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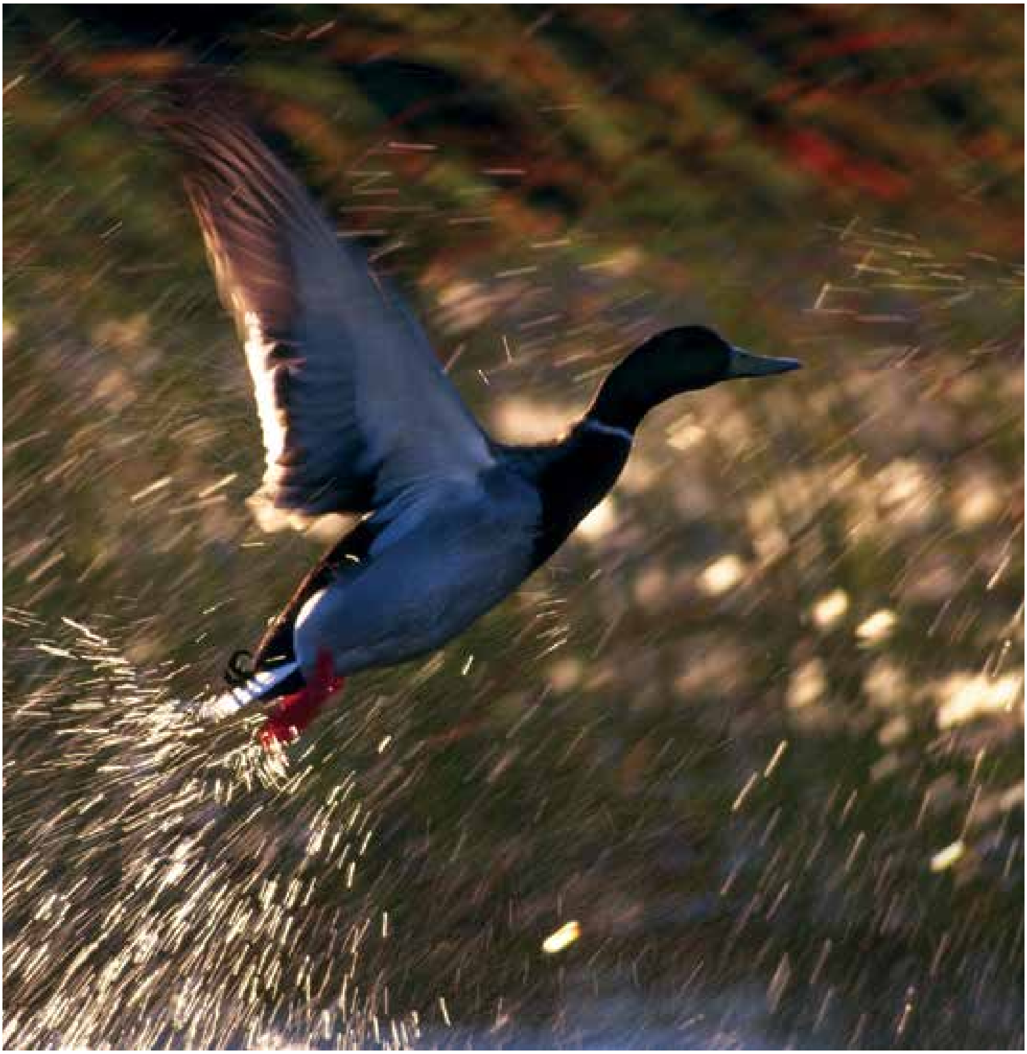

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Contents

California Fish and Game 104(2):48; 2018

Notes from the Editor

In this issue of the Fish and Game Journal we have a nice mix, one article about trout, another about ducks, and one about elk. Plus, a book review about mountain lions. The elk article is another in a string of publications from a long-term study in Redwood National Park featured recently in a book review appearing in the last issue of the Journal, 104-1. The mallard article is a review of wintering and breeding populations in California; and the trout article reports the results of surveys conducted using citizen science, a welcomed and growing trend in wildlife and fisheries management.

