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Photo by L. Hayes

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Notes from the Editor

The California red-legged frog and the coho salmon, both listed species, are two species that have been studied and reported on extensively in the scientific literature. Yet, amazingly, there are still new things being discovered about them. In this issue of *California Fish and Game* we are publishing two species notes describing methodological discoveries that will improve our ability to locate, in the case of red-legged frog egg masses; and track, in the case of juvenile coho salmon; which will give biologists a better chance to manage their recovery. These improvements can be reported and the benefits to the species may be realized because the authors went through a process to design a study, collect data, analyze that data, and then draw conclusions on what it all meant. Finally, they did the most important thing in science (my opinion); they wrote it up for publication in a scientific peer-reviewed journal. Too many times this process ends with a final report or an oral presentation without making its way to publication. There is absolutely nothing wrong with a final report or an oral presentation; they are both encouraged in the Department's new policy on integrity in science. But also, the policy commits the Department to support quality science and provides standards for scientific conduct and key elements for scientific work including scientific publications. By completing this process, we give others a chance to learn and build on our finding, which adds integrity to our work as scientists.

On the cover is a Nelson's bighorn sheep. This is to honor and celebrate the life of Dick Weaver, a longtime sheep biologist with the Department. I met Dick only twice as a young wildlife biologist. Dick retired during my third year with the Department. But I remember those times clearly. One was at a statewide wildlife managers meeting we had in Oakhurst. I was so impressed and in awe of the knowledge, dedication and professionalism on display by the old guys, including Dick. Dick gave a presentation on sheep and the guzzlers. So eloquent. Little did I know at the time that I would see one of those guzzlers 25 years later. All the old guys—my mentors Bruce Elliott, Don Pine, Jim Lidberg, and all the others—made lasting contributions to wildlife in this state and they should all be thanked.

We featured bighorn sheep with our archive paper, and to contrast that, we have a new paper on sheep by the most recent past Editor-in Chief of *California Fish and Game,* Vern Bleich. It's nice to know some people retire but they don't stop working.

Armand Gonzales
Editor-in-Chief

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"Mr. Bighorn"
Richard A. Weaver (1926–2017)

Dick Weaver's friends and family joined him to celebrate his 90th birthday in January 2016, when this photo was taken. Here, Weaver demonstrates his ability as an accomplished raconteur while Steve Hill, a long-time friend and colleague, listens intently.

Richard A. Weaver, known throughout the West as "Mr. Bighorn," passed away on February 10, 2017, at the age of 91. With his passing, bighorn sheep and the deserts they inhabit lost one of the best friends they ever had. Dick began his career in 1948 with—what at the time was—the California Division of Fish and Game and, over the following 69 years, he retained a presence in the organization that shortly thereafter became the California Department of Fish and Game (CDFG). In his first position, he was assigned to build watering devices for upland game birds—commonly referred to as quail guzzlers—near Amboy, San Bernardino County. During that assignment, he recorded in his notes a midnight temperature of 112°F and, perhaps, his love affair with the desert then was born.

Early in his career, Weaver also worked in Riverside County, where he was involved in the production and distribution of pheasants for sport harvest. In 1951, he was assigned to Federal Aid in Wildlife Restoration Project W-26-D, where he again concentrated on the construction of wildlife watering devices for game birds and other wildlife. While assigned to that project, he ensured the availability of surface water for use by wildlife at springs throughout southern California. During his years with Project W-26-D, he developed a tremendous knowledge of California's deserts and their associated fauna. Among the species that most intrigued him was the desert bighorn sheep (*Ovis canadensis*). Weaver eventually was promoted to a supervisory position and became the manager of the Imperial Wildlife Area in Imperial County, where he remained for 8 years.

In 1968, the California Senate passed Resolution 43, which provided funds for CDFG to conduct a statewide inventory of bighorn sheep. Weaver, who was still at the Imperial Wildlife Area, applied for the opportunity to lead the investigation, all the while realizing there were two potential benefits, and one potential detriment associated with that assignment. He would be able to leave the Imperial Wildlife Area (a positive), he would be able to put his vast knowledge of California's deserts and the natural history of bighorn sheep to constructive use (a positive), but it would entail a demotion from his supervisory role at IWA (a negative). Despite the cut in salary, Weaver always maintained that transferring to the bighorn sheep project was the best decision of his career.

From 1968 to 1972 Weaver investigated the status of bighorn sheep throughout California. During this period, he and the co-investigators who worked with him produced the first-ever comprehensive evaluation of bighorn sheep populations and their habitat in California. Their efforts resulted in publication of 14 detailed reports, with each one addressing the distribution, habitat conditions, disease issues, illegal take, recommendations for habitat acquisition, availability of water sources, and habitat enhancement needs in each of the geographic regions investigated. Much additional information has become available since those reports were published, but they remain as useful today as they were then, and are referenced on a regular basis in the professional literature.

Dick recognized water as one of many important habitat components for bighorn sheep, and he initiated the first projects to improve its distribution and availability with the goal of enhancing habitat for bighorn sheep. He realized that his agency couldn't do it alone, and he understood the value of using volunteers. In 1970, Weaver collaborated with the Society for the Conservation of Bighorn Sheep (SCBS)—the organization that played the primary role in passage of Senate Resolution 43— to create the Volunteer Desert Water and Wildlife Survey. That summer, he organized more than 200 Society volunteers to visit and report on habitat conditions and use by bighorn sheep at the numerous water sources that Weaver had personally selected. Born from that initial effort were the Society's Area Captain Program and the periodic 4th of July waterhole counts, both of which remain active today.

Such was the beginning of a long-term relationship between SCBS and CDFG; with Department personnel providing leadership, SCBS began implementing the habitat enhancements that Weaver had recommended. There was also enthusiastic support and cooperation from the Bureau of Land Management. The first wildlife water development designed to serve the summer needs of desert bighorn sheep was constructed in the Cady Mountains of San Bernardino County, where it continues to serve the needs of bighorn sheep and other desert wildlife. Subsequently, Weaver's recommendations resulted in the construction of dozens of similar water developments in the desert mountains of southeastern California.

In 1984 Dick and SCBS patriarch Marvin Wood jointly proposed a campaign they termed "10,000 by 2000." Ten thousand bighorn sheep in California by the year 2000 was far more than an unrealistic goal; it was, instead, a talking point intended to reinvigorate supporters and keep the ball moving to benefit bighorn sheep. And it worked! The slogan raised awareness, money, volunteer participation and, ultimately, bighorn numbers. In 1986 Weaver addressed the California Legislature in an effort to reclassify selected populations of desert bighorn sheep as game animals, and he co-authored the legislation that resulted in the first bighorn sheep hunting season in 114 years. That action yielded benefits in terms of enhanced funding, additional management opportunities, and new-found support for habitat protection and enhancement, population restoration, and overall interest in the status of bighorn sheep in the Golden State. During the initial hunting season, Weaver emphasized the benefits associated with the harvest of the oldest, but not necessarily the largest, bighorn sheep. The result was creation of the Patriarch Award in 1987 (the first year of the hunt) and it has been presented on an annual basis by SCBS to the hunter taking the oldest ram.

Following completion of the bighorn sheep survey work, Weaver transferred to Sacramento and became the statewide project leader for bighorn sheep, mountain lion, and black bear management programs. Dick was also the CDFG expert on the distribution and numbers of feral donkeys in California, and the threats they presented to bighorn sheep and other desert wildlife. Weaver remained in his position as statewide coordinator until his retirement in 1989. Many don't know it, but Dick radio-collared the first mountain lion in California, and was also the first to use a dart-gun fired from a helicopter to capture a bighorn sheep. He shared leadership responsibilities for numerous capture events and translocations, and participated regularly in aerial surveys, even following his retirement. Weaver was one of two survivors of a helicopter crash in 1986 that resulted in the tragic deaths of pilot Don Landells and fellow wildlife biologist Jim Bicket.

An additional, and very important, aspect of Weaver's life involved the Desert Bighorn Council (DBC), a professional organization of biologists, naturalists, educators, and advocates, all with the goal of enhancing conservation and sharing knowledge of desert bighorn sheep. He was a charter member of that organization and, with one exception, attended every meeting since its founding in 1957. Why did he miss the one meeting? Weaver's boss at the time prohibited him from attending because bighorn sheep were not a priority for CDFG.

Weaver's career and leadership ultimately changed that and, even in retirement, he continued to support the Council. Over the years, Weaver attended more meetings of the DBC than any other individual. He served many years as Chair, or as a member, of the Council's Technical Staff, he was the long-term chair of the DBC Awards Committee, and he presented the status reports from California over a period of several decades. In 1986, Dick was recognized by the Council with the Desert Ram Award for his professional contributions to the conservation of bighorn sheep and his 30 years of service to the Council. The last meeting that Dick attended was held in Borrego Springs, California, in 2015; he was remembered fondly during several moving tributes presented at the 2017 Council meeting in St. George, Utah.

