the development of protection, mitigation, and enhancement measures for freshwater mussels in the Klamath River in Oregon and California. The river is of concern for water quality and fisheries issues as well as the possibility of future dam modifications or removal (PacifiCorp 2003). In addition, this study generally updates the baseline characterization of the larger bivalve species (mussels) of the upper Klamath River by adding a number of upstream locations that corroborate and extend the extensive statewide surveys of Howard (2010; 2015). Prior surveys of California and Klamath River locations for bivalves did not include most of these Klamath River locations upstream of the Shasta River confluence (Ingram 1948; Bonnot 1951; Taylor 1981; Williams et al. 1993; Frest and Johannes 1998; Nedeau et al. 2009). In addition, our records of Klamath River mussels provide further data on the abundance and diversity of these species over time.

Our study, which was completed from 2-6 September 2003, focused on large (generally, five to ten centimeters) bivalve species of the order Unionoida, which in California includes the genera Anodonta (floaters), Gonidea (ridgemussel), and Margaritifera (pearlmussel). Anodonta and Gonidea are classified within the family Unionidae, while Margaritifera is classified within the family Margaritiferidae (note: in this paper, we collectively refer to mussels of the order Unionoida as "unionid mussels", which is not technically correct).

Sampling locations are quantified as river kilometers (RK) measured upstream from the mouth of the Klamath River at the Pacific Ocean. For purposes of this freshwater bivalve study, the study area is defined as that portion of the Klamath River mainstem from immediately downstream of the Keno Dam (RK 409), which impounds Upper Klamath Lake, and the Shasta River confluence (RK 284), a distance of 125 km.

The study area may be further partitioned into five distinct reaches of the Klamath River and one of Fall Creek, with reach breaks generally occurring between reservoirs and defining the intervening riverine habitats. Fall Creek may be considered comparable habitat but outside the influence of the mainstem Klamath reservoirs. These reaches and individual sampling locations are shown in Figure 1. All sites were lotic, beginning immediately downstream of Keno Dam, and included locations upstream and downstream of each of the 3 reservoirs within the study boundaries (J. C. Boyle, Copco, and Irongate; Figure 1).

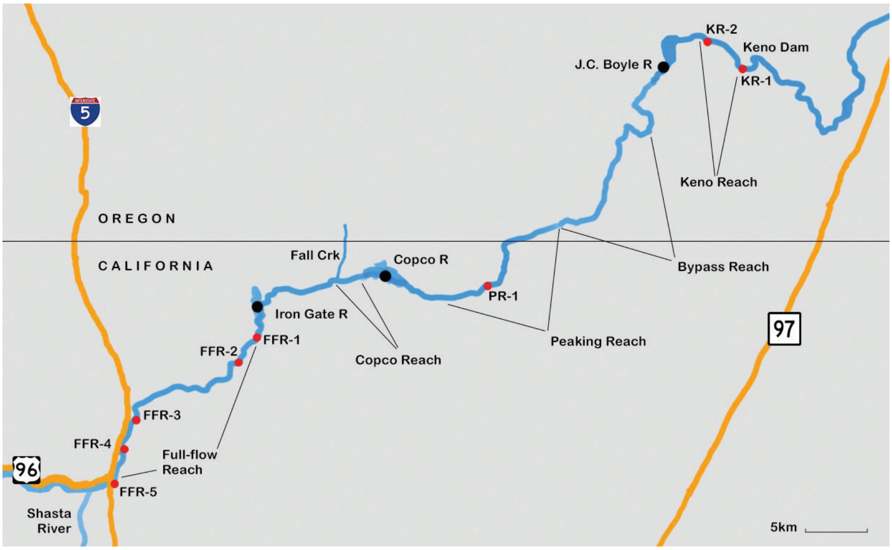

Figure 1.— Map of the Northern California/Southern Oregon study section of the Klamath River from Keno Dam to the Shasta River showing the separate study reaches, reservoirs (R), and individually numbered sampling sites for mussels (e.g., FFR-4)

Suitable habitat for large bivalve sampling was determined by a review of available literature (i.e., Frest and Johannes 2000) and professional judgment of the biologists conducting this study. In general, suitable habitat included those areas with benthic substrates finer than gravels (i.e., coarse sands to silts). Exceptionally swift and deep water areas were not sampled due to safety concerns, and sampling was therefore restricted to low- to moderate-velocity locations of approximately 0.6 m/s or less.

Accessible areas of suitable habitat were first inspected for the presence of empty shells (valves) on the riverbank, or in the nearshore water. Empty shells are commonly indicative of small mammal (e.g., muskrat, river otter) predation (Convey et al. 1989) and the likely presence of nearby bivalve beds. Where empty shells were observed, biologists used buckets with clear Plexiglas bottom panels to view the nearshore sediments in wadeable depths of 0.5 to 1 m, depending on water visibility. Deeper habitats (1 to 2 m) in areas of low to moderate flows were examined using snorkeling gear.

If large bivalves were found using either method, the "bed" was characterized in terms of its size and species composition referencing the methods of Duncan (2008) and Strayer and Smith (2003). Several methods were used to characterize located mussel beds. For large, dense beds, composition and abundance was determined by observations within randomly located 0.25-m quadrats. For smaller and/or less-dense beds, bed margins were located and all bivalves located within the bed were identified and enumerated through intensive searches. Substrate composition was noted for each collection location and characterized as fines, gravel, cobble, boulder, or bedrock.

Results of bivalve abundance, diversity, and site characteristics within the study area by specific sampling location are shown in Table 1, for larger unionid species. Note that only three of the Klamath River reaches revealed the presence of these species.

