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Notes from the Editor

The first issue of 2021 is (the winter issue) is a bit late—and a bit smaller than our recent issues. We imagine that the COVID-19 pandemic, which has been shown to significantly impact scientific research over the last year-plus, is impacting publications as well. A recent article in Nature Human Behavior documented that some groups have been disproportionately affected, highlighting the impacts on female scientists, especially those with young children.

Despite the challenges that the pandemic has brought, we are seeing some momentous changes to the Journal this year. At the end of 2020, our online submission system went live! All manuscripts must now be submitted through this system, which creates a streamlined and time-saving process for me, my Associate Editors, and our reviewers. Please note that with the new submission system, the Journal submission guidelines were updated to reflect the changes. Be sure to use the most up-to-date guidelines when submitting to the *California Fish and Wildlife Journal*. Also, this issue is the first to implement our new DOIs (Digital Object Identifiers). DOIs, used by most major scientific journals, are permanent identifiers for each article and will provide increased accessibility and visibility for the Journal's publications.

Our editorial team continues to grow, meeting the challenges of increased submissions from our new online submission system—we have three new Associate Editors. Justin Dellinger, a Senior Environmental Scientist (Specialist), received a B.S. in Biology at University of North Carolina-Wilmington in 2008 and a M.S. in Wildlife Biology at Auburn University in 2011 studying foraging and spatial ecology of red wolves in North Carolina. After that, he did a 1.5-year stint as a mountain lion researcher in Arizona and New Mexico. Next, in 2018, he completed a PhD in Wildlife Biology at the University of Washington in Seattle studying impacts of gray wolves on mule and white-tailed deer in Washington state. He started working for the Department in December 2015 after finishing his field work for his PhD. For the past five years, he has been the agency researcher for mountain lions and the agency researcher for wolves since June 2017.

Pete McHugh is a Senior Environmental Scientist (Supervisor) in the Marine Region. He received a B.S. from Ohio State University (1999) and graduate degrees (M.S. [2003], PhD [2006]) from Utah State University, with a focus on Fisheries Management and Fish Ecology. Inclusive of graduate work, he has worked on fish population and habitat assessments for nearly two decades, in places as far-reaching as South Island, New Zealand to the brook trout-filled streams of Vermont's Green Mountains. He has spent most of his professional career working on fishery models and stock assessments to support the sustainable management of ocean salmon fisheries in state, tribal, and federal co-management arenas. He joined the Department in 2019 and is currently a co-leader of the Department's Ocean Salmon Project in Santa Rosa. Pete has coauthored papers in a variety of scientific journals, regularly supports the scientific publishing process through peer-review activities, and is looking forward to serving as a member of the California Fish and Wildlife Journal's editorial team.

Jennifer Olson is a Senior Environmental Scientist (Specialist) with the Department's Coastal Habitat Conservation Planning group in the Eureka field office. She has worked for the Department since 2013 in a variety of roles, primarily focused on environmental review and permitting. She currently serves as the Caltrans Liaison for Del Norte, Humboldt, and Mendocino Counties. Prior to working for the Department, she worked as a Research Associate for the Montana Cooperative Wildlife Research Unit where she supervised field crews and data management for projects focused on life history variation in songbirds in the U.S, Venezuela, and Malaysian Borneo. Jen is originally from Minnesota and has a bachelor's degree in Environmental Studies from the University of Minnesota-Duluth. In her free time, she enjoys birding, running, finding new places to go hiking and backpacking with her husband and her dog, and expanding her natural history knowledge about her Northern California home.

Katrina Smith is a Senior Environmental Scientist (Specialist) that provides statewide coordination for CESA Incidental Take Permitting, including Consistency Determinations and Safe Harbor Agreements. Katrina holds an M.S. degree in Natural Resources, Wildlife from Humboldt State University and a B.S. in Ecology and Environmental Biology from University of Wisconsin-Eau Claire. Her graduate work focused on habitat selection modeling to support a long-term population monitoring program for Townsend's big-eared bats hibernating in volcanic caves. In addition to her tenure with CDFW, she has also worked for the U.S. Fish and Wildlife Service and the National Park Service, providing strategic direction and science-based adaptive management for a variety of natural resources.

Lastly, Grace Myers is the first to join our new "Junior Associate Editor" program. Junior Associate Editors are scientists without significant publishing experience, but who would like to learn. Junior AE's are paired with an experienced AE to learn about the publication and editorial process. Grace is an Environmental Scientist for our Cannabis Permitting Program and has been with us for just over a year. Her role primarily entails assisting cannabis cultivators through the Lake and Streambed Alteration (LSA) notification process. Although originally from the Bay Area, California, she spent some time on the East Coast, where she earned a B.S. in Wildlife Biology from the University of Vermont. Focusing primarily on birds and plants, she has worked on a variety of different long-term projects for monitoring breeding bird populations and their habitats. Some of her favorite projects were concentrated on the Bicknell's thrush, common loon, and rusty blackbird. Currently, she is happy to be assisting with the Wildlife Conscious Cannabis Certification program, an initiative promoting wildlife friendly cannabis practices.

Our fourth and fifth special issues will be coming out this year, so keep an eye out for both the CESA (California Endangered Species Act) and Human-Wildlife Interactions special issues later this spring or early summer (https://wildlife.ca.gov/Publications/Journal/Special-Issues).

Ange Darnell Baker, PhD
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RESEARCH NOTE

An endemic anuran and a horny toad: distributional histories, the potential for sympatry, and implications for conservation

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Key words: Amargosa River, *Anaxyrus nelsoni*, *Anaxyrus woodhousii*, *Bufo nelsoni*, *Bufo woodhousii*, genetic introgression, Great Basin, hybridization, introduced species, Oasis Valley

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The Amargosa toad (*Anaxyrus nelsoni*) is one of five bufonid species with highly restricted distributions in the Great Basin of California and Nevada (Gordon et al. 2017, 2020), and was described as *Bufo boreas nelsoni* by Stejneger (1893). The holotype (USNM 18742) and 7 paratypes were collected in Oasis Valley, Nye County, Nevada. Two paratypes (USNM 18744 and USNM 18745) originally ascribed to that taxon were collected in the Amargosa River drainage at Resting Springs, Inyo Co., California, but the taxonomic status of the Resting Springs paratypes appears uncertain (Storer 1925). The Amargosa toad is restricted in distribution to Oasis Valley (Burroughs 1999; Dodd 2013; IUCN 2019) where it occupies wetlands along or adjacent to a 15-km reach of the Amargosa River between Springdale and Beatty (Fig. 1). The taxon may be declining in number (Simandle 2006, IUCN 2019), but is not protected under the federal endangered species act (USFWS 2010). Following population assessments (Altig and Dodd 1987; Heinrich 1995; Stein et al. 2000), which generated concern about conservation of the taxon, a multi-party agreement (NDOW 2000) was developed. The most recent status assessments of the Amargosa toad (Hammerson 2004; USFWS 2010), however, were completed more than a decade ago. In this paper I do not advocate for endangered or threatened status for Amargosa toad but, rather, offer a cautionary note in the context of the potential for sympatry between *A. nelsoni* and a non-native congener, Woodhouse's toad (*Anaxyrus woodhousii*), and the consequences thereof.

Woodhouse's toad is well-adapted to a variety of ecological conditions (Bradford et al. 2005; Ryan et al. 2017), and occurs widely throughout the United States (Conant 1958; Stebbins 2003). In California, its historical range was restricted to the Lower Colorado River Valley, Imperial County (Storer 1925), and historical range in Nevada encompassed the floodplains of the Muddy, Virgin, and Colorado rivers in Clark County (Bradford et al. 2005). This generalist bufonid is highly successful at exploiting newly available habitat and, over the past century, this ability has led to a substantial expansion of its distribution in California and Nevada (Bradford et al. 2005; Goodward and Wilcox 2019; Bleich 2020).