In preparing this tribute, we thought deeply about what it means to be a mentor, because that's what Dick was. Eventually, we came to understand that the best mentors don't realize they fulfill that role! Humility, kindness, and a welcoming nature—all of which are characteristics that greatly influence and inspire others—were the foundations of Weaver's personality. At professional meetings and in personal conversations he always said, "Do what's best for bighorn sheep." These words sometimes were uttered during challenging times or periods of passionate disagreement, but they always seemed to simplify decisions.

Dick's personality traits—his love and passion for bighorn sheep and their surroundings, his watching and being very aware of what was going on around him, his ability to listen to others without interrupting, his constant desire to learn, his sharing of knowledge and mentoring others, and his recognition of others for their accomplishments—made him the special person he was. He was also a great story teller—a true raconteur—and he loved that role.

Weaver's knowledge—in terms of ecology, geography, and history—of the deserts of California was unparalleled. He was very likeable and he got along with everybody—a trait that helped him spread the word about desert bighorn sheep and the importance of the habitats upon which they depend. And his knowledge, gained from years of wearing out boot leather in the mountains and canyons of California, served him well when dealing with bureaucrats, whether in other agencies or in his own Department. Weaver seldom raised his voice, and he was slow to anger. One exception involved the poaching of numerous bighorn sheep by an individual whom Dick had befriended, trusted, and believed in; Dick was truly hurt by what transpired, and he never got over that betrayal.

Throughout his career, Dick inspired numerous young professionals and multitudes of equally passionate volunteers; many of those individuals became mentors to others. Thus, second and third generations—and beyond—are part of Weaver's legacy, and they will continue an advocacy for conservation. He had a "Yogi Berra" quality, and many of his quotes are still heard today. In their simplicity, though, there was also wisdom. We all know how he often said, "Do what's best for bighorn sheep."

Dick Weaver was a pioneer, an innovator, and a leader. He was an advocate for the desert as a special place: it was not a wasteland to be neglected. The late George Welsh, a long-term colleague of Weaver's, noted that, "Every good wildlife biologist should leave a number of footprints on the path of wildlife management." We submit that Weaver did not leave a few footprints—instead he established the path of wildlife management for desert bighorn sheep in the American southwest, a path that others will be following for many decades to come.

— *Friends and Colleagues of Richard A. Weaver*

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Mineral content of forage plants of mountain sheep, Mojave Desert, USA

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The importance of trace minerals to living organisms is well established, albeit poorly studied in large, free-ranging mammals. We investigated concentrations of 11 minerals among 9 species of forage plants used by bighorn sheep (*Ovis canadensis*) in the Panamint Range, Inyo County, and at Old Dad Peak, San Bernardino County, California, USA. We sampled vegetation monthly, and used established protocols and analytical techniques to determine the concentrations of Ca, Cu, Fe, Mg, Mn, P, K, Na, S, Zn, and Se. Our analyses indicated that differences in concentrations of trace minerals and macro-minerals existed in forage plants between those mountain ranges, and likely portend similar differences among other geographic areas. Our results emphasize the potential importance of testing for levels of minerals in forage plants by specific geographic area rather than relying on published information from other areas when those elements are thought to play meaningful roles in population performance of bighorn sheep or other ruminants.

Key words: bighorn sheep, chemical composition, macro-minerals, micronutrients, Mojave Desert, nutrients, *Ovis canadensis*, ruminant nutrition, soil chemistry, trace minerals

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Forage quality is important in the dynamics of ungulate populations and, as such, is of interest to managers (Mahon 1969, Wallmo et al. 1977, Hobbs and Swift 1985, Robbins 1992). Nevertheless, minerals as a necessary component of ruminant diets

(Davis 1968) are poorly understood (Robbins et al. 1985, Grasman and Hellgren 1993, Krausman et al. 1999, Barboza et al. 2009). Nutritional value and chemical composition of forage plants are influenced by many factors, yet few investigators have studied availability of trace minerals in forage plants used by bighorn sheep (*Ovis canadensis*). Although some authors (Seegmiller et al. 1990, Bleich et al. 1992) have investigated selected nutritional characteristics of forage plants, few have presented information on mineral concentrations (Morgart et al. 1986, McKinney et al. 2002, McKinney et al. 2006).

Several variables influence forage abundance, forage quality, or mineral concentrations in forage plants (Krausman et al. 1989). Among those are climate (Noy-Meier 1973, Beatley 1974, Marshal et al. 2005) and substrate chemistry (Carlisle and Cleveland 1958, Hunt 1966, Lisk 1972, Banuelos and Ajwa 1999). Further, rainfall patterns can influence the concentrations of minerals in vegetation (Greene et al. 1987, Sprinkle et al. 2000) resulting in seasonal variation in blood because of variation in mineral intake (Poppenga et al. 2012). Moreover, differences in habitat selection between male and female ruminants as a result of sexual segregation (Bowyer 2004) can result in the consumption of forages of differing quality by the sexes—even within plant species (Bleich et al. 1992). Sexual segregation has been particularly well-studied in desert bighorn sheep (Bleich et al. 1992, Bleich et al. 1997, Mooring et al. 2003, Bleich et al. 2016), and has important implications for the conservation of those specialized ungulates (Rubin and Bleich 2005). In all probability, each of those factors, when combined with the expense associated with mineral analyses, contributed to the conclusion of Duffy et al. (2009) that knowledge of biogeochemistry, food webs, and metals as stressors in bighorn sheep occupying arid environments is limited.

Minerals play a crucial role in overall animal health through disease resistance (Failla 2003), antler growth or strength (French et al. 1956, Bowyer 1983, Johnson et al. 2007), recruitment (O'Hara et al. 2001), and vital rates (Flueck 1994). As a result, availability of trace minerals is an important nutritional consideration (Fox et al. 2000, McKinney and Noon 2002, McKinney et al. 2006). Although many investigators emphasized protein, digestibility, and moisture content as primary indicators of forage quality, some (Morgart et al. 1986, McKinney and Noon 2002) have described mineral content of forages consumed by bighorn sheep. Others (Holl and Bleich 1987) analyzed mineral licks and inferred seasonal requirements of trace minerals from those data, or researched roles of the need for trace elements in declines in populations of bighorn sheep (Watts and Schemnitz 1985, McKinney et al. 2006). Nevertheless, there remains a paucity of information on the availability of micronutrients in forages of bighorn sheep, and information on geographic variation in mineral content of various forage species remains poorly researched.

In this paper, we quantify and compare availability of 5 trace minerals and 6 macrominerals in nine species of forage plants consumed by bighorn sheep in two Mojave Desert mountain ranges in which the ecology of bighorn sheep has been investigated in detail. Our purpose was to provide information on trace mineral availabilities in forage plants common to both locations and to test for overall differences in the concentrations of those minerals in forage plants between locations. We hypothesized that overall differences in the mean concentrations of minerals would not differ because both study areas were located in the Mojave Desert and supported healthy populations of bighorn sheep.

Materials and Methods

Study areas.—We conducted research in the Panamint Range (36° 00′ N, 117° 10′ W), Inyo County, California and at Old Dad Peak (35° 05′ N, 115° 45′ W), San Bernardino County, California, USA (Bleich et al. 1992, Oehler 1999). The Panamint Range and Old Dad Peak are situated in the northwestern part of the Mojave Desert. Bighorn sheep at both locations have been investigated intensively, and detailed descriptions of geology, topography, vegetation, fauna, and anthropogenic influences in each study area were provided by Bleich (1993), Bleich et al. (1992, 1997, 2016), Oehler et al. (2003, 2005), and Duffy et al. (2009).

Mean annual rainfall at Panamint Range was 51 mm, and occurred in a unimodal pattern with 50% occurring from January to March. Temperatures ranged from 40°C during summer to -7°C during spring (Oehler et al. 2003). Mean annual rainfall near Old Dad Peak was bi-modal, and average annual precipitation was 101 mm; approximately one-half occurred as localized summer thundershowers, and the other half fell during November–March (Bleich et al. 1997). During summer, temperatures >38°C occur frequently at Old Dad Peak, and winter temperatures below freezing are not uncommon (Weaver et al. 1969).

Bighorn sheep are specialized ruminants that are strongly dependent on shrubs and grasses for forage at both locations (Bleich et al. 1992, Bleich et al. 1997, Oehler et al. 2005). Shrubs used in common by mountain sheep at Panamint Range and Old Dad Peak included *Ambrosia dumosa, Atriplex hymenelytra, Encelia farinosa, Ephedra nevadensis, Eriogonum fasciculatum, Galium stellatum, Prosopis glandulosa,* and *Sphaeralcea ambigua*, among others. Bighorn sheep at both locations also made heavy use of a perennial grass, *Stipa speciosa*, but grasses were less common in diets at the Panamint Range than at Old Dad Peak (Oehler et al. 2005, Bleich et al. 1997).