TABLE 1.—Sampling observations of Unionid bivalves, Klamath River, Oregon and California, September 2003. River kilometers (RK) measured from mouth of Klamath River.

River Reach	Station ID and Location (RK)	Species	Number sampled/density (#/m^2)/ Size range (mm)	Habitat Characteristics / Field Notes
Keno Reach (KR)	KR–1 (375)	*A. oregonensis*)	79/14.6/52 – 126	Soft sediments associated with bulrush and cattail patch just below Keno Dam. Low velocity water, depth 45 cm. *A. oregonensis* semi-buried. No other species noted.
	KR–2 (367)	*G. angulata*) and *A. oregonensis*	*G. angulata*: 6/6/43 – 84 *A. oregonensis*: 35/35/37 – 93	Coarse sand with silt associated with bulrush patch in mid-channel, just above Boyle Reservoir. Generally, smaller *G. angulata* than other sites; mostly- to completely buried. Low velocity water. Water depth 45 cm. *G. angulata* dominant species, though few *A. oregonensis* noted
JC Boyle Peaking Reach (PR)	PR–1 (330)	*G. angulata*	16/1.8/37 – 100	Coarse sand in pool below rock chute. Water depths varied, depending on release flows, from 0.7 to 1.5 m. Low velocity. No associated vegetation. *G. angulata* mostly to totally buried. No other species noted.
	FFR–1 (305)	*A. oregonensis*	37/2/56 – 96	Cobble substrate downriver of Iron Gate Fish Hatchery bridge over Klamath River. Slow water velocity in countercurrent noted. Water depth 1-1.3 m. Unidentified hydrophyte associated. No other species noted.
Full-Flow Reach (FFR)	FFR–2 (299)	*G. angulata* and *A. oregonensis*	*G. angulata*: 20/0.5/57 – 96 *A. oregonensis*: 4/0.1/66 – 77	Coarse sand substrate between cobbles and boulders. Just upstream of footbridge at Klamath River County Estates. Swift water. No associated vegetation. Water depth to 0.7 m. *G. angulata* dominant species, though few *A. oregonensis* noted.
	FFR–3 (291)	*G. angulata* and *A. oregonensis*	*G. angulata*: 142/6.8/53 – 100 *A. oregonensis*: 4/0.3/58 – 79	Coarse to fine sand substrate between cobbles in slow moving section of water (depth to 0.6 m.). Unid. hydrophyte associated (same as FFR-1). *G. angulata* dominant species, though few *A. oregonensis* noted.
	FFR–4 (289)	*G. angulata*	62/16.5/21 – 103	Coarse to fine sand with some silt substrate just upstream of I-5 bridge over Klamath River. Moderate water velocity. *G. angulata* mostly to totally buried in approx. 45 cm of water. Unid. hydrophyte associated (same as FFR-1). Four vacant shells of fresh-dead to long-dead adults to young of *A. oregonensis*, and one vacant shell of long-dead adult *Anodonta californiensis* (California floater) collected.
	FFR–5 (287)	*G. angulata*	41/14.9/47 – 94	Coarse sand substrate between cobbles. Just downstream of I-5 rest stop. Moderate velocity water, 30 - 45 cm. deep. No associated vegetation. No other species noted.

The major changes in substrate composition are longitudinal and elevation related with dominance by boulder and bedrock in higher elevations (Keno Reach 1-2, PJ. C. Boyle Peaking Reach 1), grading to cobble and gravel in the middle and lower elevation reaches (Full-Flow Reach 1 - 5).

The distribution of large bivalves within the study area is patchy and is strongly related to the patchy distribution of suitable habitat (Table 1). Low-energy areas where finer sediments accumulate and where hydrology is consistent were most suitable for A. oregonensis. While these types of habitats also supported Gonidea angulata, this latter species appeared to prefer faster waters and, consequently, coarser substrates such as medium- and coarse sands. Even areas with boulder and bedrock substrates had pockets of finer materials in which G. angulata were aggregated.

Both species could be locally dense in number and were highly variable in relation to burial in the substrate (Table 1). Some were completely isolated below the riverbed surface. Commonly, G. angulata were found buried to depths of 15 cm and often stacked atop one another. Presumably intergravel flow in the areas of faster moving water provided enough oxygen and food to support the completely buried animals with no apparent connection to the overlying water column (Unionid mussels lack siphons). As a general characteristic, G. angulata were always buried at least 80%, with only the tops of shells visibly evident. In contrast, A. oregonensis were less buried and sometimes found laying atop the substrate. While others were buried slightly, they were never buried as deeply as G. angulata.

It is unlikely that the Peaking Reach, with its highly variable reservoir-discharge flows, supports broadly distributed populations of unionid bivalves. In contrast, selected microhabitats within the Keno Reach and Full-Flow Reach appear to support extensive populations of both A. oregonensis and G. angulata (Table 1). Of the two, the latter appears more broadly distributed, possibly reflecting the relative abundance of preferred habitat (faster water, coarser substrate) and relative scarcity of slower, nutrient enriched habitats (e.g., near eutrophic lakes).

Several locations were searched without the discovery of mussels and were therefore not reported in Table 1. These areas include the boulder-dominated Bypass Reach (RK 357), the Peaking Reach (RK 330), the Bypass Reach (RK 318), and the Full-Flow Reach (RK 297) and a location with too few G. angulata to establish a sampling site at RK 294 (but presence noted).