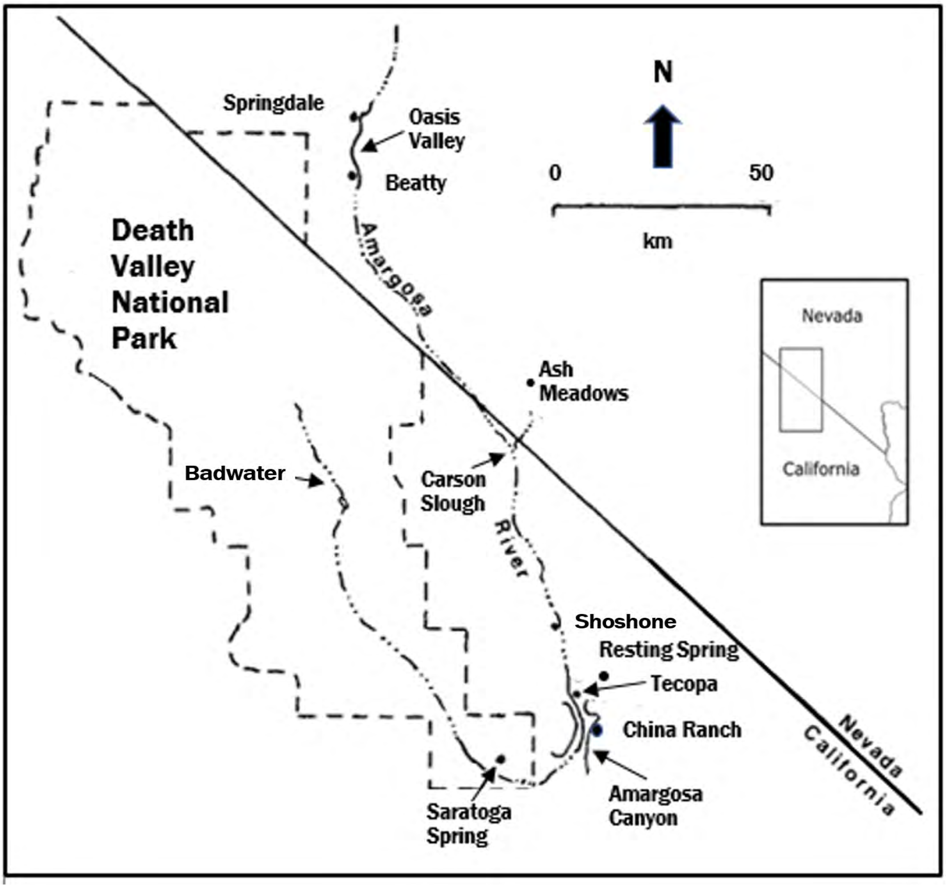

Figure 1. The Amargosa River has its origin at an elevation of 1,200 m on Pahute Mesa, about 20 km north of Beatty, Nye County, Nevada. The river flows southward, westward, and then northward over a distance of 185 km, reaching its terminus near Badwater in Death Valley, Inyo County, California. Sections of the Amargosa River that do not support perennial surface flows in the absence of substantial rainfall events are indicated by the broken line; those sections normally supporting surface water occur primarily in Oasis Valley, in the vicinity of the Amargosa River Canyon, and near Saratoga Spring, and are indicated by a solid line; adapted from Williams et al. (1984).

In general, amphibian movements are occasional and limited (Sinsch 1990; Blaustein et al. 1994), but long-distance dispersal by anurans may be more common than historically assumed, in part because logistical realities often limit the size of study areas (Smith 2003). Further, the distances over which specific taxa can disperse often are poorly known (Smith and Green 2006), but long-distance movements by many species of bufonids have been described, and *A. woodhousii*—as well as a number of other congenerics—is capable of such movements (Smith and Green 2005, 2006; Palmeri-Miles 2012; Bleich 2020; Myers 2020). Expansion of the distribution of *A. woodhousii* in California and Nevada can be explained in large part by anthropogenic introductions, or other anthropogenic actions that have created suitable habitat (Bradford et al. 2005; Goodward and Wilcox 2019). In addition, severe precipitation events likely have provided opportunities for *A. woodhousii* to move long distances along intermittent waterways and colonize areas not contiguous with extant populations (Bleich 2020). Rainfall events similar in severity to those described by Bleich (2020) occur within the historical range of *A. nelsoni*, and further south along the Amargosa River (Tanko and Glancy 2001; WRCC 2020). Water flows above ground in and adjacent to the Amargosa River (Fig. 1, Fig. 2) for extended periods following such events (Tanko and Glancy 2001) and, although some sections dry spatially and temporally, other stretches remain wet year-round (Dodd 2013; Humphrey et al. 2017).

Numerous records of *A. woodhousii* recently have been confirmed along the Amargosa River, and elsewhere in the Amargosa River drainage basin, in Inyo and San Bernardino counties, California and Nye County, Nevada. In 2012, *A. woodhousii* was reported from an undisclosed location along the Amargosa River "south of Death Valley" (California Herps 2020a), and the species later was reported from wetlands along the Amargosa River ~5 km south of Tecopa, Inyo County (Greene and Branston 2013). Information provided initially by California Herps (2020a) was revised (California Herps 2020b) after the location was confirmed (G. Nafis, *in litt.*, 20 July 2020) to be that reported by Greene and Branston (2013). Observations (iNaturalist 2020) or museum specimens obtained in 2017 (VertNet 2020) confirmed persistence of the population described by Greene and Branston (2013), as well as additional locations along the Amargosa River. Further, *A. woodhousii* has become established in a reservoir and in wetlands along Willow Creek, a tributary to the Amargosa River near the China Ranch, in northern San Bernardino County and southern Inyo County (Appendix A). Greene and Branston (2013) estimated the Euclidean distance from their

Figure 2. Extreme precipitation events in the Amargosa River drainage basin frequently result in temporary wetlands that can serve as 'stepping-stone' habitat and facilitate dispersal by *Anaxyrus woodhousii*. This image depicts flooding on State Line Road at Carson Slough near Death Valley Junction, Inyo County, California, on 25 February 1998; adapted from Tanko and Glancy (2001).

recently discovered population of *A. woodhousii* to the nearest population of *A. nelsoni* to be 130 km. As of 2017, the Path Distance Function in Google Earth Pro indicated the distance between the nearest population of *A. woodhousii* on the Amargosa River to that of *A. nelsoni* in Oasis Valley was approximately 150 km as measured along the river channel. Nevertheless, in 2016, 2019, and 2020, Woodhouse's toad was confirmed at Ash Meadows National Wildlife Refuge (AMNWR), Nye County, an area supporting numerous springs and wetlands (Kodric-Brown and Brown 2007) and proximate to the Amargosa River. Confirmation of *A. woodhousii* at AMNWR increases the potential of its presence in the main channel of the Amargosa River at the same latitude, thereby placing it within a Euclidian distance of ~70 km (~100 km as measured along the river channel) of populations of *A. nelsoni*.

Neither date(s) nor source(s) of origin of these recently confirmed populations of *A. woodhousii* can be determined with certainty. A herpetofaunal survey of the Death Valley region that included portions of California and Nevada (Stejneger 1893) yielded no records of *A. woodhousii* (described at the time as *Bufo lentiginosus woodhousii*) in the vicinity of the Amargosa River, including Saratoga Spring—a perennial source of surface water separated from the river by a damp salt flat and thin layer of water (Bradley 1970)—or elsewhere along the Amargosa River, including Oasis Valley. Norris (1949:46) confirmed the presence of treefrogs (*Pseudacris regilla*), and Turner and Wauer (1963) confirmed the presence of *P. regilla* and red-spotted toads (*Anaxyrus punctatus*) at Saratoga Spring, but neither party reported *A. woodhousii* at that location. Norris (1950:117–118) also reported the presence of treefrogs and of introduced bullfrogs (*Lithobates catesbeianus*) at Fairbanks Ranch and at Fairbank's Springs—both within AMNW and having abundant water, mesquite trees, cottonwoods, tamarisk, and grass (Norris 1950:117–118; McCracken 1990:22). Neither Norris (1950) nor McCracken (1990) mentioned the presence of toads at either of those locations. It is certain, however, that *Anaxyrus* sp. was collected at Resting Springs in Chicago Valley, Inyo County, in 1891 (Stejneger 1893); Resting Springs is connected to the Amargosa River by a normally dry watercourse (Hershler and Pratt 1990) of ~5 km in length (Fig. 1).

Nearly 80 years following Stejneger's (1893) report, Bezy and Wright (1972) reported *A. punctatus*, but not Woodhouse's toad, during their herpetological survey of the Amargosa River Canyon. Additionally, I did not encounter Woodhouse's toad during extensive fieldwork along the Amargosa River between Willow Creek and Shoshone (Bleich 1972, 1974, 1979, 1980; Gould and Bleich 1977). Further, F. A. Gomez (*in litt.*, 7 September 2020), a resident of Tecopa from 1961 to 1985, does not recall observing any toads during countless hours spent recreating along the Amargosa River. Moreover, and roughly a century after Stejneger's (1893) report, neither Pratt and Hoff (1992) nor Persons and Nowak (2006) reported *A. woodhousii* in the Amargosa River drainage. Thus, available evidence suggests that Woodhouse's toad had not become established in that region prior to the work of Persons and Nowak (2006).