Collection and preparation of forage samples.—As a result of sexual segregation, diet quality differs between male and female bighorn sheep (Bleich et al. 1997), and some forages differ in quality between ranges used primarily by males when compared with ranges used primarily by females (Bleich et al. 1992). To minimize the potential for sexual segregation to influence availability of trace minerals in forage plants within each area, we collected forage plants from ranges inhabited primarily by females at Old Dad Peak (Bleich et al. 1992) and the Panamint Range (Oehler et al. 2005). We collected green leaves, grass seed heads, flowers, or otherwise new growth from each plant (Bleich et al. 1992) to minimize the potential influence of dead vegetation on mineral concentrations (Greene et al. 1987). We obtained samples (~100 g/sample) from five plants of each species from each area at mid-month throughout the year. Suitable samples (i.e., leaves or new growth) of *P. glandulosa*, however, were not available every month at Old Dad peak. As samples were collected, we placed them in paper bags and weighed them to the nearest 0.1 g; we then dried them in a convection oven at 50°C until a constant weight was reached (Bleich et al. 1992).

We used a Wiley mill to grind individual samples to <1-mm particle size, took equal volumetric measures from each monthly sample, and created a composite monthly sample for each forage species from each range (Bleich et al. 1992, Oehler et al. 2005). We mixed each composited monthly sample thoroughly, and then combined equal volumetric portions of each composited sample into six categories (Jan–Feb, Mar–Apr, May–Jun, Jul–Aug, Sep–Oct, Nov–Dec) for each plant, resulting in 54 and 51 composited samples of forage species from the Panamint Range and Old Dad Peak, respectively, because only three bimonthly composites of *P. glandulosa* were available from Old Dad Peak. Selenium (Se) for each of the nine forage species collected from each range was analyzed for three composited bimonthly samples.

Analytical methods.—Composited samples were analyzed for Calcium (Ca), Copper (Cu), Iron (Fe), Magnesium (Mg), Manganese (Mn), Phosphorus (P), Potassium (K), Sodium (Na), Sulfur (S), and Zinc (Zn) with inductively coupled plasma emission spectroscopy at Cumberland Valley Analytical Services (Maugansville, MD, USA 21767). Selenium was determined with capillary gas chromatography with electron capture detection (University of Arizona Veterinary Diagnostic Laboratory, Tucson, AZ, USA 85721). Concentrations of Fe, Zn, Mn, Cu, and Se are expressed as ppm; concentrations of all other elements are expressed as percent (%) dry weight.

The taxon was the sampling unit for most of our tests, and we predicted that there would be no overall difference in concentrations of 10 trace minerals between Panamint Range and Old Dad Peak among the nine plant species. For descriptive purposes, we calculated annual mean values of trace minerals for each species from the Panamint Range and Old Dad Peak (Table 1). With the exception of *P. glandulosa*, we used Wilcoxon Matched-pairs Signed-ranks tests (Zar 1984) to compare concentrations of Ca, Cu, Fe, Mg, Mn, P, K, Na, S, and Zn between areas for each of the forage species considered (Table 1).

We were interested in whether overall differences existed in mineral availabilities between Panamint Range and Old Dad Peak; hence, we used analytical results (Table 1) and a 2-tailed sign test to determine if mean annual values in one area differed from expectation when compared with mean annual values for the other area. Additionally, we used a Z-test for proportions (Zar 1984) to test for a difference in proportion of the number of pairs of plants in which mean annual values in one area differed significantly from those in the other area.

For Se, the 11th trace mineral we examined, we first used the 2×3 extension of Fisher's Exact Test (Freeman and Halton 1951) to test for an overall difference in the proportion of taxa in which Se levels at Panamint Range exceeded those at Old Dad Peak. Upon finding no difference, we compared all paired results for Se simultaneously with a sign test (Zar 1984).

Our analyses were confounded by the absence of new growth or leaves on *P. glandulosa* for part of the year at Old Dad Peak, and fiscal constraints that limited analyses of Se to three, rather than six, paired comparisons during the year. Each of the tests performed was, nevertheless, directed toward the null hypothesis of no overall difference in the concentrations of micro-nutrients among the forage species used in common by bighorn sheep at Panamint Range and Old Dad Peak. Thus, we used results of the combined probability test (Fisher 1925, Sokal and Rohlf 1981), where $X^2 = -2\Sigma\ln(P)$ with $2k$ degrees of freedom, and k = the number of individual tests as an index to the congruence among outcomes of tests of the null hypotheses. We recognize that not all tests in this meta-analysis were independent and, accordingly, we reduced alpha for this analysis to 0.02 (Bowyer et al., 2007). Meta-analyses of this type have been increasingly recognized as a valuable tool when probabilities are focused on single hypotheses (Arnqvist and Wooster 1995, Osenberg et al. 1999).

Results

Mean annual value of trace nutrients in Panamint Range were greater than those at Old Dad Peak in 64 of 80 total comparisons, mean annual values at Old Dad Peak exceeded those at Panamint Range in 15 of 80 comparisons, and mean annual values were the same in only 1 of 80 pairwise comparisons ($P < 0.0001$; Table 1). Further, a chi-squared test in-

TABLE 1.—Concentrations ($\bar{x}$ and SD) of 10 trace elements in nine species of bighorn sheep forage plants from the Panamint Range (PR), Inyo County and Old Dad Peak (ODP), San Bernardino County, California, USA. Mean values for trace elements in each species that differed on an annual basis are denoted by paired matching superscripts (see footnotes 4 and 5).

		Calcium[2]		Phosphorus[2]		Magnesium[2]		Potassium[2]		Sodium[2]		Sulfur[2]		Iron[3]		Manganese[3]		Zinc		Copper	
Taxon[1]		PR	ODP	PR	ODP	PR	ODP	PR	ODP	PR	ODP	PR	ODP	PR	ODP	PR	ODP	PR	ODP	PR	ODP
Ambrosia	$\bar{x}$	3.104	2.22[4]	0.11	0.15	0.47[4]	0.34[4]	2.42	2.13	0.18[4]	0.09[4]	0.33	0.30	332.47	405.52	127.81[4]	47.28[4]	56.76[4]	18.92[4]	11.57[4]	6.11[4]
	SD	0.63	0.11	0.03	0.02	0.04	0.06	0.21	0.38	0.04	0.03	0.02	0.04	145.71	135.70	42.02	9.52	12.08	2.99	1.87	0.88
Atriplex	$\bar{x}$	2.81	2.23	0.06[4]	0.09[4]	0.89[5]	0.48[5]	3.40[4]	2.30[4]	7.55	7.88	0.42	0.39	440.34	238.86	278.54	90.44	33.74[5]	19.86[5]	13.69[5]	4.16[5]
	SD	0.84	0.42	0.01	0.04	0.17	0.43	0.43	0.38	1.12	0.85	0.04	0.07	461.04	116.49	124.09	24.33	17.16	4.68	4.89	0.93
Encelia	$\bar{x}$	3.21	2.96	0.21[4]	0.14[4]	0.46[5]	0.30[5]	3.31[4]	1.98[4]	0.12[4]	0.06[4]	0.51	0.35	326.11	307.48	71.75	55.47	46.81[5]	18.57[5]	19.66[5]	9.12[5]
	SD	0.91	0.57	0.06	0.01	0.05	0.04	0.80	0.45	0.04	0.03	0.13	0.10	329.99	143.87	44.25	5.02	5.64	1.82	5.19	3.19
Ephedra	$\bar{x}$	1.65[5]	2.46[5]	0.09	0.08	0.19	0.21	0.67	0.74	0.04	0.03	0.24	0.23	121.51[5]	86.27[5]	41.38	52.14	13.37	14.02	3.68	4.17
	SD	0.49	0.19	0.01	0.01	0.04	0.02	0.16	0.13	0.01	0.01	0.01	0.05	20.73	15.20	15.12	15.89	1.27	3.97	0.78	1.89
Eriogonum	$\bar{x}$	1.65	1.57	0.07	0.07	0.27[4]	0.20[4]	0.98	0.79	0.07[5]	0.02[5]	0.22[5]	0.09[5]	325.83	313.57	53.61[4]	36.97[4]	16.58[5]	10.24[5]	5.94[5]	2.10[5]
	SD	0.18	0.24	0.02	0.02	0.03	0.01	0.16	0.12	0.01	0.004	0.01	0.02	197.84	61.29	11.37	2.74	1.90	1.54	0.65	1.12
Galium	$\bar{x}$	2.66[4]	1.79[4]	0.12	0.09	0.37[4]	0.26[4]	2.26	1.02	0.20[4]	0.03[4]	0.25[4]	0.13[4]	390.52	681.80	72.05[4]	47.59[4]	24.82	58.53	11.83	4.47
	SD	0.35	0.19	0.06	0.02	0.10	0.03	0.17	0.17	0.17	0.005	0.02	0.02	309.12	171.65	22.77	7.39	13.42	68.34	6.69	1.88
Prosopis[6]	$\bar{x}$	1.12	1.20	0.14	0.09	0.42	0.31	1.36	1.19	0.03	0.02	0.49	0.62	146.27	126.60	65.23	60.21	53.17	49.60	22.18	13.95
	SD	0.27	0.27	0.16	0.02	0.08	0.03	0.39	0.04	0.01	0.005	0.10	0.14	74.79	28.10	13.74	14.31	8.48	5.91	5.29	4.52
Sphaeralcea	$\bar{x}$	1.96[4]	1.76[4]	0.24	0.17	0.41[4]	0.32[4]	1.98	1.93	0.17	0.04	0.38	0.36	1181.08	555.76	99.63[4]	46.92[4]	36.38	30.26	13.16[5]	7.45[5]
	SD	0.15	0.06	0.06	0.03	0.05	0.03	0.26	0.25	0.15	0.01	0.03	0.07	1199.83	279.19	41.59	6.41	5.52	9.00	3.76	1.72
Stipa	$\bar{x}$	0.40	0.37	0.04[4]	0.07[4]	0.09[5]	0.07[5]	0.54	0.62	0.04[5]	0.01[5]	0.23[5]	0.15[5]	257.16	354.37	51.33[5]	30.53[5]	14.66	20.50	9.13[5]	3.21[5]
	SD	0.07	0.04	0.01	0.01	0.02	0.01	0.13	0.18	0.01	0.002	0.01	0.01	158.45	80.34	11.29	8.89	4.21	7.99	5.16	0.47