We welcome the contributions from Department scientists for publication in the Journal. Sometimes, other venues for publications are pursued, which I would not ordinarily comment on, but with this exception, I want to bring to your attention the publication of: J. W. van Wagtendonk, N. G. Sugihara, S. L. Stephens, A. E. Thode, K. E. Shaffer, Editors. 2018. Fire in California's Ecosystems, 2nd Edition. U. C. Press, California, USA. It is apparent this topic has far-reaching social and ecological implications and has been a troubling reality for many here in California and elsewhere. From the news release: "Fire in California's Ecosystems describes fire in detail—both as an integral natural process in the California landscape and as a growing threat to urban and suburban developments in the state. Written by many of the foremost authorities on the subject, this comprehensive volume is an ideal authoritative reference tool and the foremost synthesis of knowledge on the science, ecology, and management of fire in California." The knowledge provided in this book will be valuable for resource managers as we cope with increased risk of wildlife exacerbated by climate change.

Armand Gonzales
Editor-in Chief

California Fish and Game 104(2): 49-66; 2018

California mallards: a review

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Mallards (*Anas platyrhynchos*) are the most abundant breeding waterfowl species in California and are important to waterfowl hunters in the state. California is unique among major North American wintering waterfowl areas, in that most mallards harvested in California are also produced in California, meaning that California must provide both high quality wintering and breeding habitats for mallard populations to remain stable. California's breeding and wintering mallard population estimates have generally declined since the mid-1990s. Herein, we synthesized existing information on the ecology of breeding mallards in California and summarize key demographic rates. In general, demographic estimates differed substantially from other mallard populations in North America, highlighting the importance of separate management of western mallard populations. We suggest long-term research and monitoring activities to help improve management.

Key words: *Anas platyrhynchos*, mallard breeding ecology, vital rates, California

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California is unique among major North American wintering waterfowl areas because it produces a large proportion of several species of ducks, primarily mallards, that contribute significantly to hunter harvest (De Sobrino et al. 2017, Zuwerink 2001, and Munro and Kimball 1982). DeSobrino et al. (2017) estimated that between 1966 and 2013, 60% of the annual mallard harvest within California was comprised of birds produced in California, and 96% of the mallards produced in California were harvested in California.

In North America, three distinct mallard populations are recognized by the U.S. Fish and Wildlife Service; the Western, Mid-continent, and Eastern populations. Until the mid-1990's and the work of McLandress et al. (1996), western mallards received relatively little attention compared to mid-continent and eastern populations. However, following recognition of their importance to hunters, it became clear that western mallards, specifically those produced in California, are important to the recreational waterfowl harvest in California, and as a result, influence wetland habitat management decisions by the state (Smith et al. 1996).

Due to their importance to hunters, private and public wetland managers have spent large amounts of time and resources managing both breeding and wintering waterfowl habitats (Williams et al. 1999). Winter habitat management specifically for mallards has become increasingly common on private lands in the Central Valley of California. Declining northern pintail (*Anas acuta*) populations, and subsequent harvest restrictions (from a bag limit of 6-7 a day in the 1970's to a bag of 1-2 a day in 27 of the last 28 years), have caused landowners to manage for less open water habitats, and more diverse vegetation structure (e.g. watergrass, smartweed, and hard-stem bulrush) that are preferred by mallards.

There is a wealth of unpublished data on California mallards, largely from decades of work by the California Waterfowl Association (CWA), at times in conjunction with the California Department of Fish and Wildlife (CDFW). Although we could not access every unpublished data set, herein, we summarize what we believe is the pertinent information on California mallards from both published and unpublished literature. Currently, no synopsis of information exists for mallards breeding in California. We have separated this review into three sections: abundance, ecology, and information needs.

Since management of mallards occurs on both breeding and wintering habitats, we report information from the CDFW annual breeding waterfowl survey and the cooperative federal and state surveys for wintering waterfowl populations. Because relatively few mallards breed outside the Central Valley and northeastern California, we present information from these core breeding regions in California; the Suisun Marsh and Bay-Delta, the Central Valley (which includes the Sacramento and San Joaquin Valley), and northeastern California.

Abundance

The current California breeding duck survey has been operated by CDFW using the same methodology, since 1992 (Skalos and Weaver 2017). The mallard has been the most abundant species encountered, and breeding estimates have varied from approximately 260,000-560,000 (Skalos and Weaver 2017). Despite the apparent recent decline (Figure 1), population trends remain equivocal because of the high variation inherent in the survey (e.g., the mallard breeding estimate was up 52% in 2016, however not statistically different from the 2015 estimate, p=0.37).