Our findings of unionid bivalve distribution and diversity are in agreement with the findings of Howard (2010) and Howard et al. (2015) (both as part of her 2008/2009 statewide mussel survey that included Klamath River locations) in that we did not document the presence of *Margaritifera falcata*, although that species was historically present in our study area. In other studies, *M. falcata* has been described as extirpated from eastern California streams (Hovingh 2004). Howard's study reach of the Klamath River started at our most downstream boundary and progressed downstream, whereas our study area progressed upstream from that site (I-5 rest stop and Hwy 96 crossing of the river, FFR-4) and therefore our study locations on the Klamath River were only in overlap at that one location. We found only *Gonidea* in the river at this location and immediately upstream, confirming the Howard et al. (2015) results that both *A. oregonensis* and *M. falcata* have apparently disappeared from this section of the river, at least as early as 2003 (our result) and 2008 (Howard et al. 2015). We also confirm the Howard et al. (2015) reports that *M. falcata* were not present in our Klamath River study reaches although they had been present (at least in the lowest elevation portions of our study) historically (Howard 2010; Howard et al. 2015) and are still present at downstream locations, outside our study area (Howard 2015).

We note only a single, individual dead shell of *A. californiensis*, at station FFR-4, indicating it was present in the river in that general area or possibly upstream (Table 1). Regardless, no living individuals were found in our survey and it must be considered to be very rare throughout our study reach. Historically, it was known from the lower Klamath and Shasta rivers, which includes the general area of our collection (T. J. Frest, Deixis Consultants, unpublished report). Taylor (1981) stated that most natural populations of *A. californiensis* have probably been eliminated from California.

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Elemental Content Of Mineral Licks In The Klamath Mountains, Siskiyou County, California

T. E. Laurent, R. C. Graham*, B.D. Lee, And W. Tripp

U.S. Forest Service – Klamath National Forest, 1711 S. Main St., Yreka, CA 96097, USA (TEL [retired], WT)

Soil and Water Sciences Program, University of California, Riverside, CA 92521-0424, USA (RCG)

Department of Plant and Soil Sciences, University of Kentucky, Lexington, KY 40546-0091, USA (BDL)

**Correspondent: robert.graham@ucr.edu*

Mineral licks are important components of terrestrial ecosystems that have special value in the annual life cycle of deer and elk. Lick use helps herbivores maintain a proper electrolyte balance even as forage quality changes seasonally. In this study, 5 lick sites, mostly in soft weathered rock or deep soil exposed in roadcuts, were sampled on the Klamath National Forest in northwestern California. Lick samples were analyzed for pH, electrical conductivity (reflective of salinity), and 10 water-extractable elements (Ca, Na, K, Mg, Mn, Fe, I, Cl, S as SO4, and N as NO3). Soil textures varied from sand to silty clay. Lick pH varied from 3.6 to 9.8. Electrical conductivities of the saturated paste extracts varied from 0.2 to 16.7 dS m-1. While iodine is the element that is most often higher in lick samples compared to non-lick materials, no single and consistent soil attribute was overwhelmingly enhanced at the lick sites. Each site had at least one chemical condition that was different from the non-lick comparison samples, so the individual licks may provide different nutrient supplements.

Key words: deer licks, elk licks, geophagy, Klamath Mountains

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Mineral licks are important components of terrestrial ecosystems, in particular because of their significant contributions to the life cycle of herbivores (Heimer 1973, Weeks and Kirkpatrick 1976, Weeks 1978). Research as far back as the 1950s indicates that herbivores have reduced access to high concentrations of mineral elements, such as sodium and calcium, compared to carnivores and omnivores (Rea and Rea 2005). While ungulates often incidentally ingest soil adhering to plant roots (Healy et al., 1972; Arthur and Alldredge, 1979), purposeful ingestion of soil (geophagy) by herbivores can be a symptom indicating deficiency in various nutritional elements, such as phosphorus, calcium, and sodium, and to a lesser degree, magnesium, sulfate, and the micro-elements cobalt and copper (Eksteen and Bornman 1990, Jones and Hanson 1985).

In North America, plants may provide insufficient levels of nutrients during certain times of the year (Belovsky and Jordan 1981). Animals use natural mineral licks predominately in the spring and early summer months during gestation and lactation (Jones and Hanson 1985, Robbins 1993, Ayotte et al. 2008). The use of natural mineral licks can help maintain a positive balance for sodium during these critical periods (Weeks and Kirkpatrick 1976).

Other elements (Mg and Ca) consumed at mineral licks may be more important to ungulates than sodium. High concentrations of magnesium and calcium are associated with optimum development of antlers and body weight of white-tailed deer (Jones and Hanson 1985). Frequent use of mineral licks in spring has been attributed to a high intake of potassium in forage, which interferes with essential absorption of magnesium in the ruminant digestive tract and causes grass tetany (Weeks and Kirkpatrick 1976, Jones and Hanson 1985, Schultz et al. 1988). As with sodium, supplementing magnesium intake can counter high potassium ingestion during spring (Schultz et al. 1988). The literature indicates that sodium chloride is the most probable attractant, while a strong nutritional need is for calcium and magnesium (Jones and Hanson 1985, Moe 1993, Kennedy et al. 1995).

Mineral licks used by deer were noted a century ago in the Klamath Mountains of northern California, where they were favored sites for deer hunting until protected by a game refuge (Bryant, 1918). Deer and elk licks are commonly observed on the Klamath National Forest, but have not been described, analyzed, and classified. The objectives of this study were to begin identifying known locations of mineral lick sites, to determine their physical and chemical properties, and to create a useful classification system to communicate information about them to wildlife biologists and land managers.