[1] Taxa are identified to species in the text
[2] Expressed as percent dry weight
[3] Expressed as parts per million (ppm)
[4] $P \leq 0.10$
[5] $P \leq 0.05$
[6] No statistical comparison was made because plants were bare of leaves during 6 sampling periods at Old Dad Peak.

dicated a striking and highly significant difference ($P < 0.001$) in the proportion of mineral concentrations that differed between areas: mean annual concentrations were significantly greater at Panamint Range in 37 pairwise comparisons and in three instances at Old Dad Peak (Table 1). For Se, concentrations in forage plants at Panamint Range exceeded those at Old Dad Peak ($P = 0.011$) in 18 of 23 pairwise comparisons (Table 2). The combined probability test yielded a highly significant result ($X^2_{20} = 53.782$, $P < 0.001$), indicating that results of all tests were consistent and, thus, we reject the hypothesis of no overall difference in trace mineral concentrations among forage plants between Panamint Range and Old Dad Peak.

Discussion

To the best of our knowledge, we are the first to examine availability of micronutrients in forage plants used by bighorn sheep inhabiting different mountain ranges. Our tests yielded consistent results, and we reject our overall hypothesis that there were no differences in trace-mineral concentrations of forage plants used by bighorn sheep at Panamint Range and Old Dad Peak. Given the similarities in vegetation between the two ranges, our results were unexpected. Climatological differences, however, have important consequences for the population ecology of bighorn sheep at Panamint Range and Old Dad Peak (Oehler et al. 2003). Rainfall patterns can influence the concentrations of minerals in vegetation (Greene et al. 1987, Sprinkle et al. 2000), with the result that seasonal variation in mineral concentrations among individual animals are likely because of variation in mineral intake (Poppenga et al. 2012). Although differences in timing and amount of rainfall between Panamint Range and Old Dad Peak are not substantial, they likely affected the availability of micronutrients in forage plants in each geographic area (Greene et al. 1987, Sprinkle et al. 2000). In addition, we surmise that structural or compositional differences in substrate (Hunt 1966, Hall 1971, Dunne 1977, Curry and Resigh 1983) contributed to differing availabilities of micronutrients at Panamint Range and Old Dad Peak. Indeed, substrate chemistry plays a role in availability of trace elements (Hunt 1966) with resultant effects on the availability of those nutrients in plants (Carlisle and Cleveland 1958) and, ultimately, their availability to herbivores (Lisk 1972, Banuelos and Ajwa 1999).

Few investigators have analyzed the mineral content of forage plants used by wild ruminants in desert environments, and even fewer have considered differences in those measures among geographic areas. Our results are similar to those of Fox et al. (2000), who described substantial differences in availability of several trace minerals in forage plants in two geographic areas used by Sonoran pronghorn (*Antilocapra americana sonoriensis*). Collectively, our results and those of Fox et al. (2000) emphasize the importance of considering nutrient availability and its potential importance to ungulate populations on a geographic basis. Thus, we caution other investigators not to assume that published values from other study areas are universally representative.

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TABLE 2.—Concentrations of Selenium in nine species of bighorn sheep forage plants from the Panamint Range (PR), Inyo County and Old Dad Peak (ODP), San Bernardino County, California, USA. The detection limit for Selenium using capillary gas chromatography with electron capture was ≥0.04 PPM.

		Selenium (ppm)	
Taxon[1]	Period[2]	PR	ODP
Ambrosia	M–A	0.12	<0.04
	J–A	0.08	0.056
	N–D	0.11	0.04
Atriplex	M–A	0.11	<0.04
	J–A	0.13	0.11
	N–D	0.13	0.08
Encelia	M–A	0.06	0.043
	J–A	0.08	0.058
	N–D	0.10	0.049
Ephedra	M–A	0.04	<0.04
	J–A	<0.04	<0.04
	N–D	<0.04	0.04
Eriogonum	M–A	0.07	<0.04
	J–A	<0.04	<0.04
	N–D	0.05	<0.04
Galium	M–A	0.08	<0.04
	J–A	0.08	<0.04
	N–D[3]		<0.04
Prosopis	M–A[4]	0.06	
	J–A	0.08	0.28
	N–D	0.10	0.54
Sphaeralcea	M–A	0.07	0.54
	J–A	<0.04	0.04
	N–D	0.24	<0.04
Stipa	M–A	0.04	<0.04
	J–A	0.06	<0.04
	N–D	0.06	0.043

provided safe transport into remote regions of the study areas on multiple occasions. L. Parmenter (CDFW) processed samples and assisted with data management. This work was supported indirectly by a grant from Canyon Resources Corporation through the Institute of Arctic Biology at the University of Alaska Fairbanks. Additional financial support was provided by M. P. Northam, Boone and Crockett Club, California Association of Professional Scientists, CDFW, Society for the Conservation of Bighorn Sheep, San Fernando Valley and San Diego chapters of Safari Club International, Wild Sheep Foundation (formerly Foundation for North American Wild Sheep), San Bernardino County Fish and Game Commission, Bureau of Land Management, and the National Park Service. Manuscript preparation was supported by the Eastern Sierra Center for Applied Population Ecology. This is Professional Paper 081 from the Eastern Sierra Center for Applied Population Ecology.

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Traditional surveys may underestimate *Rana draytonii* egg-mass counts in perennial stock ponds

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Understanding growth potential in populations is essential to the recovery of species in decline such as California red-legged frogs (*Rana draytonii*). Quantifying frog egg masses can be an effective method for estimating population trends of pond-breeding frogs, and a measure of habitat quality as well (Crouch and Paton 2000; Grant et al. 2005). Female ranids deposit one egg mass per breeding season (Storer 1925; Zweifel 1955), although poor environmental conditions may preclude breeding in any given year (Wells 1977). The relative reproductive output of each female is influenced environmentally (Ryser 1989; Veysey et al. 2011), and each egg mass represents energy redirected from growth and survival to the energy demands of vitellogenesis (provisioning egg yolks with nutrients) (Wells 2007). These energy needs are met by *R. draytonii*, at least partially, through foraging in uplands (Bishop et al. 2014). Annual egg-mass deposition may reflect not only population trends, but also the quality of foraging habitat near the immediate oviposition site. Radio-telemetry studies have demonstrated that female *R. draytonii* make extended terrestrial forays during summer and between the onset of seasonal rains in the fall and the winter breeding season (Tatarian 2008; Fellers and Kleeman 2007; Bulger et al. 2002). Tatarian (2008) hypothesized that female *R. draytonii* venture farther and longer than males to forage in order to meet the energetic needs of egg production.

Knowing where female frogs are likely to deposit egg masses is critical to quantifying annual oviposition. In a comprehensive report of *R. draytonii* egg-mass deposition sites, Alvarez et al. (2013) described microhabitats used for oviposition of 747 egg masses at eight localities in California, categorizing microhabitats within four major habitat types: artificial pond, artificial channel, natural creek, and seasonal marsh. Although attachment substrates varied widely throughout the four habitats (45 different substrates), Alvarez et al. (2013) found decadent cattail (*Typha spp*.) to be the preferred attachment site for *R. draytonii* in artificial ponds, such as stock ponds. Whatever the substrate, the distance from shore to the point of oviposition in all habitats was less than 1 m, except within the seasonal marsh habitat. The mean water depth at oviposition sites over all four habitats was 38 cm, and mean distance from the water surface to the top of submerged egg masses ranged from 9.5 cm to a maximum of 65 cm (Alvarez et al. 2013). Given the sample size and the broad range of habitat types, these parameters could be said to define only a narrow area in which investigators might be expected to find egg masses in the littoral zone of ponds and streams. Here, we report on new parameters for *R. draytonii* oviposition sites in two proximal artificial ponds over two winters, 2016 and 2017.