Whether the current distribution of *A. woodhousii* in the Amargosa River drainage represents multiple anthropogenic introductions, or is the result of range expansion from a single introduction, is not known. It is possible that Woodhouse's toad was present at one or more of these sites (Appendix A) prior to 2012, but the initial date(s) of any such appearance(s) cannot be ascertained, and the presence of *A. woodhousii* in the Amargosa River drainage is most apt to be a recent phenomenon. The ability of Woodhouse's toad to disperse along normally dry streambeds confirms it can move substantial distances when surface flows create suitable, albeit perhaps temporary, 'stepping stone' habitat (Bleich 2020), and such may contribute to an expanding distribution of *A. woodhousii* in the Amargosa River drainage and elsewhere. Stepping-stone habitat enhances the probability of dispersal into areas of noncontiguous—albeit otherwise suitable—habitat that can arise as a result of stochastic occurrences, among which are extreme rainfall events. Further, these habitat patches have allowed expansion of *A. woodhousii* (and other anurans) into previously unoccupied areas (Goodward and Wilcox 2019). Stepping-stone habitat also has the potential to promote gene flow among isolated populations, potentially enhancing persistence of recently established, but noncontiguous, demographic units (Bleich et al. 1990).

Anaxyrus spp. are especially vulnerable to congeneric hybridization, and interbreeding between Woodhouse's toad—a highly successful species capable of rapid or long-distance dispersal under suitable conditions—and ≥10 other bufonids has posed a conservation risk to several taxa (Hillis et al. 1984; Sullivan and Lamb 1988; Gergus et al. 1999; Lannoo 2005). If Woodhouse's toad becomes sympatric with *A. nelsoni*, the ramifications for disease transmission, ecological relationships (i.e., competition), hybridization and resultant genetic introgression (Fig. 3), or behavioral modifications, singly or in combination, bode poorly for the future of Amargosa toad as a viable taxon (Carey et al. 2003; Sullivan 2005).

Figure 3. Woodhouse's toad (*Anaxyrus woodhousii*) has hybridized with at least 10 other species in the western United States as summarized by Sullivan (2005), and readily breeds with other members of the family Bufonidae as demonstrated here with a red-spotted toad (*Anaxyrus punctatus*). If Woodhouse's toad attains sympatry with Amargosa toad (*Anaxyrus nelsoni*), the potential for genetic introgression will become a primary conservation concern. Photograph © B. J. Putman, 6 April 2017, China Ranch, San Bernardino County, California; used with permission.

The recent and continuing de-emphasis of natural history as a respectable scientific discipline by many colleges and universities (Noss 1996; Kessler and Booth 1998; Bleich and Oehler 2000; Bleich 2018) has yielded decreased interest in the relevance of descriptive ecology or distributional records. Citizen science, however, is beginning to fill that void, and increasingly is recognized as a valued and valid source of information (Gura 2013; Ballard et al. 2017; Spear et al. 2017; Parker et al. 2018b). It is through such efforts that shifts in the distribution of *A. woodhousii* along the Amargosa River (iNaturalist 2020) and elsewhere (Goodward and Wilcox 2019), or documentation of the western toad (*Anaxyrus boreas*) in the Amargosa River drainage (iNaturalist 2020) recently have become available or are tractable, but shortcomings do exist. For example, while emphasizing the value of the riparian ecosystem associated with the Amargosa River and its importance to a variety of taxa, Parker et al. (2018a) failed to note that *A. woodhousii* is not native to that system or to call attention to the ramifications of its presence.

Proximity of Woodhouse's toad to the distribution of *A. nelsoni* was noted by Greene and Branston (2013). More recently, *A. woodhousii* has been confirmed at multiple locations along the Amargosa River, and potentially within 100 km of Oasis Valley. The dispersal ability of Woodhouse's toad and the occurrence of multiple disjunct populations of this highly adaptable bufonid in the same river drainage occupied by a vulnerable congeneric raise concern and suggest additional efforts are necessary to understand the current distribution of *A. woodhousii*. Demonstrating the potential impact of an exotic or invasive species, however, need not require conclusive proof (Carey et al. 2003) before action is taken to prevent development of an egregious, and perhaps irreversible, situation. As emphasized by Bradford et al. (2005), doing so is a tremendous challenge, but fear-of-failure to preclude development of sympatry between an endemic species of limited distribution and a widespread and highly adaptable invasive species should not prevent efforts to ensure the persistence of *A. nelsoni* as a viable taxon (Meek et al. 2015). I suggest conservation agencies and interested parties—including citizen-scientists (Bass 2016)—work collaboratively to record shifts in the distribution of Woodhouse's toad along the Amargosa River and that actions to prevent the northward dispersal of *A. woodhousii*—and the potential for sympatry with *A. nelsoni*—be initiated immediately.

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Greene (CDFG) for correspondence and conversations regarding the potential sources of *A. woodhousii* initially documented in the Amargosa River drainage basin. I also thank two anonymous reviewers for helpful comments that improved the manuscript. My early work in the Amargosa River watershed was funded in part by a travel grant from the El Dorado Chapter of the National Audubon Society, and later by CDFG Federal Aid in Wildlife Restoration Projects W-26-D (Wildlife Habitat Development) and W-54-R (Special Wildlife Investigations). Manuscript preparation was supported by the Eastern Sierra Center for Applied Population Ecology. This is Professional Paper 136 from the Eastern Sierra Center for Applied Population Ecology.

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APPENDIX A. RECORDS OF *ANAXYRUS WOODHOUSII* IN THE AMARGOSA RIVER DRAINAGE

The Amargosa River drains a watershed of 15,540 km^2 (Menges 2008). The river extends ~198 km from its origin on Pahute Mesa, Nye County, Nevada, through a portion of southern Inyo and northern San Bernardino counties, California, and reaches is terminus in Death Valley, Inyo County. Within the drainage basin, and as of the date of this publication, *Anaxyrus woodhousii* has been confirmed in that portion of Amargosa River near Tecopa, California, and at Ash Meadows National Wildlife Refuge, Nye County, Nevada.

Date	General Location	County	Latitude	Longitude	Source
Apr 2012	Amargosa River, ~4 km SSE of Tecopa	Inyo [a]	35.815919	-116.214778	LACM PC 1602, 1603 [d, e]
Mar 2016	Ash Meadows National Wildlife Refuge	Nye [b]	36.401367	116.274716	iNaturalist 10173429 [f]
Apr 2017	China Ranch Reservoir, China Ranch	Inyo	35.804388	-116.183839	iNaturalist 5633718 [f]
Apr 2017	China Ranch Reservoir, China Ranch	Inyo	35.805131	-116.183450	iNaturalist 5633759 [f]
Apr 2017	China Ranch Reservoir, China Ranch	Inyo	35.804388	-116.183839	iNaturalist 5633770 [f]
Apr 2017	China Ranch, adjacent to main parking area	Inyo	35.799762	-116.194764	iNaturalist 5645084 [f]
Apr 2017	China Ranch downstream from main parking area	Inyo	35.799008	-116.195107	iNaturalist 5645092 [f]
Apr 2017	Amargosa River, S confluence with Willow Creek	SB [c]	35.783139	-116.201470	iNaturalist 5645123 [f]
Apr 2017	Amargosa River, 4.2 km S Old Spanish Trail Hwy	Inyo	35.814089	-116.210463	iNaturalist 5712521 [f]
Apr 2017	Amargosa River, 4.0 km S Old Spanish Trail Hwy	Inyo	35.815352	-116.21093	iNaturalist 5633669 [f]
Apr 2017	China Ranch, adjacent to main parking area	Inyo	35.799733	-116.194892	iNaturalist 5648539 [f]
Apr 2017	Amargosa River, 3.7 km S Old Spanish Trail Hwy	Inyo	35.817289	-116.21411	iNaturalist 5645134 [f]
Apr 2017	Amargosa River, 3.7 km S Old Spanish Trail Hwy	Inyo	35.817325	-116.214076	iNaturalist 5645137 [f]
Apr 2017	Amargosa River, 4.4 km S Old Spanish Trail Hwy	Inyo	35.810046	-116.211608	iNaturalist 5645143 [f]
Apr 2017	Amargosa River, 1.4 km S Old Spanish Trail Hwy	Inyo	35.836011	-116.222668	iNaturalist 5645177 [f]
Apr 2017	Amargosa River, 750 m S Old Spanish Trail Hwy	Inyo	35.841682	-116.225401	iNaturalist 5645175 [f]
Apr 2017	China Ranch Reservoir, China Ranch	Inyo	35.80505	-116.18379	LACM Herps 188785 [e]
Apr 2017	China Ranch Reservoir, China Ranch	Inyo	35.80505	-116.18379	LACM Herps 188786 [e]
Apr 2017	Amargosa River, 4.0 km S Old Spanish Trail Hwy	Inyo	35.81580	-116.21164	LACM Herps 188789 [e]