On average, northeastern California (~23%) and the Sacramento Valley (~39%), account for >60% of the breeding mallards in the surveyed regions. The San Joaquin Val-

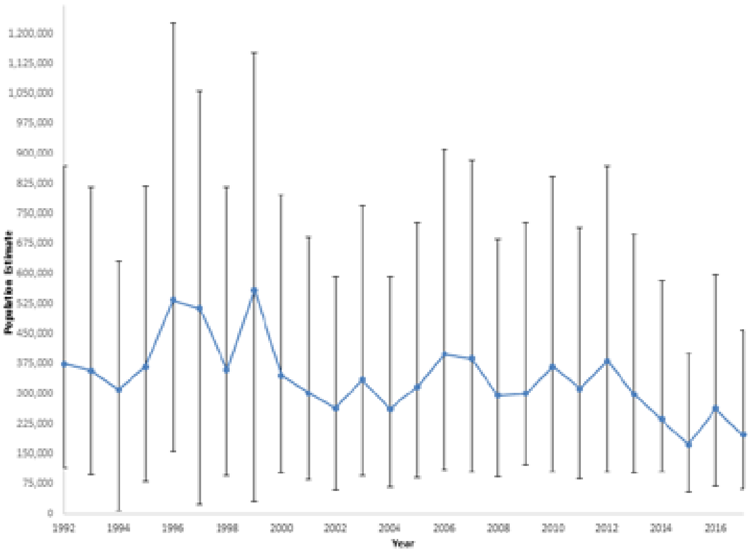

FIGURE 1.—California breeding mallard estimate with 95% confidence intervals 1992-2017.

ley's breeding mallard population comprises on average 20% of the total estimated mallard breeding population and the Bay Delta/Suisun Marsh, 11%. Since 1992, the estimate has shown an apparent decline in the Central Valley (Figure 2) and the Bay-Delta/Suisun Marsh (Figure 3). The northeastern California estimate appears stable to increasing (Figure 4).

The midwinter waterfowl survey conducted during the first week of January by the USFWS and CDFW provides a winter index to waterfowl populations throughout California (Olson and Trost 2013). Based on these surveys, the Sacramento Valley may support 55-86% of the state's wintering mallards, and northeastern California may support as much as 30% of the state's wintering mallards. Although, population trajectories vary throughout the state, since 1992 the mallard midwinter index has shown an apparent decline (Figure 5). Similarly, the proportion of mallards comprising the mid-winter waterfowl index has varied over the years from 4.5% to 13.2%, but has generally declined (Ackerman et al. 2014).

ECOLOGY

Breeding Probability.—Breeding probability in mallards is defined as the percentage of adult females attempting to reproduce during the breeding season. Some authors have considered breeding probability to be 100% in dabbling ducks (Rohwer 1992). In California, two studies have captured and radio-marked pre-breeding mallard females to estimate breeding probability. In the Grasslands Region of the San Joaquin Valley, Riviere (1999) reported a breeding probability of 41% in 1995, but this estimate is likely biased low due to the use of transmitter type (i.e., nape) and its associate high rate of tag loss (Arnold et al. 2011). In 2004 and 2005, using pre-breeding radio-marked mallard females in the Sacra-

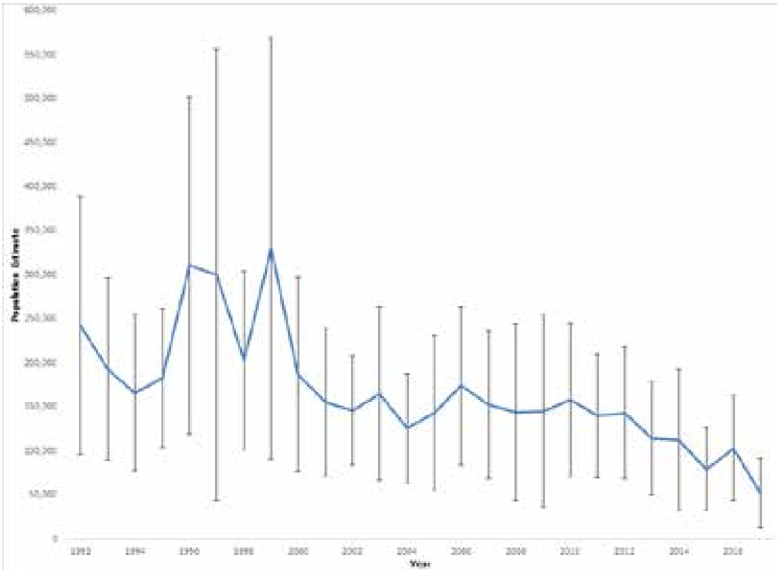

FIGURE 2.—California breeding mallard estimate with 95% confidence intervals for the Central Valley 1992-2017.