The Mitsui Ranch, owned and operated by the Sonoma Mountain Ranch Preservation Foundation, is a 256-ha working cattle ranch located atop Sonoma Mountain in Sonoma County, California (Figure 1). Approximately 60% of the property is located within designated California red-legged frog Critical Habitat Unit SON-2 (USFWS 2010). The ranch consists of more than 80% open rangelands, within which lie two perennial stock (artificial) ponds: Leaky Lake and Bonnie's Pond. *Rana draytonii* reproduce successfully each year on the ranch, but prior to February 2016 *R. draytonii* egg masses had only been detected in Bonnie's Pond (Figure 1). At nearby Leaky Lake, for several years, *R. draytonii* oviposition could only be inferred from the presence of larvae and metamorphic frogs. Leaky Lake has a maximum surface area of 0.5 ha and is relatively shallow (2.5–3.0 m). Bonnie's Pond has a surface area of 0.15 ha and the maximum depth is approximately 5 m. The littoral zone in both ponds is dominated (approximately 90% coverage) by stands of common spikerush (*Eleocharus macrostachya),* and both have a few small patches of California bulrush (*Schoenoplectus californicus*) slightly deeper in the littoral zone that makes up the remaining 10% of emergent vegetation. In the season of oviposition,

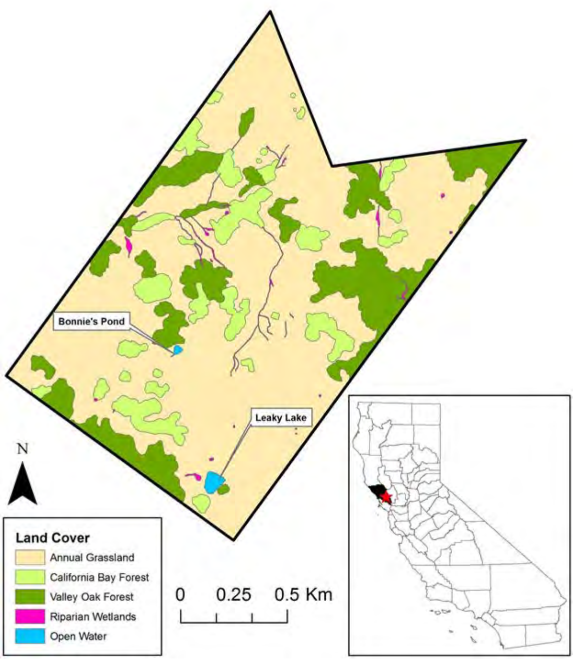

FIGURE 1.—*R. draytonii* breeding ponds and surrounding habitats on the Mitsui Ranch (Sonoma Mountain), Sonoma County, CA.

decadent littoral vegetation is inundated as reservoirs fill. Unless turbulence obscures visibility in the water column, much of the vegetative structure is visible beneath the water surface. At Leaky Lake on 29 February 2016, incidental to a student research project, a dark mass was detected associated with a submerged stand of decadent California bulrush many meters from shore. When investigated from a canoe, the dark area was found to be an attached egg mass of *R. draytonii*, located 12.2 m from shore at a water column depth of 3.2 m. We searched the lake's remaining stands of submerged California bulrush by canoe and discovered four additional egg masses. At each location we measured distance from shore, water column depth, and the water depth at top of egg mass (Table 1).

Table 1.—Oviposition parameters of 21 egg masses from two artificial ponds over two breeding seasons on the Mitsui Ranch.

	Depth at Oviposition (cm)		**Depth at Top of Egg Mass (cm)**		**Distance From Shore (m)**	
	Mean	Range	Mean	Range	Mean	Range
Leaky Lake (N=9)	210	50–320	38	10–72	5.9	0.8–12.2
Bonnie's Pond (N=12)	68	49– 84	38.5	0–73	5.82	1.7– 8.95

Our observations at Leaky Lake prompted a canoe search of nearby Bonnie's Pond that revealed an egg mass in California bulrush that had previously gone undetected due to its depth (38 cm) and distance (5.3 m) from shore. This winter (2017), we recorded 12 *R. draytonii* egg masses at Bonnie's Pond (none at Leaky Lake due to poor visibility), nine of which had not been detectable from shore. Of the three visible from shore, one was attached to a small (six stems) decadent California bulrush, and two were attached to common spikerush. Although some of the nine distant egg masses in Bonnie's Pond might have been detectable by wading into the shallow areas of the pond, this practice is discouraged by guidance measures issued by the U.S. Fish and Wildlife Service (USFWS 2005). The agency's protocol for surveying all life history stages of *R. draytonii* stipulates that "Surveyors should begin by first working along the entire shoreline, then by entering the water (if necessary and no egg masses would be crushed or disturbed), and visually scanning all shoreline areas and all aquatic habitats identified in the site assessment (USFWS 2005)."

At Leaky Lake, despite the dominant presence of common spikerush (Figure 2), female *R. draytonii* oviposited most often in stands of dead, submerged California bulrush that had been cropped by grazing cattle. Cattle are allowed access to the lake for a period of a few days each spring, and in 2016 had grazed the fresh growth of California bulrush leaves down to the water surface, leaving a "trimmed hedge" appearance. The following winter, when water levels in the pond increased (Figure 3), the grazed-down California bulrush formed a submerged wall of dead vegetation. Winter rains of 2017 resulted in prolonged high-water levels in ponds throughout the spring. Although cattle were allowed access to both ponds, they were not able to wade deep enough to crop emergent vegetation. As a result, the egg masses we discovered at Bonnie's Pond in 2017 were attached to submerged decadent California bulrush that had not been grazed by cattle. Our findings over two seasons of oviposition, suggests that in the two ponds surveyed, submerged dead, grazed and ungrazed California bulrush, is more often used by *R. draytonii* for oviposition sites than the far more abundant common spikerush (a posteriori: $\chi^2\alpha$=01=6.64; P=11.10; df=1); and that oviposi-

FIGURE 2.—Leaky Lake in July, showing common spikerush ringing the littoral zone with a few dense stands of tule in the deeper portion.

FIGURE 3.—Leaky Lake in early spring, when most littoral vegetation is inundated by rising water and cattle have cropped much of the tule growing close to shore when water levels were lower in late summer.

tion sites could occur at significantly greater distances from shore than previously thought.

Our discovery of previously undetected oviposition sites at two artificial stock ponds is significant because biologists and land managers may use egg-mass counts to estimate population size (Merrell 1968; Crouch and Paton 2000), since female ranid frogs lay one egg mass annually (Storer 1925; Zweifel 1955). Had we not deployed a canoe to search for egg masses in the two water bodies, we would have underestimated egg mass totals by 75% at Bonnie's Pond (9 of 12) in 2017, and by 77% at Leaky Lake (7 of 9) in 2016. This leads us to conclude that visual egg-mass surveys of artificial pond habitats conducted in the traditional way (on foot around the perimeter, or wading only into the shallows), may potentially underestimate the abundance of breeding female *R. draytonii* significantly. This is particularly likely when emergent vegetation grows distant from shore, in water too deep to wade or too turbid to permit detection from a distance.

Artificial stock ponds are common within the range of *R. draytonii* and are readily used as breeding habitat (USFWS 2002). However, such ponds are built in a wide variety of landscapes, with varying exposure, substrate type, basin shape, and maximum depth, and are colonized by highly variable plant communities. We found *R. draytonii* egg masses deposited well outside of parameters reported by Alvarez et al. (2013) for artificial ponds. Although our sample size is small (N=21), our findings suggest that the varying properties of artificial stock ponds may warrant the use of detection methods beyond shoreline foot surveys (that is, by wading out or by boat) to detect *R. draytonii* egg masses. This is particularly true in shallow ponds where rainfall may seasonally flood or inundate emergent vegetation, creating available oviposition sites far from shore. Water-level changes should therefore be considered when developing schedules and techniques for conducting egg mass surveys for this species. Also, surveys should be conducted during periods of low wind, when water turbidity is reduced and visibility maximized. Finally, like Alvarez et al. (2013), we found tall, robust aquatic plants (cattail in the case of Alvarez, California bulrush on Mitsui Ranch) to be the most frequently used attachment substrate for *R. draytonii* in artificial ponds. Although further study is required, allowing cattle (limited) access to ponds does not appear to eliminate subsurface oviposition structure—and may in fact create favorable deposition substrates for *R. draytonii* on well-managed sites. Finding egg masses at such deposition sites requires greater effort, but may yield a more accurate estimate of reproductive activity by *R. draytonii* on managed lands. Underestimating egg mass counts potentially misinforms management efforts and confounds efforts to understand how habitat quality relates to *R. draytonii* population recruitment.