APPENDIX A. CONTINUED

Date	General Location	County	Latitude	Longitude	Source
Apr 2017	Willow Creek, downstream of China Ranch [g]	SB	35.789746	-116.199901	iNaturalist 5633649 [f]
May 2017	Ash Meadows National Wildlife Refuge	Nye	36.401093	-116.274748	iNaturalist 6409166 [f]
Apr 2019	Ash Meadows National Wildlife Refuge	Nye	36.432697	-116.310188	iNaturalist 22147290 [f]
Mar 2020	Ash Meadows National Wildlife Refuge	Nye	36.401542	-116.273897	iNaturalist 40312776 [f]

[a] Inyo Co., California
[b] Nye Co., Nevada
[c] San Bernardino Co., California
[d] Greene and Branston (2013)
[e] Los Angeles County Museum of Natural History specimen number
[f] Locations associated with iNaturalist records are available at https://www.inaturalist.org/observations
[g] Location at which image in Fig. 2 was obtained

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FULL RESEARCH ARTICLE

Population estimate of wild rainbow trout in a remote stream of southern California

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Recreational fishing for Rainbow Trout (*Oncorhynchus mykiss*) is important economically in California. We determined the upstream and downstream distribution of Rainbow Trout in a southern California stream, and classified all available habitat within that area as riffle, pool, cascade-pool-complex, and flatwater. Approximately 10% (based on length) of each habitat type was sampled using depletion electrofishing. We estimated Rainbow Trout abundance, both <100 mm and ≥100 mm, by extrapolating average number of fish per m^2 in each habitat type sampled to the total m^2 of each habitat type. A total of 854 fish were captured, with the greatest proportion coming from the cascade-pool-complex habitat type, followed by pool, flatwater, and riffle. The population estimate for Rainbow Trout <100 mm was 1,763 fish (95% CI ±442), and for Rainbow Trout ≥100 mm was 5,383 fish (95% CI ±1,688).

Key words: depletion electrofishing, population estimate, Rainbow Trout

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Recreational fishing for trout in California has cultural, historic, aesthetic, and economic importance. Many anglers from the United States as well as foreign countries travel to California for the opportunity to fish its inland waters (Alkire 2003). Of these anglers visiting California, approximately 2.7 million chose angling in freshwater systems, and 1.9 million of those anglers pursued wild trout (Anderson 1990; U.S. Department of the Interior 1998;). In 2011, the U.S Fish and Wildlife Service reported 54% of all freshwater fishing days in California were focused on trout and estimated trip and equipment expenditures at $1.1 billion (USFWS 2011).

In San Diego County, Rainbow Trout (*Oncorhynchus mykiss*) are near the southern limit of their distribution (Abadia-Cardoso et al. 2016). Although many of the reservoirs in San Diego County are stocked in the winter months with Rainbow Trout, these facilities require fees to fish and do not provide the solitude and wild fish many trout anglers seek. Only three stream populations of wild Rainbow Trout are available for anglers to pursue in San Diego County (i.e., Pauma Creek, West Fork San Luis Rey River, and Sweetwater River), yet only Los Angeles County has a greater number of people (United States Census Bureau 2020). The California Department of Fish and Wildlife regularly monitors these populations, but no angler survey boxes are present, no creel surveys have been conducted, and no baseline population estimates for these populations have been conducted or published. To manage stream populations of Rainbow Trout more effectively we sought baseline data on their distribution and abundance. Here we report findings for Pauma Creek conducted in the summer of 2012 and 2013.

Sound statistical design is essential when attempting an abundance estimate within a stream. The study design must be mindful of time and person hours necessary to complete the abundance estimate, but also be detailed enough for the data to be useful. Some of the many ways to adjust fisheries research to these design complexities are reviewed by Johnson and Nielsen (1983), Brown and Austen (1996), Willis and Murphy (1996), and Ney (1999). Appropriate statistical design must also consider locations carefully to ensure a moderate degree of success. To provide data for future management of the Pauma Creek Rainbow Trout population, we chose to create a statistically sound estimate of abundance in the perennial section of Pauma Creek by censusing all available habitat and estimating density in a random sample of habitat units.

METHODS

Study Area

Pauma Creek is a second order stream (Strahler 1964), in northern San Diego County, California, and drains 62.9 km^2 of the southwestern face of the Agua Tibia Mountain Range and Palomar Mountain (Fig. 1). The 13 km stream begins at the confluence of French and Doane creeks. Rainfall is seasonal with most precipitation occurring from October to April, approximately 76 cm annually (Kajtaniak and Downie 2010). Palomar Mountain rainfall exceeds the amounts reported elsewhere in San Diego County, and this, coupled with high relative humidity, supports the dominant vegetative cover of mixed hardwood forest. The gradient of Pauma Creek is steep (> 10%) and elevation ranges from 223 m above mean sea level at the confluence with the San Luis Rey River to elevations as high as 1,585 m in the headwaters of Doane and French creeks (Kajtaniak and Downie 2010). Our temperature logger data from 2015 indicate water temperatures are moderate with summertime highs reaching 21° C and winter lows reaching 7° C. The riparian zone is dominated by White Alder (*Alnus rhombifolia*), with limited willows and dogwood. Primary landowners are the U.S. Forest Service, California State Parks, and local Native American tribes (Fig. 2). The wild Rainbow Trout present in Pauma Creek are descendants of hatchery fish (Abadia-Cardoso et al. 2016), located upstream of multiple barriers to anadromous migration, and therefore, not considered part of the Southern California Distinct Population Segment of anadromous steelhead.

Habitat Typing

Classification and enumeration of each habitat type facilitates statistically sound estimates of abundance through censusing the amount of each habitat type within a particular stream, and then sampling a randomly selected subset of each habitat type for fish abundance (Hawkins et al. 1993). This approach provides estimates of fish abundance for each specific habitat type and can be combined to estimate population abundance for the entire stream (Hawkins et al. 1993).

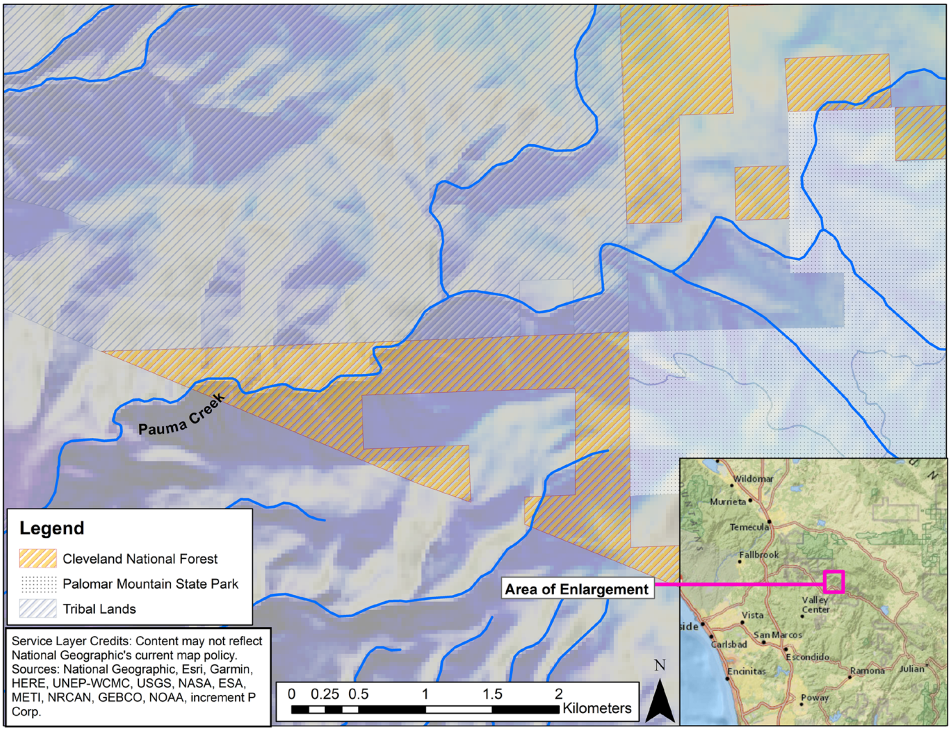

Figure 1. Overview showing the location of Pauma Creek, San Diego County, California.