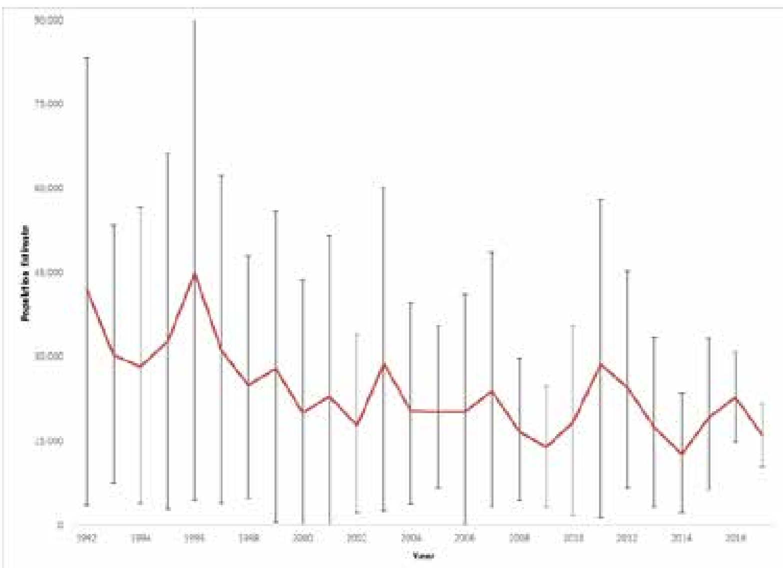

FIGURE 3.—California breeding mallard estimate with 95% confidence intervals for the Bay Delta/ Suisun Marsh 1992-2017.

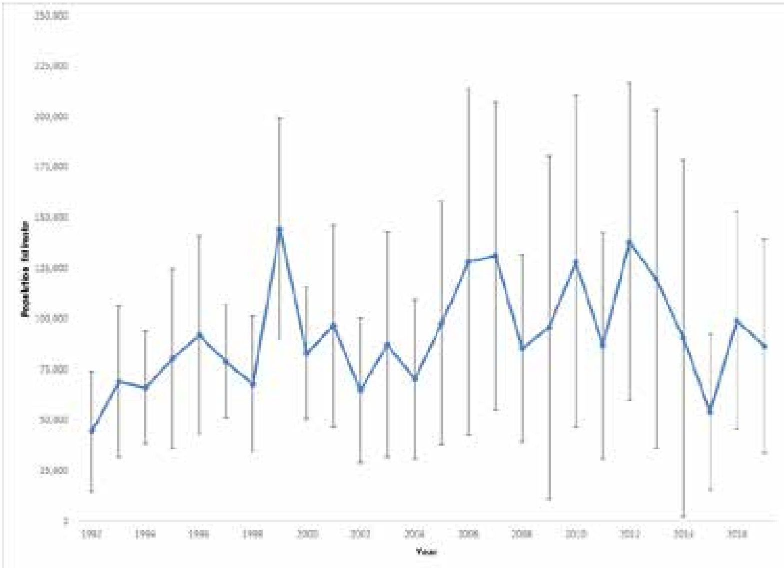

FIGURE 4.—California breeding mallard estimate for northeastern California with 95% Confidence Intervals 1992-2017.