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A previously undocumented life history behavior in juvenile coho salmon (*Oncorhynchus kisutch*) from the Klamath River, California

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Key words: coho salmon, *Oncorhynchus kisutch*, Klamath River, Prairie Creek, ocean entry

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During the fall of 2012 juvenile coho salmon (*Oncorhynchus kisutch*) were sampled by Yurok Tribe employees in two tributaries of the Lower Klamath River: McGarvey Creek (41°29’03.09”N, 124°00’48.09”W) and Hunter Creek (41°35’44.28”N, 124°02’12.02”W). Fish were captured by either seining or electrofishing and if the FL was greater than 65 mm then a full duplex Passive Integrated Transponder (PIT) tag was inserted into the body cavity. A hand-held device was used to scan each PIT tag before it was implanted. The code was manually recorded and later proofed against the electronic download from the scanner. All fish were released in the immediate vicinity of each sampling site. A total of 32 coho was implanted with PIT tags in McGarvey Creek on 5 September 2012 and 70 in Hunter Creek on 15 October 2012.

Three Streamwidth Passive Interrogation (SPI) monitoring stations (41°29’9.74”N, 124° 0’41.33”W; 41°29’30.48”N, 124° 0’20.67”W; 41°29’58.00”N, 123°59’56.91”W) for detection of PIT tags were operated by the Yurok Tribe in McGarvey Creek during the fall and winter of 2012–2013.The SPI monitoring stations were equipped with multiplexing transceivers capable of reading full duplex PIT tags. Hunter Creek was not monitored with a SPI monitoring station. Both the initial PIT tagging event information from McGarvey and Hunter Creeks and subsequent detections at SPI monitoring stations in McGarvey Creek were uploaded into the Klamath River Basin (KRB) PIT tag database maintained by the United States Geological Survey (USGS) Western Fisheries Research Center located in Klamath Falls, Oregon.

Redwood Creek (41°17’33” N; 124°05”31” W) enters the Pacific Ocean 17 miles south of the Klamath River and Prairie Creek (41° 17’57.73”N, 124°03’02.15”W) is a tributary to Redwood Creek. Although Prairie Creek was equipped with a SPI monitoring system, operated by California Department of Fish and Wildlife (CDFW), it was not capable of detecting full duplex tags. All PIT tagged juvenile coho salmon in the Klamath River were implanted with full duplex PIT tags. Therefore, no SPI data were available for detecting the presence of Klamath River coho salmon in Prairie Creek.

In the spring of 2013 a rotary screw trap (RST) was operated in lower Prairie Creek, located just upstream from the confluence with Redwood Creek (river mile 3.2). The trap was operated for monitoring purposes in the Prairie Creek system unrelated to Klamath River studies (Sparkman et al. 2014). The RST was operated continually (24 hrs/day, 7 days a week) except during high discharge events during the smolt migration period (10 March 2013 to 13 August 2013). Captured juvenile coho salmon were measured for fork length (mm) and weighed (g). All fish of a size that potentially held a PIT tag were scanned with a hand-held device. If the device detected a PIT tag code it was manually recorded and later proofed against the electronic download from the scanner. The locations of the initial PIT tagging events in McGarvey and Hunter Creeks, the McGarvey Creek SPI monitoring stations, and the Prairie Creek RST are displayed in Figure 1.

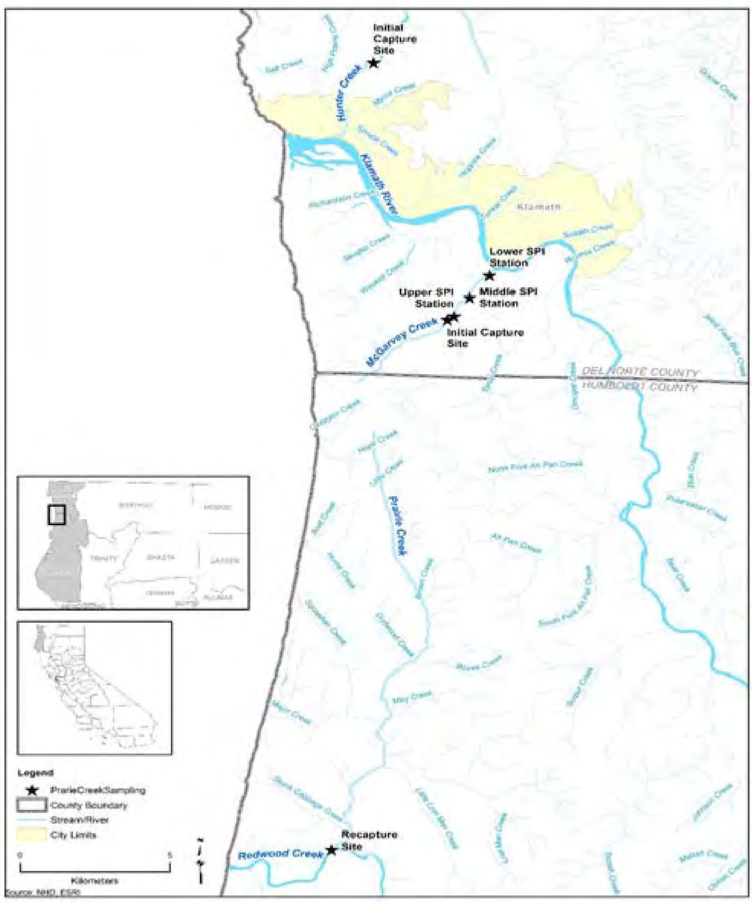

FIGURE 1.—Map of the study area showing tagging locations, SPI monitoring stations, and recapture site of juvenile coho salmon from three streams in coastal northern California. The tagging sites were in the Lower Klamath River watershed and the recapture site was located in a tributary to Redwood Creek.

During analysis of the PIT tag data collected from the Prairie Creek RST, it was determined two of the captured coho were not tagged in either Prairie Creek or Redwood Creek. To obtain information on where these fish were initially tagged the two PIT tag codes were entered into the KRB PIT tagging database. The query revealed that the initial tagging events for PIT# 985121025924963 and PIT# 985121025905793 were in McGarvey Creek and Hunter Creek respectively (Table 1). The query also displayed detections of PIT# 985121025924963 on two of the three McGarvey Creek SPI stations during 6 December 2012. The initial marking location was above all three SPI monitoring stations and the fish was detected at Upper SPI station at 19:00:51 hrs and at the Middle SPI station at 19:39:47 hrs indicating the fish was moving downstream. Data for Klamath River discharge were retrieved from the USGS gaging station (KNK) near Klamath, California, through the California Data Exchange Center (http://cdec.water.ca.gov). The flow data indicated the fish was moving downstream during a major freshet that occurred in early December 2012. Although the fish was not detected at the lower-most SPI station this is not surprising since the entire lower portion of the McGarvey Creek Valley becomes inundated during high flow events from the Klamath River and the monitoring station only covers a small fraction of the channel width during high water. The flows on 2 December and 5 December 2012 are the two highest December flows for the Klamath River over a 10 year record spanning 2006 to 2015. Discharge from the Klamath River during December 2012 and date of detections for the fish are displayed in Figure 2.

Table 1.—Tagging and subsequent recapture events for two juvenile coho salmon. Both of the coho were initially tagged in Lower Klamath River tributaries and recaptured in a tributary of Redwood Creek.

	Initial Tagging				**Recapture**			
PIT Tag #	Location	Date	Fork Length (mm)	Wet Weight (g)	Location	Date	Fork Length (mm)	Wet Weight (g)
985121025924963	McGarvey Creek	09/05/12	99	13.0	Prairie Creek	04/29/13	120	17.0
985121025905793	Hunter Creek	10/15/12	97	11.0	Prairie Creek	04/28/13	123	18.5

In response to high flow events juvenile coho salmon may redistribute in search of better overwintering habitat (Giannico and Healey 1998; Bell et al. 2001). Based on the detections of the McGarvey Creek fish leaving during a major freshet, we hypothesize that this fish entered the mainstem of the Klamath River in search of better overwintering habitat. No data are available to indicate when the Hunter Creek fish emigrated, but it is likely this fish moved into the mainstem Klamath River during the same general period due to the protracted freshet that was occurring. During the same freshet (1-7 December 2012) 5 fish PIT tagged in McGarvey Creek and 9 from Hunter Creek were detected entering non-natal tributaries in the Lower Klamath River estuary. It is possible the two coho recaptured in Prairie Creek were swept out to sea by high flows. However, since other fish were capable of locating new overwintering sites during the freshet it seems probable the movement was volitional rather than passive. Once in the Klamath River, we hypothesize that these fish continued downstream until they encountered the ocean. The lower river as