In 2012, we surveyed the entire perennial section of Pauma Creek to determine the extent of Rainbow Trout occupancy. No water was present on the valley floor, and most of the tributaries were dry. Doane and French creeks contained a few fish in isolated pockets but were mostly dry when sampling occurred. We habitat typed all of Pauma, Doane, and French creeks. Two people typed habitat during summer base flows, one to measure lengths, widths, and depths, and one to record data. We maintained consistent classification of habitat units by having the same person be responsible for all classification. Once a determination of habitat type was made, we marked a piece of orange flagging indicating the habitat type and tied it to a tree near the downstream end of the unit. Individual habitat units were classified as riffle, pool, cascade-pool-complex (CPC), and flatwater, which we based on level III surveys detailed in Flosi et al. (2010). We measured total thalweg length in each unit, along with three randomly selected widths. For units longer than 20 m, a total of five randomly selected widths were measured, and we estimated average depth.

Depletion Sampling

To estimate the Rainbow Trout population, we randomly selected habitat units from our census, and used depletion electrofishing. To determine which units would be sampled we randomly selected a number and walked upstream until the randomly selected number of units had been traversed. For example, if the number three were randomly selected while we were standing at the upstream end of a pool, the unit above the pool would be counted as unit number one. The next three units would be walked through, and the fourth unit would

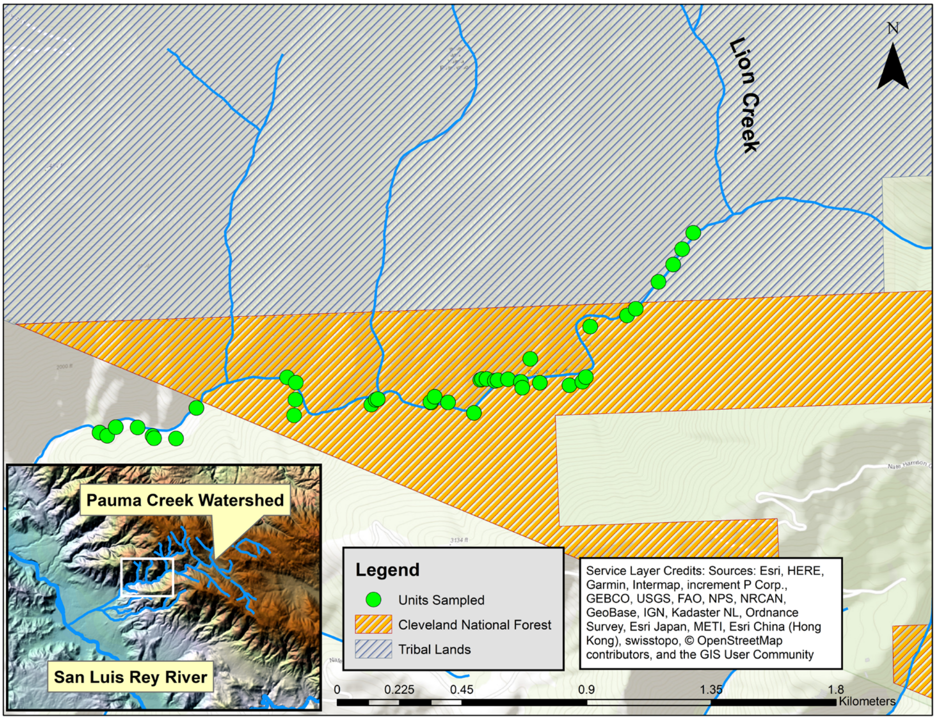

Figure 2. Detail map of Pauma Creek, San Diego County, California. Only the lower portion of Pauma Creek is shown to provide details regarding the location of each habitat unit sampled.

be sampled. The only exceptions were deep pools. Any randomly selected pools deeper than 2 m were skipped due to poor sampling efficiency of backpack electrofishing equipment.

We halted sampling at the confluence with Lion Creek due to low flows and a lack of water within the stream. An approximately 300 m section of stream had no surface water on 23 August 2013 and all sections upstream of the dry section exhibited flows <1 ft^3 sec^{-1}. While there were a small number of isolated pools that appeared to contain fish upstream of Lion Creek, we chose not to include them in our sample as they were atypical of pools in the free flowing section of Pauma Creek previously sampled.

We employed the standard block net and depletion electrofishing techniques detailed in Temple and Pearsons (2007). The crew consisted of three individuals: one to run the backpack electrofishing unit, one to net fish, and one to carry the bucket in which stunned fish were placed. Each habitat unit was fished in an upstream direction only. No pass was made in the downstream direction because walking upstream typically produced a sediment cloud that precluded an effective downstream pass. A reduction rule was used to determine the number of passes for each habitat unit: if the number of Rainbow Trout captured on the first pass was less than 10, additional passes were made until we achieved a 50% reduction in the number of Rainbow Trout captured from the preceding pass; if the number of Rainbow Trout captured on the first pass was greater than or equal to 10, additional passes were made until we achieved a 66% reduction in the number of Rainbow Trout captured from the preceding pass (Rodgers et al. 1992). For example, if nine fish were caught on the first pass, four fish were allowed on the second pass. If 20 fish were caught on the first pass, seven fish were allowed on the second pass.

We used a Smith Root LR-24 backpack electrofishing unit throughout the study. Settings were based upon the quick-set-up function available with the LR-24 and raising the suggested voltage by 30 volts. We used a pulsed DC waveform with a frequency of 30 Hz and a 12% duty cycle. Voltage used varied from 200-300 volts and was dependent upon conductivity. Habitat complexity (i.e., large rocks with interstitial spaces) prevented the effective use of long-handled, large dip nets within Pauma Creek, so 8-inch aquarium nets and hands were used to capture most fish. All stunned fish were placed in a bucket with a bubbler until the end of each respective pass. Captured fish were measured after each pass to the nearest mm (fork length), weighed to the nearest gram, and placed in an additional bucket with an air bubbler. Anesthetic was not used to measure and weigh fish. Initiation of the next pass would not begin until a minimum of 30 minutes had elapsed from the end of the previous pass. This allowed recovery of remaining fish to improve the chance of equal capture probability among electrofishing passes (*sensu* Cross and Stott 1975). All fish captured during each electrofishing pass were kept in separate buckets with air bubblers until sampling of the unit was completed. Once all passes were completed, fish were released over the entire length of the sampled habitat unit.

Population Estimate

Data from captured fish were subdivided into fish with fork length <100 mm and fish ≥100 mm because previous research has shown that smaller trout have lower catchability (Lohr and West 1992; Anderson 1995; Thompson and Rahel 1996; Korman et al. 2009), and electrofishing capture efficiency in streams may be influenced by size of fish (Sullivan 1956; Mahon et al. 1979). Estimates of Rainbow Trout abundance, both <100 mm and ≥100 mm, were made by summing first and second pass captures and third and fourth pass captures across each of the four habitat types and extrapolating average number of fish per m² in each habitat type sampled to the total m² of each habitat type in the creek. Only units sampled 2 or 4 times were used to facilitate use of equations associated with the case of two removals in Bohlin et al. (1989). We conducted Simple Random Sampling ratio estimation of population size and estimated the total fish population in each stratum using equation 23 from Bohlin et al. (1989)

$$\hat{Y} = M\sum^{n} \hat{y}_i / \sum^{n} m_i$$

Where M is the total size m² of the stratum, $\hat{y}_i$ is the total number of fish captured within the stratum, and m_i is the total area m² of the stratum sampled. The population density was estimated using equation 23′ from Bohlin et al. (1989)

$$\hat{Y} = \sum^{n} \hat{y}_i / \sum^{n} m_i$$

Where $\hat{y}_i$ is the estimated number of fish within a sampled unit, and m_i is the area m² of the sampled unit. The number of fish/m² was estimated for all units sampled, then extrapolated to the total m² of that habitat type. The estimated number of fish in a sampled unit was calculated using equation 13 from Bohlin et al. (1989)

$$\hat{y}i = c_1^2/(c_1 - c_2)$$

Where c_1 is the number of fish captured in pass 1 and c_2 is the number of fish captured in pass 2. Sample variance was calculated using equation 14 from Bohlin et al. (1989)

$$\hat{V}(\hat{y}i) = \frac{C_1^2 C_2^2 (C_1 + C_2)}{(C_1 - C_2)^4}$$

Where c_1 is the number of fish captured in pass 1 and c_2 is the number of fish captured in pass 2. This sampling variance is the second part of equation 22 from Bohlin (1989), while the first part is spatial variance. Statistical analysis used a standard two-stage sample design (Bohlin 1981) to estimate variances. Total variance was calculated using equation 22 from Bohlin et al. (1989)

$$\hat{V}(\hat{Y}) = \frac{N}{n}(N-n)\hat{V}(\hat{y}) + \frac{N}{n}\sum^{n}\hat{V}(\hat{y}_i)$$

Where N is the total number of units of each habitat type and n is the total number of units of each habitat type sampled. The first term in this equation represents the spatial variation of the trout population while the second is sampling error based on the above calculation of sample variance. Spatial variance was calculated using

$$V(\hat{y}) = \sum^{n} \frac{(\hat{y}_i - \hat{y})^2}{n-1}$$

Approximate (95%) confidence limits were calculated using equation 3 from Bohlin et al. (1989)

$$\hat{y} + /-2\widehat{SE}(\hat{y})$$

Where $\widehat{SE}$ s standard error estimated from the square root of the total variance calculated above.