Materials And Methods

Study area.—The study area is located on the Klamath National Forest within the Klamath Mountains physiographic province in western Siskiyou County, California. The general locations of sampled lick sites are indicated in Figure 1. The sites are within a 50-km radius of 41° 31' N, 123° 10' W. The climate is Mediterranean with cool, wet winters and hot, relatively dry summers. The mean annual precipitation of the sampled sites varies between 787 and 1651 mm with most of the precipitation occurring as rain between October and April (Table 1) (Rantz 1968). Elevations of the lick sites range from 220 to 1459 m. All of the licks are located in coniferous forest vegetative types. Douglas fir [*Pseudotsuga menziessi* (Mirbel) Franco] dominates on most sites, with white fir [*Abies concolor* (Gordon and Glend.) Lindley], ponderosa pine (*Pinus ponderosa* Laws), incense cedar [*Calocedrus decurrens* (Torrey) Florin], tanoak [*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.], and black oak (*Quercus kelloggii* Newb.) on some sites (Table 1). Soils at the sites are mapped as Haploxerults, Haploxeralfs, Dystroxerepts, and Humixerepts (Table 1). Lick materials are from metavolcanic, serpentinite/talc, diorite, and quartz diorite lithologies (Table 2) (Wagner and Saucedo 1987).

Sample collection.—The lick sites sampled for this study were being used by California black-tail deer (*Odocoileus hemionus columbianus*) (all sites; Figure 2) and Roosevelt elk (*Cervus canadensis roosevelti*) (Sites 1 and 7). Lick samples were taken where actual ingestion was indicated by teeth and tongue marks (Figures 3 and 4) in the dry or wet soil or soft rock material (i.e., regolith). The actual lick ingestion spots varied from less than 1 m^2 to several m^2 in size. Sites 1, 2, 6, and 7 were originally sampled in 1998. Site 8 was sampled in 2016. Non-lick soil samples for comparison were collected in 2016 near the licks (within 1-10 m) at Sites 1, 2, 6, and 8, but in places that showed no

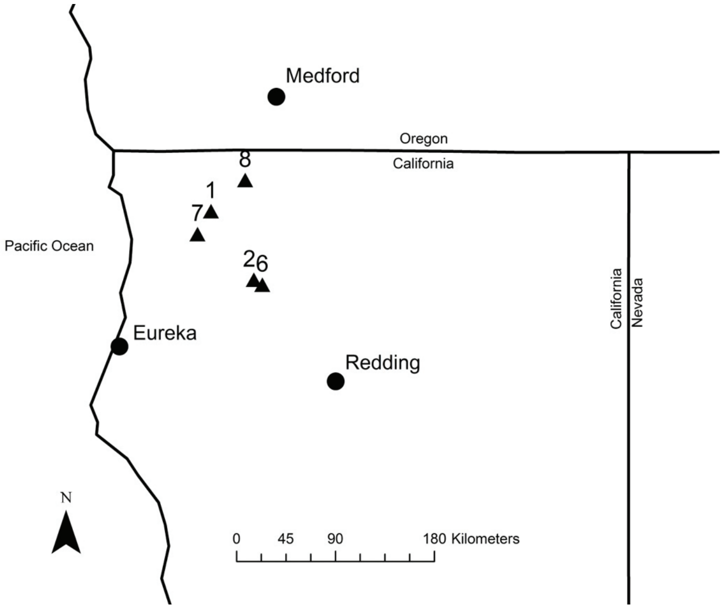

Figure 1.—Locations of sampled mineral lick sites.

Table 1.—Environmental descriptions of mineral lick sites.

Site	Elevation (m)	Mean annual precipitation (mm)	Exposure	Summer moisture	Vegetation	Soil classification
1	730	1650	Road cut	dry	Douglas fir, tan oak	Haploxerults
2	973	1143	Road cut	dry	Douglas fir, mixed conifer	Haploxeralfs
6	1459	1397	Road cut	dry	White fir, mixed conifer	Dystroxerepts
7	220	1651	Landslide	dry	Douglas fir, tan oak	Haploxerults
8	640	787	Landslide	wet	Douglas fir, ponderosa pine, black oak	Dystroxerepts, Humixerepts

concentrated hoof prints or marks of gnawing or licking. Replicate non-lick samples were taken at all sites, except Site 7. Lick sample replicates were obtained at Sites 2, 6, and 8.

Sampled lick sites occurred mostly in road cutbanks (Table 1, Figure 2). Roadcuts generally expose regolith materials that are located one to several meters below the soil surface, which would not normally be accessible to animals. In the Klamath Mountains, 4,000 miles of roads increase the occurrence of roadcut lick sites compared to natural surface-occurring lick sites. The lick at Site 1 is in a deep soil exposed in a roadcut. The licks at Sites 2 and 6 are in soft, weathered bedrock (known as saprock; Graham et al. 2010). Site 7 is in saprock exposed in a landslide scarp. Site 8 is at a wet seepage area associated with a small, stabilized landslide. Eight sites were investigated, but only five (Sites 1, 2, 6, 7, and 8) were used in this study because the others could not be found when revisited in 2016 for additional sampling.

Figure 2.—Doe and fawn using lick at Site 1.

Laboratory methods.—Materials from lick and non-lick sites were sampled, air-dried, gently crushed, and sieved to remove coarse fragments (>2 mm). Soil textural classes of the regolith materials were determined by tactile evaluation (Thien 1979). The pH of the materials was determined on a 1:1 ratio of regolith/distilled water. Saturation paste extracts, using distilled water, were obtained and electrical conductivity (EC), an indicator of overall salt content (Soil Survey Staff 1993), was immediately measured (Burt 2004).