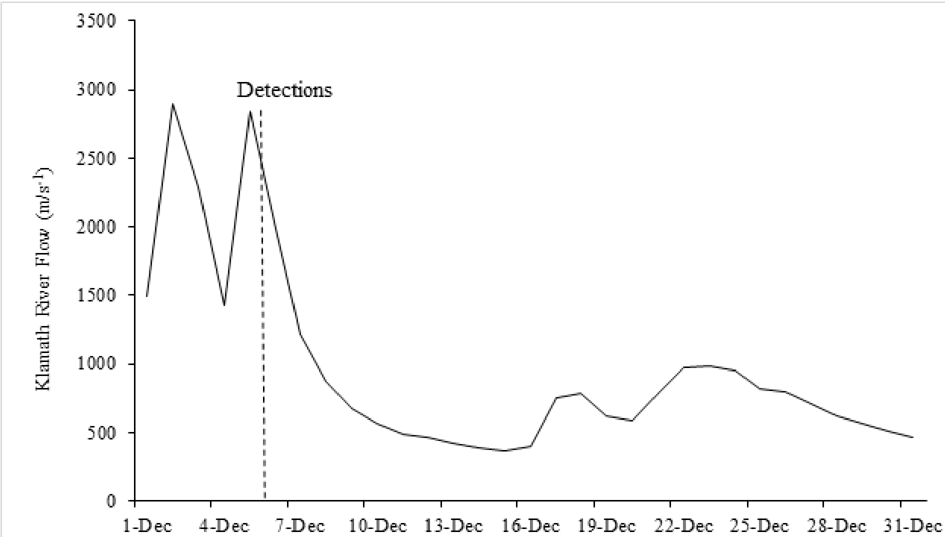

FIGURE 2.—The SPI monitoring station detections of a PIT tagged juvenile coho salmon in McGarvey Creek on 6 December 2012 in relation to Klamath River stream flow (m/s^{-1}). Data for Klamath River discharge were retrieved from the U.S. Geological Survey gaging station (KNK) near Klamath, California through the California Data Exchange Center (cdec.water.ca.gov).

it enters the ocean flows swiftly during high flow events, and the freshwater plume would have extended some distance out into the ocean. Upon ocean entry juvenile salmon typically follow the direction of ocean currents (Royce 1968; Brodeur et al. 2003; Azumaya and Ishida 2004). The current direction at the surface of the ocean is largely driven by the direction of prevailing winds (Nelson 1977) and the surface current in the coastal zone of Northern California is highly variable during the fall and winter months based on current direction images accessed from the Cooperative Ocean Prediction System website (west.rssoffice.com). Ocean current images revealed sustained southward current from the Klamath River to Redwood Creek from 6-11 December 2012 (J. Farrara, Remote Sensing Solutions, Inc., personal communication; Figure 3). During the remainder of December current direction was northward. Therefore, we conclude the period of 6−11 December 2012 was the likely time these two fish immigrated to Redwood Creek. It is probable the two fish moved into Prairie Creek soon after entering Redwood Creek since it contains higher quality over-wintering habitat. However, there is no data available to determine for certain when these two fish entered Redwood or Prairie Creek. If the coho were either implanted with half duplex PIT tags or the SPI station in Prairie Creek was capable of detecting full duplex tags more information might be available. Furthermore, since a SPI station is more efficient at detecting recaptures than a RST, the likelihood of encountering this coho movement pattern in the future would be enhanced by compatible PIT tag technology.

Spring and early summer is the typical period for juvenile coho salmon parr-smolt transformation and entry into the ocean (Sandercock 1991). Although juvenile coho are capable of surviving saltwater before parr-smolt transformation it generally results in poor growth (Folmar et al. 1982; Mahnken et al. 1982). Furthermore, ocean entry typically coincides with seasonal peaks in marine productivity and good feeding opportunities (Spence and Hall 2010). Since

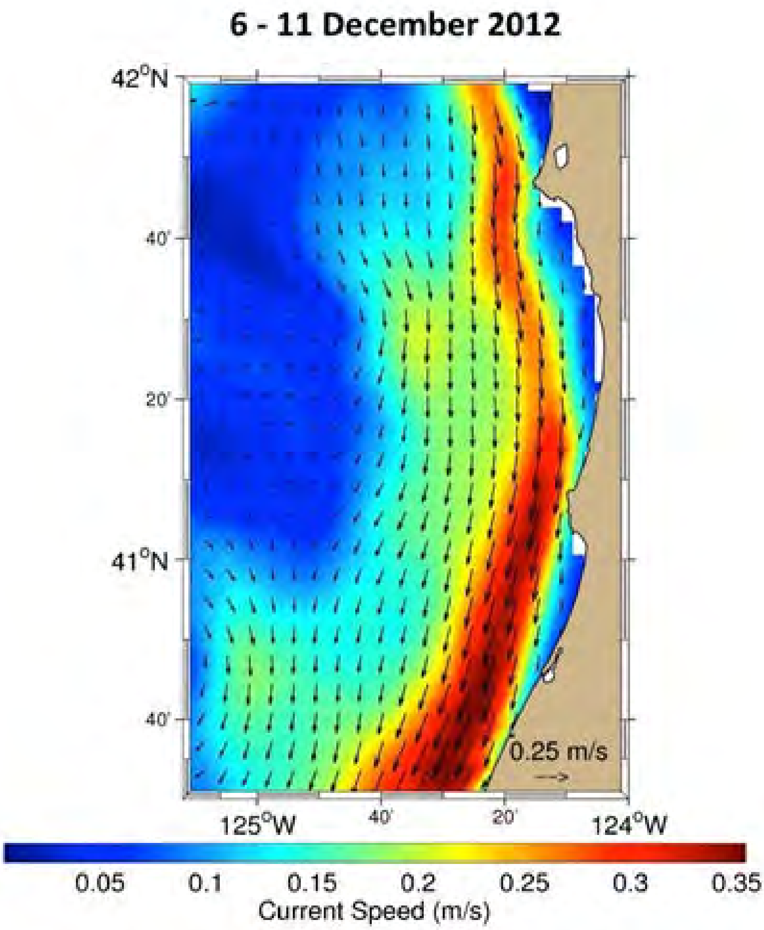

FIGURE 3.—Prevailing current direction off the coast of northern California adjacent to the Klamath River (41°32'37" N; 124°04'53" W) and Redwood Creek (41°17'33" N; 124°05"31" W).

December is not a typical month for coho entry into the ocean or a period of high marine productivity we conclude these two fish reentered freshwater to enhance their chances of survival.

Migrations through saltwater to find suitable freshwater rearing habitat have been previously documented in age-1^+ coho salmon from Alaska that out-migrate in the spring, rear and travel significant distances in saltwater (upwards to 113 km), then enter another river system to overwinter in the fall and out-migrate to the ocean as age-2^+ smolts the following spring (Shaul et al. 2011; Shaul et al. 2013). Our finding documents behavior different than observations in Alaska since the two coho from the Klamath River entered saltwater at age-0^+ during late fall and most likely returned to freshwater shortly thereafter.

It is well established that juvenile coho salmon utilize rearing habitat in areas other than their natal streams (Tschaplinski and Hartmann 1983; Peterson and Reid 1984; Bramblett et al. 2002; Roegner et al. 2010; Sutton and Soto 2012). Peterson (1982) suggested that potential rearing habitat is not confined to a natal stream and can include other areas within a river system beyond natal areas, particularly those located downstream. Our findings demonstrates that juvenile coho salmon from the Klamath River can migrate through the ocean and rear in another river system, thereby expanding available rearing habitat beyond their river of origin.

Our findings would not have been possible without the existence of the KRB PIT tag database especially since the recapture events took place in sampling outside the Klamath River watershed and by different organizations. Therefore, it provides a good example of the importance for funding and maintaining databases which cover large geographic areas and contain tag information from the multiple agencies involved in studies that include PIT tagging and recapture events. A template for creating a PIT tag database could be the Regional Mark Information System coded wire tag database maintained by the Pacific States Marine Fisheries Commission. We suspect as the use of PIT tag technology increases in the Pacific Northwest and California, and access to data from different organizations is expanded, the extent and significance of coho salmon movement patterns will become better understood.

Acknowledgments

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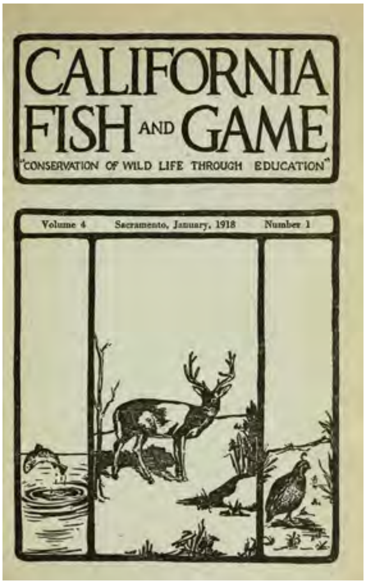
From the Archives:
Bighorn Sheep in the Vicinity of Claremont, California

By Leon L. Gardner (Contribution from the Department of Zoology of Pomona College.)