RESULTS

Habitat Typing

The length of Pauma Creek occupied by Rainbow Trout was just over 9 km, leading to us habitat type 9,191 m of stream channel. Stream habitat was dominated by CPC which was over half of all habitat classified (Table 1) and included several reaches that were over 50 m in length. The percentage of each habitat type was 8%, 29%, 54%, and 9% for riffle, pool, CPC, and flatwater, respectively. Pools deeper than 2 m were skipped if randomly selected, and of the 306 total pools, only 8 were deeper than 2 m. The total length of these 8 pools was 101 m and represents 4% of all pool habitat. Only one deep pool was randomly selected and skipped.

Table 1. Total number of each habitat type, total length of each habitat type, mean width of each habitat type, and mean depth of each habitat type in Pauma Creek.

Habitat Type	Total no. units	Total length (m)	Mean width (m)	Mean Depth (m)
Pool	306	2685	4.11	0.5
Riffle	95	707	2.18	0.1
Flatwater	64	840	3.09	0.2
Cascade Pool Complex	267	4960	3.23	0.2

Population Estimate

Sampling began 29 July 2013 and was completed 20 October 2013 just downstream of the confluence with Lion Creek (Figure 2). Reducing the area available for sampling left 4.3 km and altered the percentage of each habitat slightly. The percentage of riffle habitat within the 4.3 km went up to 10%, while pool increased to 38%, CPC decreased to 50%, and flatwater decreased to 2%. Within the revised sampling area, 45 habitat units were sampled (Figure 2), representing 14% of the habitat based on length and area and 11% based on number (Table 2). A total of 854 fish were captured, with the greatest proportion coming from the CPC habitat type, followed by pool, flatwater, and riffle.

The population estimate for Rainbow Trout <100 mm was 1,763 fish (95% CI ±442). Population estimates ranged from 116 to 776 (Table 3) in the different habitat types, while 88% of all estimated fish <100 mm were in the pool and CPC habitat types.

Table 2. Within the revised sampling area of Pauma Creek, the number of units of each habitat type (N), the total number of units of each habitat type sampled (n), and the sample percent of the total. Area is in m^2, and length is in m.

Habitat	Total habitat			Sampled habitat			Sample percent of total		
type	N	area	length	n	Area (m^2)	Length (m)	n	Area (m^2)	Length (m)
Riffle	65	985	403	5	119	55	8	12	14
Pool	185	6803	1658	17	630	153	9	9	9
CPC	134	6672	2172	16	1066	330	12	16	15
Flatwater	8	413	100	7	275	89	88	67	89
Total	392	14873	4333	45	2090	627	11	14	14

Table 3. Population estimate of Rainbow Trout in Pauma Creek <100 mm.

Habitat type	Fish captured	Population estimate	Variance	±95% CI	CI % of pop. est.	Fish/m^2
Riffle	14	116	1,394	73	63	0.118
Pool	64	767	25,211	311	41	0.113
CPC	116	776	28,984	334	43	0.116
Flatwater	60	104	338	36	35	0.252
Total	254	1,763	55,927	442	26	0.119

The population estimate for Rainbow Trout ≥100 mm was 5,383 fish (95% CI ±1,688). Population estimates ranged from 50 to 3,414 (Table 4) in the different habitat types, and 97% of all estimated fish ≥100 mm were in the pool and CPC habitat types.

DISCUSSION

Estimating the abundance of stream-dwelling salmonids is a frequently used management strategy (Rodgers et al. 1992). For example, Habera et al. (2010) note many small southern Appalachian streams are sampled regularly with depletion techniques to obtain

Table 4. Population estimate of Rainbow Trout in Pauma Creek ≥100 mm.

Habitat type	Fish captured	Population estimate	Variance	CI % of ±95%CI	pop. est.	Fish/m^2
Riffle	6	50	2,499	98	196	0.051
Pool	279	3,414	540,606	1,441	42	0.502
CPC	262	1,821	197,698	871	48	0.273
Flatwater	53	98	531	45	46	0.237
Total	600	5,383	741,334	1,688	31	0.362

abundance estimates (Neves and Pardue 1983; Ensign et al. 1991; Habera et al. 1996). These sampling efforts serve the same purpose as similar efforts here in southern California: to inventory and monitor wild (self-sustaining) trout populations and provide data to assist in current and future management.

We estimate a total of 7,146 Rainbow Trout were present within the perennial 4.3 km of Pauma Creek. This breaks down to 0.6 fish/m, or 2 fish/m^2. Approximately 88% of the estimated population of fish < 100 mm are thought to be in the CPC and pool habitat types. Approximately 97% of the population of fish ≥100 mm are thought to be in the CPC and pool habitat types. These complex habitats contained more boulder substrate, which previous research has shown influences the presence of both juvenile and adult salmonids (Baltz et al. 1991; Gries and Juanes 1998; Meyer and Gregory 2000). The CPC and pool habitat types were also the dominant habitat types in terms of both length (~88%) and area (~91%).

The abundance estimate for Rainbow Trout in Pauma Creek is likely an underestimate of the true abundance. Many researchers have reported that multiple pass removal estimates overestimate capture efficiency and underestimate abundance (Peterson and Cederholm 1984; Riley and Fausch 1992; Peterson et al. 2004; Habera et al. 2010; Meyer and High 2011). However, Myer and High (2011) also report that depletion electrofishing in small Rocky Mountain streams with moderate channel complexity can produce estimates of abundance that are only slightly biased in the negative direction.

To address the size selectivity of electrofishing for Rainbow Trout, captured fish were subdivided into fish <100 mm, and fish ≥100 mm. Habera et al. (2010) found stratification of electrofishing data by fish size was essential to help offset catchability variation, and reported recapturing 88% of Rainbow Trout over 100 mm and 65% of Rainbow Trout under 100 mm. Furthermore, the measured first pass capture efficiencies in Habera et al. (2010) were 46% for fish <100 mm and 74% for fish >100 mm, while estimated first-pass capture efficiency for all habitat types in Pauma Creek were 73% for fish <100 mm and 73% for fish ≥100 mm. To limit bias, electrofishing was conducted by a few experienced individuals, and the same crew lead was always present. We believe our high estimates of first pass capture efficiencies coupled with an experienced crew led to fairly low levels of negative bias.

Our population estimates for Rainbow Trout ≥100 mm (5,383) and <100 mm (1,763) were very different, with substantially fewer fish <100 mm. We attribute these differences to the inherent size selective nature of electrofishing. Reynolds (1983) wrote that conclusions regarding length frequency data from electrofishing samples should be treated cautiously because data regarding the relative abundance of small fish is probably biased in the negative direction. Sullivan (1956) and Mahon et al. (1979) showed capture efficiency of electrofishing in streams may be influenced by the size of fish, and other researchers such as Zalewski and Cowx (1990) and Reynolds (1996) have linked immobilization thresholds of electrofishing to fish size. More detailed research indicates small trout tend to have lower catchability than large trout (Lohr and West 1992; Anderson 1995; Thompson and Rahel 1996; Korman et al. 2009). It is also likely the complex habitats of CPC and pools, dominated by boulder substrate, influenced depletion estimate bias as Myer and High (2011) found.

Considering our population estimate of 7,146 Rainbow Trout in the perennial 4.3 km of Pauma Creek, we believe this population is abundant and stable. Repeated annual surveys since this intensive effort in 2013 have revealed minor fluctuations in the relative abundance of fish (R. Barabe Unpublished Data). Halting sampling at the confluence of Lion Creek prevented us from estimating abundance in all of Pauma Creek, but as noted earlier, we were unable to determine a way to randomly select habitat units when only one habitat type (pools) contained fish and water. While extreme changes in flow ranging from drying to flooding has been reported as a common occurrence in arid southern California (Gasith and Resh 1999), Pauma Creek does not become intermittent annually. This area of San Diego County receives an average annual rainfall of 76 cm, versus 30 cm in the lower elevation areas of the County. The conditions witnessed in 2013 were likely in response to drought.