No consistent chemical extraction method has been adopted for compositional analysis of mineral licks. Extractants include water, acid extracts of varying strengths, and other methods typically used in soil fertility assessments (e.g., Arthur and Alldredge 1979, Kennedy et al. 1995, Dormaar and Walker 1996, Ayotte et al. 2006). The wide variety of methods makes it difficult to compare values among studies reported in the literature. In this study, water-soluble components were extracted from the saturated pastes of regolith (soil or thoroughly crushed saprock) and distilled water. Elemental analysis (Ca, Na, K, Mg, Mn, Fe) of the solutions (acidified with 2% $HNO3$ after extraction) was performed using an ICP-OES. Chloride, nitrate, sulfate, and iodine were analyzed by ion chromatography. The chemical compositions reported are concentrations (mg L-1) in the regolith extract solutions, not as concentrations in the solid phase, so they can only be used for comparison of similarly analyzed samples.

Results

Use of licks.—All of the lick sites have evidence of heavy traffic by deer (and elk in the case of Sites 1 and 7); i.e., hoof prints and droppings. Beyond this, the soil or soft rock of the dry licks have tooth marks (Figure 3) and smooth surfaces (Figure 4) where the deer have gnawed and licked the earthen materials. This activity has produced concavities in roadcut escarpments ranging in size from no wider than a deer's tongue to holes large enough for the deer to enter (Figure 3). The wet lick at Site 8 is on more level ground rather than an escarpment, and the deer consume the mud near a seep (Figure 5). We were able to place a game camera at Site 1 for three days in early August 2016. The lick was visited for 19 minutes by a doe and two fawns on the first morning (Figure 2), a single doe for four minutes the second morning and a single doe for 10 minutes late that afternoon, and two does for six minutes the third morning.

Physical properties.—Most of the licks (Sites 2, 6, 7) were in saprock, one was in a deep subsoil (Site 1), one was in a surface soil (Site 8). The textural classes of the lick regoliths ranged from sand to silty clay (Table 2). Regolith textures for metavolcanic, argillite, and serpentinite lick sites were loam and finer, while quartz diorite and diorite lick samples had loam and sandy loam textures. One sample from the quartz diorite (6L-c) was finer textured (silt loam) because it was weathered from a xenolith, an inclusion of finer-grained, more mafic rock.

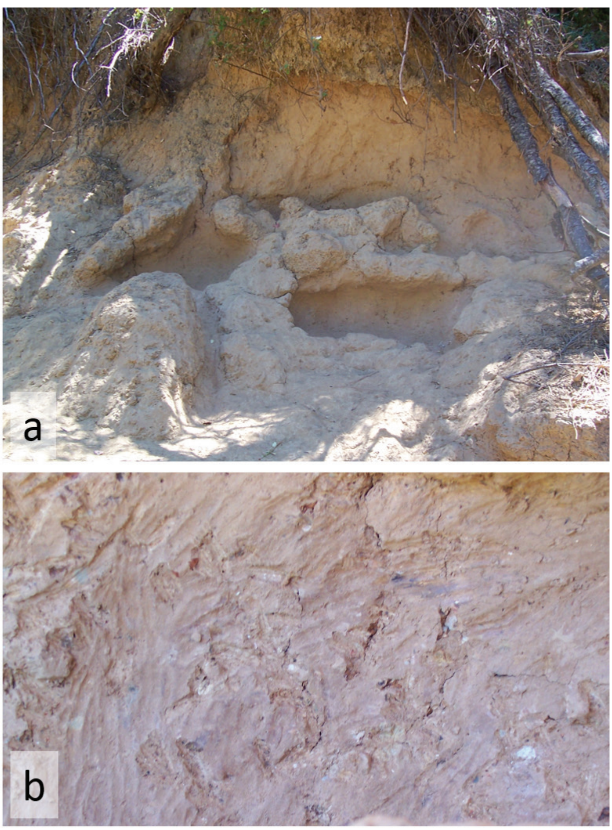

Figure 3.—Site 1 (a) roadcut with holes produced by deer and elk eating soil, (b) close up showing teeth marks in the soil. Horizontal field of view in (a) is 2.75 m.

Figure 4.—Site 2 (a) rock vein in road cut being used as a lick by deer, (b) close up showing rock surface smoothed by licking.

Figure 5.—Site 8, wet lick at a seep. Note the tile spade blade (40 cm long) at right for scale.

Table 2.—Rock type and physical properties of lick materials.

Site/sample ID[a]	Rock type at site	Sample regolith type, texture	Lick material dry color (Munsell notation)[b]	Depth below surface (m)
1L	Metavolcanic	Soil, silty clay loam	Brown (7.5YR5/4)	1.5 - 2.0
1NL	Metavolcanic	Soil, silty clay loam	Reddish yellow (7.5YR 6/6 - 7/6)	1.5
2L-a	Metavolcanic	Saprock, clay loam	Very pale brown (10YR8/2)	2.0
2L-b	Metavolcanic	Saprock, clay loam	Light gray (2.5Y7/1)	3.5
2NL	Metavolcanic	Fine material in rock fractures, loam - sandy clay loam	Pale - very pale brown (10YR 7/3)	3.5
6L-b	Quartz diorite with iron oxide stains	Saprock, fine sandy loam	Strong brown (7.5YR5/6)	4.0 - 6.0
6L-c	Xenolith	Saprock, silt loam	Light olive gray (5Y6/2)	4.0 - 6.0
6NL	Quartz diorite	Saprock, Sand	Light gray (10YR 7/2)	3.0 - 6.0
7L	Serpentinite/talc	Saprock, silty clay	Light greenish gray (5GY7/1)	2.0+
8L	Diorite	Soil, loam - sandy loam	Gray - pale brown (10YR5/1 - 6/3)	0-0.05
8NL	Diorite	Soil, loam - sandy loam	Grayish brown (10YR5/2)	0-0.05

[a]Samples from mineral licks are indicated with “L”, those from non-lick samples for comparison are indicated with “NL”.