That mountain or bighorn sheep still exist in small bands in various parts of the California mountains is a fact well known. It, however, comes as a welcome surprise to find them living, breeding and at least holding their own in numbers, in the mountains not farther than 30 miles from Los Angeles. Vague reports from old hunters that in certain parts of the ranges near Mount San Antonio, commonly known as "Old Baldy," there were "wild goats and sheep," and that they were "mighty hard to get near to," furnished the incentive for investigations which have demonstrated that one species of bighorn sheep occurs in the ranges north of Claremont, Los Angeles County. Whether or not this is the Nelson bighorn "*ovis nelsoni*" is an open question which can be decided only by the collection and study of specimens.

The rumor relating to the occurrence of wild goats is undoubtedly based upon the observation by hunters of the females and young sheep with their smaller horns. A case in point is the sheep's head found in Ice House Canyon in the spring of 1916. The severe rains of the year had washed it down from the mountainside and it was found at the canyon bottom and brought into Camp Baldy. Word went out that the head of a mountain goat had been found, and the writer immediately hastened up to the camp to see it. It proved to be the head of a young bighorn, but on account of the short horns and hair, now bleached nearly white through weathering, the mistake had been very natural.

The mountains of the region are much like all the southern California mountains, with brush-covered, south-facing slopes. While the shaded north-facing areas are fairly well wooded. The outstanding feature of this particular region is Mount San Antonio, or better known as "Old Baldy," which stands 10,080 feet above sea level. From it radiate great mountain ridges to the north, east, west and southwest, much as spokes from the hub of a wheel. The whole system is thus connected up by continuous ridges. In this great extent of territory the sheep occupy a very definite area. This includes Ontario, Cucamonga and Telegraph peaks, with their intervening ridges, also Iron Mountain and its connection with "Old Baldy," and the ridge between this latter peak and Telegraph . In the writer's opinion, this is the area of their widest distribution, their favorite haunts being the region around Ontario, Cucamonga and Telegraph peaks.

To seek out and study the sheep in this array of jagged spurs and protecting hollows is a task difficult in itself, and is made none the easier by their timidity. Their wariness was impressed upon the writer by an encounter on June 12, 1915. The approach to Telegraph Peak was made by the ridge from "Old Baldy." While this peak was yet a considerable distance away, the writer's attention was attracted to a spot near the summit by a clear, thin rattling caused by a rock slide down the steep slope. It was apparent that some large animal was the cause of it, and close scrutiny disclosed three heavy-bodied animals bounding up the mountainside with great speed, and with no regard to the great quantities of stones dislodged. As each sheep in turn reached the summit, curiosity gained the upper hand, and it turned, gazed down in a bland, questioning way, and the with a quick turn, head erect, trotted stiffly over the top and disappeared to view. On account of the hard soil, the tracks could not be followed and pursuit was impossible.

Just what the sheep were doing on that barren rock slide is hard to say. They could hardly have been in the act of quitting the peak, for that particular spot was some distance from any ridge, being on a slope that ended only in the canyon a considerable distance below. If it was food they were seeking, they were certainly going to a great deal extra effort, for there was plenty at the summit. This was quite evidently a stray trio of more adventuresome or restless females or young males, for no bighorned ram was with them. They might very possibly have been members of a larger band on the other side of the mountain. This seems the more likely in view of the fact that about an hour later, in a location not so very distance from where the sheep were seen, the writer came across fresh tracks of a whole band of sheep.

Just how the sheep detected the presence of a human being is an interesting question. The air was quite still, so they could have received no warning through a telltale scent. It seems more likely they were given notice through the sense of sight. If so, their vision is very acute, for the writer was alone, dressed very inconspicuously and still at a considerable distance.

Another definite encounter occurred in September of 1914. This one was purely fortuitous. A fruitless hunt for deer had at last led to the outermost point on Ontario Peak, and here a rest was taken on the top of a big rock. About midafternoon the silence was broken by faint yet unmistakable sounds, which could have only been made by a whole troop of animals. There was the sound of twigs snapping, the bleating of lambs and the peculiar shuffling sound caused by the tramp of many feet. It was very evident that a band of sheep was approaching. A cautious observation over the edge of the rock disclosed a very interesting sight. Coming along the top of the ridge was a party of sheep, an individual stopping here and there to nibble at the vegetation. The rams, with their great curling horns, were a majestic sight, while the young of the year were exceedingly playful and altogether charming. Unfortunately at this stage a scent warned the sheep. In a second the whole band halted, heads up, noses questioning, then at an invisible signal they all wheeled and made off in jerky stiff-legged, bouncing leaps, and quickly disappeared from view.

At various other times sheep were seen, but under very unsatisfactory conditions. Either the distance was so great that nothing could be learned, or but a very fleeting glimpse was caught of the band in flight. One is often given the aggravating impression that he comes too late or that the sheep were too sharp-eyed and had taken to safety.

However, although themselves difficult to locate, unmistakable traces of the sheep are to be found if carefully sought. Here one sees the grass cropped, the bushes nibbled, there the scattered droppings, and in spots where the soil is powdery enough, or by a moist stream bank, the clear large footprints in great abundance. One might almost study the distribution of the sheep through this means alone. Thus the writer one day came across a well-beaten sheep trail on the ridge between Ontario and Telegraph peaks. In most places the soil is too hard and rocky to take a print, hence tracks are not as abundant as one might suppose.

Regarding the general habits of the sheep, several points seem clear. As before noted, they are very shy and alert, despite years of freedom from pursuit by man. From the fact that tracks when found are usually in great abundance, and from direct observation, it is evident that they travel most often in bands. However, the occasional sight of one, two or three odd sheep perhaps points to the conclusion that certain individuals at times stray from or are cast out of the band. This might occur in the case of several males striving for the leadership of the band. It seems very possible that adventuresome young especially males, not yet arrived at the breeding age, might stray from the herd. From the appearance of the lambs in late September, at which time they are quite active, the writer would put the lambing season in late February and early March.

The question of water is not a serious one for the sheep. Not only is water accessible in the headwaters of the canyon streams, but springs issuing from the sides of Ontario Peak, at some places within 200 feet of the top, give a ready supply. This whole region in winter is covered with a heavy blanket of snow, and this, when melting in the summer, often forms large pools of clear water. That the sheep move about and drink at night is evidenced by one observation, when several of them were seen one moonlight night to slip down to one of the springs on Ontario and drink.

What constitutes their food can not readily by told without long-continued observation during feeding (a very difficult and well-nigh impossible task) and by a study of the stomach contents. There is no doubt, however, that the following plants form an important part of the diet: the leaves of the chinquapin *(Castanopsis sempervirens)*, a wild parsnip *(Palpinacea sativa)* growing around water holes, berries of the manzanita *(Arctostaphylos)*, twigs and leaves of *Rhus trilobata* and *Rhamnus crocens californicus*, and finally grass growing near springs and streamlets.

All that has been said applies to the sheep only during the warm season of the year. What becomes of them in winter is not known. They are certainly not at the mountain tops. The heavy snow blanket covering the mountains thaws during warmer spells only to freeze again into a solid sheet of ice. At such times they become exceedingly slippery and dangerous, and it seem inconceivable that the sheep or any living creature of large size could avoid sliding off into the canyons below.

There are two places that give great promise as wintering areas. These are the spurs to the northeast of Cucamonga and Telegraph peaks, respectively. They drop low enough to receive only an occasional transient snow covering. This region is exceedingly wild, trailless, and not visited by man, and would seem to present all the requirements of winter quarters for the sheep.

Regarding the number of sheep living in this territory, it is not possible to say definitely. If all the sheep are in one band, then their number is between 50 and 60 head There is, however, no evidence to show that there are not dozens of sheep scattered all over the range, or that there are not two or more bands of varying sizes. The writer is inclined to feel that there is but one band, with only a few outlying stragglers. Much can be done toward answering these points if the sheep could be found in the winters, when their range is greatly restricted.

A study of this kind presents many other questions of great interest. It would, for instance, be very interesting to obtain, if possible, a history of these sheep. How long have they been known in this section, and are they remnants of a one-time larger band that was more widely distributed? It also seems very possible that there are other bands of sheep in favorable localities, such, for instance, as North Baldy and the series of unfrequented peaks in connection with it. Even the species is unknown, and from this as a starting point the problems extend endlessly.

With a wise and rigorously protective state law and a range that will not for years to come be encroached upon by man, there is everything in favor of a bright future for the mountain sheep of eastern Los Angeles County.

Front—A two-year-old male bighorn sheep (Ovis canadensis nelsoni) at the Kelso Peak Wildlife Water Development, San Bernardino County, California, on 21 May 2013. Some of the forages analyzed and described in this issue by Bleich et al. were collected near this location. Photograph by L. Hayes of Baker, California.

Rear—The California red-legged frog (*Rana draytonii)* is federally listed as Threatened and is considered a Species of Special Concern in the state of California. It was named the official California State Amphibian in June 2014. Photo by Dave Feliz, CDFW.

Photo by Dave Feliz.

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