The Rainbow Trout in Pauma Creek are one of three remaining wild Rainbow Trout populations within San Diego County. Stocking Rainbow Trout in reservoirs has been and continues to be prevalent, but stocking streams was halted in the early 2000s. The Rainbow Trout of Pauma Creek provide nearby residents a fairly local experience where anglers can capture wild fish without driving to the Sierra Nevada mountains. This is important when we consider that San Diego County is the second most populous county in California. Additionally, access to Pauma Creek is limited to a single location upstream and a single location downstream, making it difficult for fishermen to deplete this population through harvest or catch and release. We believe these data could be useful for comparisons in the future and might even help future managers if restrictive regulations are needed.

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COMMENTARY

Fire on the mountain—run boys, run!

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Key words: bighorn sheep, California, conflict, habitat enhancement, land management, legislation, litigation, *Ovis canadensis*, politics, prescribed fire, protected area, wilderness

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> *Perhaps it is time to once again steal fire from the mountain gods and through a great relay, bring fire and the message of disturbance ecology back to the modern-day people of the world.*
>
> *J. Saveland (1995)*

Fire was among several topics dominating the news in 2020, and it received unprecedented coverage in California. As a result, publication of the special issue of *California Fish and Wildlife Journal* that focused on fire and fire management (Baker et al. 2020) was timely, and it provided the impetus for these comments. As noted by Shaffer (2020) in his introduction to the special issue, native plant and animal communities are greatly impacted in the absence of fire or by greatly altered fire regimes; further, it must be kept in mind that effects of fire management policies on wildlife can be direct or indirect (Shaffer and Laudenslayer 2006). Moreover, there is a continuing need to enhance understanding about ecological systems and their drivers, of which fire is a critically important element (Britting 2020) and, perhaps, second only to water with respect to its ecological influence in California (Shaffer 2020). Thus, topics as diverse as policy and vegetation treatments (Church et al. 2020; Fuller et al. 2020; Green et al. 2020), effects of fire on vegetation (Ayres et al. 2020; Klip et al. 2020; Lindstrand et al. 2020), or impacts or benefits of fire to wildlife or water (Cook and Hayes 2020; Doyle et al. 2020; Williamson and Weckerly 2020) included in the special issue are meaningful and welcomed contributions to the literature on resource conservation and management. Missing from the discussion was an assessment of fire management in the big picture context of wildlife conservation—particularly as it relates to protected areas—and that omission provided the impetus for this commentary.

Shortly before publication of the special issue, Covington and Pyne (2020) offered opinions on wildfire in the contexts of climate change and vegetation management strategies, and noted that wildfire is not, "[a] 'wicked' problem so entangled with scientific and social complexities that solutions are impossible". Despite that optimism, social and political complexities associated with fire or fire management are burdensome—and all-too-frequently are impossible—to overcome. Controversy associated with the use of prescribed fire has impacted 'naturalness' outside of, but especially within, legislated wilderness (Christensen 1995; Cole and Landres 1996). Even small projects, such as those advocated by Holl et al. (2012) to help ensure viability and persistence of bighorn sheep (*Ovis canadensis*)—a USFS sensitive species (USFS 2005) dependent on chaparral habitat in southern California (Light et al. 1966; Holl et al. 1983; Bleich 2010; Bleich et al. 2008, 2019)—can require thousands of pages of analysis (Stemler 2020). Further, the Equal Access to Justice Act (EAJA) provides almost unlimited opportunities to recoup expenses for lawsuits against the federal government (Lofthouse et al. 2014; Baier 2011, 2015). Thus, the EAJA virtually guarantees that any action not to the liking of a special-interest group will be opposed (see, for example, Wilderness Watch 2021) and followed by litigation. Win or lose, the plaintiffs are rewarded and federal reimbursements for legal fees incentivize and encourage subsequent litigation (Mortimer and Malmsheimer 2011).

It is well established by Pyne et al. (1996) and many others that, "… from the earliest times, humans have altered the natural fire regimes [everywhere]", and for thousands of years the number of anthropogenic fires far exceeded those from other causes across much of North America (Kay 2002; Williams 2002). Many issues complicate contemporary fire management (Czech 1996), however, and opposition to the use of fire for fuel reduction or wildlife habitat enhancement became ensconced firmly in the political arena with passage of the Wilderness Act (United States Congress 1964) and subsequent legislation that created obstacles both to prescribed ignitions and fire suppression in those 'protected' areas (Czech 1996). When these obstacles are combined with the likelihood of litigation (Baier 2011, 2015; Lofthouse et al. 2014) or persistent social and institutional barriers (Quinn-Davidson and Varner 2011; Miller and Aplet 2016), they are compounded further by bureaucratic inertia (Grumbine 1990). As a result, the need for clarifications, meaningful decisions, and proactive management is exacerbated.

Ten years after passage of the Wilderness Act the U. S. Forest Service changed its policy from one of fire suppression to one of fire management (DeBruin 1974; see also Pruden and Brennan 1998), yet prescribed fire in Forest Service wilderness occurs infrequently (Stephens and Sugihara 2006), and even more rarely in the chaparral ecosystems of southern California (Holl and Bleich 1983, 2010; Holl et al. 2012). Moreover, annual declines in hectares burned from 1998 to 2018 confirmed long-term downward trends in use of prescribed fire throughout California (Kolden 2019).

The practicality of restoring natural fire regimes in wilderness has been questioned (Husari 1995), but revised policies in place since 1968 in National Park Service wilderness allow some lightning-caused fires to burn if compatible with resource management objectives (Zimmerman and Bunnell 2000; Stephens and Sugihara 2006), and long-term programs are in place in wilderness areas of Yosemite National Park and elsewhere on some lands managed by the U.S. Forest Service (NPS 2004; Husari and McKelvey 1996). Despite these positive steps, the issues and concerns expressed by Covington and Pyne (2020) are timely and appropriate, and also are globally applicable (Kelly et al. 2020; Pickrell and Pennisi 2020).

Changing climates demand new, easily adaptable policies among agencies (Stephens and Ruth 2005), and a debunking of the notion that 'wilderness' necessitates an absence of anthropogenic manipulation (e.g., Grant and Geiger 2021). Interpretations of legislation or policies vary widely among, and even within, land management agencies, but directly impact conservation imperatives inside and outside of wilderness (Bailey 1992; Bleich

1999a, 1999b, 2005, 2016). Indeed, it is essential that fire management strategies that will enhance ecological integrity and reduce hazardous fuels (Covington and Pyne 2020) be implemented, especially in 'wilderness' proximate to, and in some cases abutting, urbanized areas; among examples are the Lone Peak Wilderness and Twin Peak Wilderness in Utah, and Arizona's Pusch Ridge Wilderness. And, where natural or prescribed fire cannot be an option, mechanical manipulation to facilitate maintenance or restoration of ecosystem processes may be appropriate and receive consideration (Leopold et al. 1963; Green 1977; Bleich and Holl 1982; Parsons and Landres 1998; Bleich 1999a; Miller et al. 2011).

Decisions to use fire or mechanical options in wilderness will be controversial (see, again, Wilderness Watch 2021), must be based on the best possible information (Parsons and Landres 1998), but also will require fundamental changes in how wilderness areas are defined and managed (Cole et al. 2008). The U.S. Congress (1964) constrained management options in wilderness; as a result, only Congress can address issues associated with fire management and its ramifications for wildlife habitat and, ultimately, species conservation therein. This paradox is confounded immensely by wilderness advocates within and outside of federal land management agencies (Bleich 1999a), the increasing likelihood of climate change (Covington and Pyne 2020; Kelly et al. 2020), and an expectation that future climate will enhance conditions favorable to ignitions and subsequent spread of large wildfires (Miller et al. 2011; Yoon et al. 2015; Goss et al. 2020). The prevailing mantra that wilderness must remain inviolate to anthropogenic influences in order to ensure "untrammeled" settings essential to otherwise intangible benefits (Spurr 1966; Larsen 1997; Fredrickson and Anderson 1999; Johnson 2002; Tin 2012; Miller et al. 2020 [but see Corliss {2019} and Henderson {2020}]) further complicates fire management, and has enormous, albeit largely negative, implications for wildlife conservation or ecosystem function.