[b]GretagMacbeth. 2000.

Chemical properties.—The pH of lick regolith material varied from 3.6 to 9.8 (Table 3). These samples were divided into three pH groups: acidic (<6.6), neutral (6.6-7.3), and alkaline (>7.4) (Soil Survey Staff 1993). Most of the lick samples were alkaline (Sites 1, 7, and 8), some were neutral (Site 6) or acid (Site 2).

The EC of lick materials varied from 0.2 to 16.7 dS m-1 (Table 3). For reference, seawater has an EC of 55 dS m-1 and soils are considered saline when the EC is ≥4 dS m-1 (Soil Survey Staff 1993). While only two sites had mean EC values that indicated them to be saline (samples from Sites 2-b and 8), lick samples had higher EC values than associated non-lick samples at every site except Site 6.

Sodium was the most abundant water-soluble cation in most of the lick samples, usually by an order of magnitude (Table 3), but it was undetectable in lick samples at Sites 2-b and 8. Despite its general abundance, sodium concentrations were not higher in lick samples than in associated non-lick samples, except at Site 1. Magnesium in lick samples ranged from abundant (Site 8) to undetectable (Site 2-b), and was not consistently more or less than in associated non-lick samples. Potassium was present in all lick samples, though more abundant than in non-lick samples at only one site (Site 2-b).

Concentrations of manganese and iron were less than 1 mg L-1, except at Site 2 (Mn in lick and non-lick samples and Fe in lick samples), and only at Site 2 were concentrations greater in lick than in non-lick samples (Table 3). Samples from Site 2 had the lowest pH values in this study and manganese and iron become more soluble under these more acidic conditions (Brady and Weil 2007).

Chloride was the most abundant water-soluble anion in lick samples at all sites except Site 2 (Table 3). Chloride concentrations were not consistently higher in lick samples compared to non-lick samples. At Site 2, sulfate was the most abundant anion in both lick and non-lick samples, but was not consistently higher in one or the other. Nitrate concentrations ranged widely (undetectable to 1285 mg L-1) with no consistent trend between lick and non-lick samples. Iodine concentrations were mostly less than 1 mg L-1 (the Site 1 lick sample had 1.4 mg L-1), but were higher in lick samples compared to non-lick.

Discussion

Clays have been hypothesized to promote digestion in ungulates by buffering the rumen pH, absorbing secondary plant compounds (e.g., tannins) that impede digestion, and ameliorating digestive ailments such as diarrhea (Ayotte et al., 2006). Ingested coarse soil material (sand) may also provide an abrasive action that is beneficial to digestion in ruminants (Cooley and Burroughs 1962). Regoliths at the lick sites we sampled span from sand- to clay-rich, and non-lick sites spanned the same range, so animal selection based solely on soil texture is not obvious.

Alkaline lick materials can help to buffer rumen pH from becoming too acidic (Ayotte et al. 2006), yet the wide range in pH of the lick sites suggests that deer are not consistently seeking material of a restricted pH range.

While no single water-soluble component is consistently higher in the lick samples than the non-lick samples, most of the licks do have at least one strongly differentiated property. At Site 1, the pH, sodium, and chloride are elevated; at Site 2-a, the lick is enriched in acidity, salinity, sulfate, manganese, and iron, while Site 2-b is enriched in calcium, potassium, manganese, and iron and is even more acidic and saline; Site 7 is highly alkaline; and at Site 8 the lick has especially elevated levels of calcium, magnesium, and chloride. All of the lick materials are more saline (higher EC) than the associated non-lick material, except at Site

Table 3.—Selected chemical analyses of saturated paste extracts from mineral licks and associated non-lick material.

Sample	pH	EC	Ca	Na	K	Mg	Cl	SO_4	NO_3	I	Mn	Fe
		dS m^{-1}	mg L^{-1}									
Site 1												
Lick	8.2	0.5	8	104	1	9	34	2	0.1	1.4	0.03	0.05
Nonlick n=3	5.4 5.1-5.5	≤0.08	35 27-41	32 19-55	10 7-12	21 14-33	5 4-6	7 6-9	ND[a]	0.02 ND-0.05	.04 0.02-0.07	0.03 0.03-0.04
Site 2												
Lick - a	4.6	1.3	100	306	14	202	162	2030	21	0.4	11.0	3.0
Lick - b n=3	3.7 3.6-3.7	12.7 9.7-16.7	458 409-517	ND	427 388-483	ND	18 5-25	450 90-698	ND	0.2 ND-0.6	65.3 57.1-71.2	6.7 2.5-11.9
Nonlick n=3	5.3 5.1-5.5	0.3 0.2-0.5	133 58-194	314 193-498	41 27-48	101 43-171	168 48-317	542 28-1254	13 5-30	0.01 ND-0.03	3.44 1.34-7.30	0.07 0.03-0.11
Site 6												
Lick n=2	6.7 6.6-6.7	0.3 0.2-0.3	6 5-7	28 23-33	1 1-1	2 2-2	17 14-20	2 1-2	7 6-7	0.4 0.3-0.5	0.03 0.02-0.03	0.2 0.1-0.2
Nonlick n=4	6.6 5.7-7.1	0.1 0.1-0.3	22 5-35	96 29-156	3 1-5	6 1-9	30 4-68	55 5-132	ND	0.02 ND-0.06	0.11 0.01-0.4	0.07 0.02-0.22
Site 7												
Lick	9.8	1.1	10	409	10	4	201	76	36	0.5	0.03	0.02
Site 8												
Lick n=3	8.1 8.0-8.1	8.2 5.1-13.7	1924 695-4196	ND	128 93-158	1071 506-2059	897 103-1946	15 7-21	≤8	0.4 ND-0.9	0.10 0.06-0.17	0.68 0.36-1.28
Nonlick n=3	6.00 5.6-6.6	0.7 0.3-1.4	447 255-579	54 36-66	810 240-1929	312 119-527	196 25-525	102 22-244	1285 2-3835	ND	0.06 <0.01-0.16	1.00 0.49-2.02

[a]ND = none detected

6, and this salinity may be what attracts the deer and elk to the sites. The potential mineral nutrient benefit must vary from site to site depending on the unique compositions of the licks.

The lick samples from Site 6 are the least extreme in all respects in that they have neutral pH, relatively low EC, and generally low concentrations of cations and anions compared to the other lick samples. Furthermore, the composition of the lick samples at Site 6 is not much different from the non-lick samples, so it is not clear why the deer are ingesting mineral matter at the site. The only element that is appreciably higher than in the non-lick samples is iodine, so perhaps the deer can detect this difference.

Of the 10 elements reported here, iodine is the one that is most often higher in lick samples compared to non-lick materials. Iodine is an essential nutrient for animals (Whitehead, 1984), as it is required for the synthesis of growth-regulating thyroid hormones. The main source of iodine in soils is atmospheric deposition of sea-water-derived iodine, but certain types of rocks and soils derived from them can be enriched in iodine (Whitehead, 1984). Ingested soil was found to be a major source of iodine for lambs in a New Zealand study (Healy et al., 1972).

In summary, no single and consistent regolith attribute was overwhelmingly enhanced at the lick sites, but each site had at least one chemical condition that was different from the non-lick comparison samples. The individual licks may provide different nutrient supplements.

Lick classification.—Classifying mineral lick sites aids in communicating site characteristics useful to wildlife biologists and land managers. Dormaar and Walker (1996) used physical site characteristics to classify lick sites in southern Alberta, Canada. They classified sites as dry earth licks, muck licks, and rock face licks. We incorporated elements of their system by specifying regolith type (soil or saprock) and whether it is dry or wet during the summer dry season (wet is reflective of groundwater seepage at the surface). We also felt it was important to indicate the type of exposure, since licks on roadcuts have different management concerns than naturally exposed lick sites. Reaction class (pH) and alkalinity (EC) are relatively simple to measure, but reflect concentrations of ions and do not necessarily relate to which nutrient ions are present. The chemical enhancement class, indicating the increase in ion concentrations above background (non-lick) levels, provides a better descriptor of potential nutrient value to animals, but requires extensive laboratory analyses. The six factors listed in Table 4 (exposure, regolith, dry/wet, reaction class, salinity, and chemical enhancement) provide useful information to understand lick sites in the Klamath Mountains.

Table 4.—Classification of mineral lick samples from the Klamath Mountains. Chemical components (cations and anions) present at levels elevated above those of non-lick samples are listed with enhancement factor in parentheses; e.g., I(28x) indicates average iodine levels from lick sample are increased by 28 times relative to highest value of nearby non-lick samples.

Site	Exposure	Regolith	Dry/ wet	Reaction class	Salinity	Chemical enhancement above non-lick levels
1	Roadcut	Soil	Dry	Alkaline	Nonsaline	I(28x), Cl(6x), Na(2x)
2	Roadcut	Saprock	Dry	Acid	Nonsaline	Fe(27x), I(13x), Mn(2x), SO_4(2x)
2	Roadcut	Saprock	Dry	Acid	Saline	Fe(61x), Mn(9x), K(9x), I(7x), Ca(2x)
6	Roadcut	Saprock	Dry	Neutral	Nonsaline	I(7x)
7	Natural	Saprock	Dry	Alkaline	Nonsaline	ND
8	Natural	Soil	Wet	Alkaline	Saline	I(>40x), Ca(3x), Mg(2x), Cl(2x)

Acknowledgments

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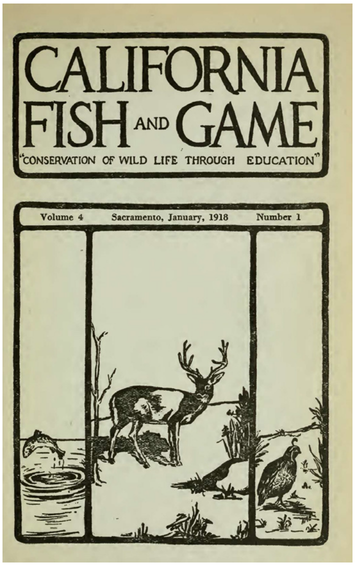
From the Archives

Harold C. Bryant was born in Pasadena, California, on January 30, 1886. He received an undergraduate degree (BS) from Pomona College, majoring in zoology/ornithology, and a MS and PhD in zoology from the University of California, Berkeley. From 1914 to 1930, he served with the California Fish and Game Commission, was a lecturer and field trip leader for UC Extension, and was a summer season ranger-naturalist at Yosemite National Park. This article was originally published in the California Fish and Game Journal in January of 1918.