It was almost simultaneously, in 1964, that the Wilderness Act became law and Bob Dylan released his near-prophetic ballad, *The Times, They Are a-Changin'* (Gray 2006). Since then, shifting environmental conditions have yielded a change in the realized niche of many species (Pineda-Munoz et al. 2021), animal distributions have been altered (Thomas 2010), and conservation priorities have evolved (Parks et al. 2020). Fire regimes are anticipated to change even further (Parks et al. 2018 for review), and mitigation in the form of proactive measures—even in 'protected areas'—has been identified as desirable, or even necessary, to maintain biodiversity and facilitate population connectivity (Hannah 2008; Thomas and Gillingham 2015; Parks et al. 2020; Pineda-Munoz et al. 2021).

Designation of wilderness is an opportunistic political process (Haufler et al. 1996) that historically has reflected a near absence of ecological considerations (Bleich 2005, 2016). Despite widespread environmental change and a realization that proactive intervention on behalf of conservation will become increasingly appropriate, the management of fire and fuels remains a complex issue. It is a problem that crosses traditional disciplinary boundaries, and resolution requires integration of social and biological issues (Conard and Weise 1998; Krausman and Czech 2000; Miller 2006, 2014; Ryan et al. 2013; Krausman 2017).

We must make good decisions about the use of fire, and not just its control (Agee 2006), and there has been some progress (Cole 2019). The special issue (Baker 2020) that spurred this commentary was a welcome contribution to the literature, and fire as a conservation imperative warrants continuing recognition and appropriate application, whether within or outside of wilderness (Zimmerman and Bunnell 2000). There must be increased acceptance that conservation, and especially wildlife conservation, often requires action that has been stymied—or even prevented—by the status quo, as exemplified by the extirpation of bighorn sheep from the Pusch Ridge Wilderness (Krausman 2017). Such an acknowledgment will demand a change in human values, however, and create a controversy that can have no technical solution (*sensu* Hardin 1964). Fire increasingly is recognized as an important ecological component, and an overzealous application of wilderness policies can be detrimental to wildlife conservation objectives (Bailey and Woolever 1992). Indeed, "… fire must be allowed to play a more prevalent natural role and thus a more natural role in wilderness ecosystems—including in some cases the artificial introduction of prescribed fire to make up for past fire prevention and control or for present suppression on lands adjacent to wilderness" (Schoenfeld and Hendee 1978:107–108).

Managers must consider the human and ecological environments associated with any wilderness area, and how they influence available management options; among the strongest of these likely are anthropogenic patterns of development, and climate (Miller 2006, 2014; Kelly et al. 2020). The time for blame, political gamesmanship, endless planning, and litigation begat by proposed use of fire in the context of conservation has passed (Schoonen 2020), but "science can [only] advise, it cannot decide" (Covington and Pyne 2020). Awareness and vigilance are necessary to assure that public trust resources are managed to benefit the public trust owners (Bailey 2015) and, "… we must work toward a common goal: the sound and productive management of the world's … ecosystems" (Bleich 1982). To achieve that goal, it is imperative that environmentalists acknowledge that setting aside preserved lands is not the only approach to the protection of ecological values (Franklin 1989), and that, "… the twin goals of noninterference with nature and of preserving pristine natural habitats are incompatible [and] … that nature reserves can't be left to nature alone to manage" (Diamond 1992). Congress must be made aware of its long history of enacting conflicting environmental legislation and the complications that have resulted therefrom, and make the corrections (Thomas 2004; Bleich 2005, 2016) that currently constrain wildlife conservation on federal lands, especially in wilderness. Absent these requisites, progress toward greater use of prescribed fire—and other public trust issues centered on wildlife conservation—will remain slow and, I suspect, will move forward even more slowly in the future.

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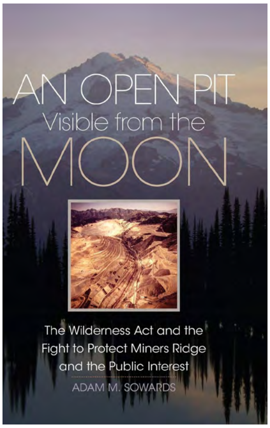
BOOK REVIEW

An Open Pit Visible from the Moon: The Wilderness Act and the Fight to Protect Miners Ridge and the Public Interest



Adam M. Sowards. 2020. University of Oklahoma Press, Norman, USA. 236 pages (hard cover). $34.95. ISBN: 978-0-8061-6501-1

Adam M. Sowards tells the tale of a successful effort to prevent development of an open-pit copper mine in the Cascade Mountains of northern Washington. This book relates an intriguing story of a struggle to overcome what some perceive to be inconsistencies within The Wilderness Act (hereafter, Act) of 1964. Sowards relates in detail the efforts of those involved who, for personal or political reasons, worked diligently to prevent Kennecott Copper Corporation's effort to establish and operate a mine on Miners Ridge, as provided for by the Act. In 1966, shortly after passage of the Act, the effort to halt Kennecott's proposed mine was grounded in a true grassroots movement; had it been 2020, however, lawyers would be lined up behind the various 'not-for-profit-organizations' to sue the federal government over technicalities or procedural discrepancies. In such a scenario the nexus, and resulting payments, to those filing such challenges would have been a direct function of the Equal Access to Justice Act, legislation that provides almost unlimited opportunities to recoup expenses for successful lawsuits filed against the federal government (Lofthouse et al. 2014).

Dr. Sowards has produced an intriguing, well-researched and well-documented historical accounting of the fight—initiated at the most basic level of American society—to prevent development of an open-pit mine in a relatively unspoiled area. The author is not entirely removed from emotional arguments to prevent Kennecott from developing the mine, however, in that he and his family maintained strong personal connections to the Casacade Range. Thus, I found the frequent use of the term 'conservationist', or various derivatives thereof, to be a bit overwhelming. In total, I tallied 277 such occurrences in 158 pages of text ($\bar{x}$=1.75/page, SD=1.67). With virtually a single exception that root word, or a derivative thereof, was used to describe individuals or organizations, and actions by those actively opposed to Kennecott's legal right to mine, despite that activity clearly being permitted by the Act. By default, those favoring the mine or having more moderate views were relegated—albeit perhaps unintentionally—to the status of being enemies of 'conservation'.

The book consists of 11 chapters distributed among three sections, a separate introduction, and a final conclusion. Part one (Bedrock) provides the background for the book, and emphasizes the standoff among competing agencies (U.S. Forest Service and the National Park Service), the local populace, and industry, "…in a context where laws and traditions, forged in public and through time, tested their ability to achieve their incompatible goals for Miners Ridge and the larger North Cascades landscape." In Part two (Challenges), Sowards relates the many scenarios centered on the issue of Kennecott's legal right to mine, as well as government prerogatives. Part three (Resolution) identifies the reasons that the mine did not open. Indeed, copper prices never got high enough to warrant the mine and, when combined with largely grass-roots opposition to the proposed mine, these factors in large part explain the outcome. Kennecott Copper eventually sold its claim and abandoned the project, the North Cascades National Park was established, and the Glacier Peak Wilderness Area remained under the administration of the Forest Service.

I found the text to be extremely well-written, and very well edited; I noted but two typographical errors in the entire text. Further, the amount of research, documentation, and clarification that support the work are astounding. For example, 579 notes in the text refer to the 9 archival collections, 6 government documents, 20 periodicals, or the 196 books, chapters, articles or websites consulted and that appear in the terminal bibliography. With that information, Adam Sowards has told an intriguing story that occurred at a time when public advocacy, at a considerably basic level when compared to that existing today, was a moving force. When compared to the 'environmental industry' that currently is dominated by multi-million-dollar organizations overseen by high-paid executives with access to legions of lawyers that are more than happy to litigate, the outcome was an amazing accomplishment. Although economics played a substantial role in the ultimate decision of Kennecott to abandon its legal right to extract copper, details of the dedication and efforts of a concerned citizenry makes this a fascinating read.

Ironically, the history of Miners Ridge was referenced nearly 25 years after the controversy began and, in my opinion, represents a classic example of the "bureaucratic inertia and interagency competition" identified by Grumbine (2000:127) as being primary obstacles to conservation. When combined with the politics and promises of confounding legislation, those factors further thwart meaningful imperatives, particularly as they relate to wildlife conservation (Bleich 2005). Thus, I paraphrase the late Jack Ward Thomas (2004): *environmental legislation, as created by Congress, has become a mess, and it is a mess that only Congress can fix.* Given the political constipation that characterizes the federal government, I am unconvinced the needed repairs will occur anytime soon.

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