Deer Licks of the Trinity National Forest Game Refuge

By Harold C. Bryant



Heretofore, we have had to base our judgement as to the value of a game refuge largely upon the results obtained in The Transvaal in South Africa, and in other states. Convincing evidence of results to be expected from game refuges in California is now available, in that the first of the large state game refuges placed in a national forest has been in existence long enough to demonstrate possibilities.

Trinity Game Refuge was established by legislative enactment in 1911. Comprising 65,000 acres of brush and timberland, with abundant water and feed, and salt licks convenient, the region affords ideal conditions. A visit to this refuge at the present time will attest the worthwhileness of a sanctuary for deer and other game.

Although in Trinity County where violations of the fish and game laws are frequent, the residents respect the game refuge. The people of the county wanted the refuge in the first place, and although it set aside much of the best deer country, everyone concerned is willing to be inconvenienced and to hunt elsewhere. Originally reporting the largest deer kill of any county, a noticeable decrease for several years brought a realization that something needed to be done to save the situation. The result was a demand for a game refuge. The interest taken by the United States Forest Service has had much to do with the attitude of the residents and the enforcement of the game laws.

Within the refuge are many famous deer licks, where in former years deer were killed by the thousands. Residents estimate that there were 10,000 deer killed at the licks near the north fork of Trinity River, up to the time of the creation of the refuge.

The writer visited the Trinity refuge during the latter part of May, 1917. Trips were made to the licks along the Trinity River near Helena, and also to the numerous licks along the Hayfork River, about ten miles from the town of Hayfork. At both of these places there was plenty of evidence that deer were very numerous and very tame.

On May 23, Deputy G. L. Laws and I went early to the large lick about two miles down Trinity River from the town of Helena. We seated ourselves about thirty-five yards away, but in plain sight of the approach and the hillside in the background. After waiting for some time we were rewarded, not only by seeing ten deer within good range along the hillside, but also had the pleasure of having two does come to the lick and spend several minutes there. We attempted to photograph them, but the early morning light was not sufficient to make the pictures successful. It was only after we had stood up to take the third photograph that the deer became sufficiently frightened to leave the lick. Even then they did not run, but simply walked back up the hill. The sand next to the river showed that large numbers of deer had been at the lick during the night. All of the deer seen at close range were does; tracks also indicated a large percentage of does. When about to leave, four deer came over the hill and started toward the lick, but they "winded" us before they had gone half way down the hill, and turned back.

A trip, in company with Mr. Shock, to the numerous licks along Hayfork River, about ten miles from the town of Hayfork, gave even better results. One large lick inspected (Sulphur Spring) had been used during the night, and it was evident that a number of deer had been frightened away upon "winding" us. Even so early in the year trails were cut three and four inches deep. The tracks here indicated a large percentage of bucks.

Farther down the river, we seated ourselves on the bank of the river opposite what local residents have often termed the "Big Lick." We had been there less than five minutes when two deer appeared and spent some time at the lick. A screen of tree branches prevented photographs being taken. After these deer had left we moved our location, taking up a station directly across from the lick. We were in plain sight and but thirty-two yards away. During a wait of a little over two hours we were rewarded by seeing a dozen deer come to the lick. Several of the animals saw us, and at each click of the camera the head was raised and the ears pointed forward, and yet there was no sign of fright. The climax came when at 10:15 in the morning two bucks and two does came to the lick, and spent five or ten minutes there.

The antlers of the bucks at this time of the year were from four to six inches in length, the knob at the end just beginning to indicate a branching. Bucks were most in evidence at this lick, only three or four does being seen.

Probably nowhere in the state is it possible to find so many deer, or find them so tame, as in this Trinity refuge. Evidently the refuge forms a great game farm where the animals increase in numbers and then spread out to surrounding localities, furnishing food and sport for all those who wish.

Natural conditions are of the best. Artificial means may, however, improve the annual crop. Deer in this breeding area, although safe from attack by man, are still subject to attack by many predatory animals. Some work is being done by the United States Department of Agriculture to reduce the number of coyotes and mountain lions, but still more work along this line needs to be done. Refuges of this kind, even though they have proved their worth, should be more than refuges on paper. They need to be well guarded and at the same time made more effective by the destruction of predatory animals. Attention needs to be paid also to every means of making the deer more prolific.

It may be that salt bricks placed in certain parts of the refuge would aid in keeping the animals in good health. This area, at several different times, has been ravaged by a disease which killed off great numbers of deer. Investigations as to the cause and the cure of this disease would also be of value in increasing the effectiveness of the area. During certain years winter feeding might prove worth while.

The creation of the Trinity Game Refuge has assured a permanent supply of big game to Trinity County and is demonstrating to the whole state the benefits which accrue as a direct result of proper game protection.

Information for Contributors

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Front—.Salt marsh harvest mouse (*Reithrodontomys raviventris*) in pickleweed (*Salicornia* spp.), captured during an annual survey on Grizzly Island Wildlife Area's Crescent Unit, Suisun, California. This tiny mouse is the only mammal endemic to salt marshes. Photo by Katherine Smith.

Rear—.Mountain Lion *(Puma concolor)* population densities vary greatly throughout California's diverse habitat types. Photo by Gerald and Buff Corsi.

Photo by Gerald and Buff Corsi © California Academy of Sciences.

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