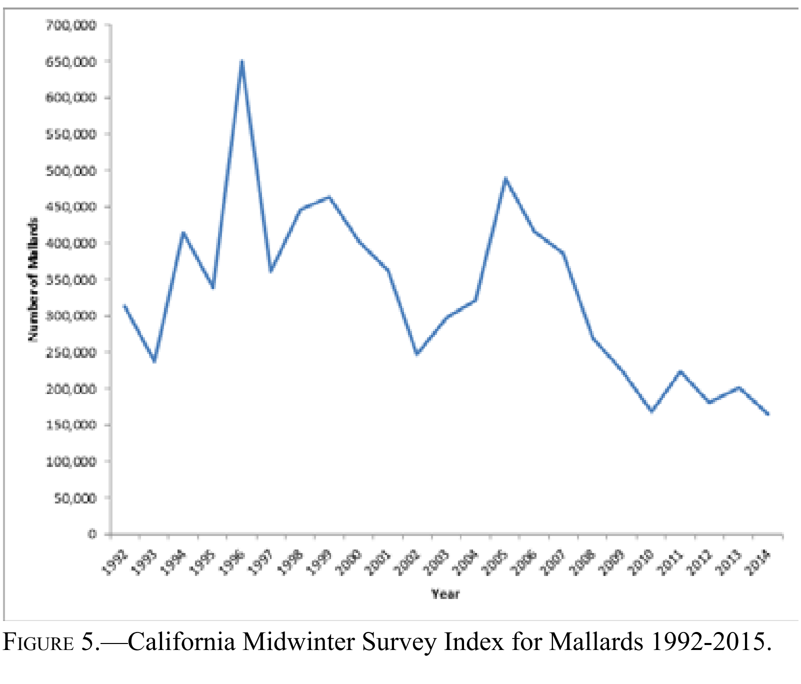

FIGURE 5.—California Midwinter Survey Index for Mallards 1992-2015.

mento Valley, Oldenburger (2008) found that breeding probability differed between a dry (73%) and wet year (94%), with differences among age classes (Second year: 81%, after second year: 86%). These findings are similar to research in other regions, which indicate that mallards may forego breeding in years of poor habitat conditions (Krapu et al., 2006, Cowardin et al. 1985, Johnson and Cowardin 1987).

Overall, breeding probability estimates from the Sacramento Valley are 10-20% below the >95% breeding probability estimates found in the Prairie Pothole Region using similar methodologies (Hoekman et al. 2002, Hoekman et al. 2006a).

Breeding probability may be driven by environmental factors (e.g., precipitation), so management may be able to increase breeding probability in certain areas by increasing the availability of late spring and summer water to provide wetland habitat. If there were no adverse effects on the production of moist-soil plants used as food for wintering waterfowl (Naylor 2002), delaying the draw-down of managed wetlands until mid-summer may allow for increased breeding territories in the Sacramento Valley (Oldenburger 2008).

Nest Initiation.—Nest initiation dates within the Suisun Marsh from 1985 to 2004 (J. Ackerman, U. S. Geological Survey, unpublished data) are similar to breeding populations in the Prairie Pothole Region (Hoekman et al. 2006). Nest success has been shown to be higher early in the breeding season and decline as the breeding season progresses (Matchett 2005, Matchett et al. 2007, Oldenburger 2008), similar to other mallard populations (Emery et al. 2005).

Clutch Size.—Earl (1950) reported an average clutch size of 8.4 eggs in irrigated lands in the Sacramento Valley. Loughman et al. (1991) similarly found clutch size in agricultural production areas in the Sacramento Valley to be an estimated 8.7 eggs. Additionally, Loughman et al. (1991) found that "After Second Year" females had larger clutch sizes (8.9 eggs) than "Second Year" females (8.4 eggs). Hunt and Naylor (1955) found clutch sizes to be similar (8.5 eggs) in northeastern California at Honey Lake Wildlife Area. McLandress et al. (1996) found similar clutch sizes among the major nesting regions in California: Suisun Marsh (8.5 eggs), Sacramento Valley (8.9 eggs), San Joaquin Valley (8.2 eggs), and northeastern California (8.3 eggs).

In the Suisun Marsh, mallard clutch size averaged 8.6 eggs from 1985 to 2004 (CWA, unpublished data). Ackerman et al. (2006) assessed clutch sizes for known age mallard hens that were caught on their nest after eight days in incubation within the Suisun Marsh from 1985 to 1997 (n=1679 clutches). Average clutch sizes for "Second Year" hens (8.6 eggs) was smaller than for "After Second Year" hens (9.0 eggs; Ackerman et al. 2006).

Based on these findings, clutch size for California mallards appears to be similar to other mallard populations in North America (Bellrose 1980). Rohwer (1992) summarized the patterns of clutch size in waterfowl, and because clutch size appears to be limited by the number of eggs a hen can successfully hatch synchronously with one egg laid a day and incubation beginning with the first egg (e.g., with a 10-egg clutch there is 9 days of incubation between the first egg and tenth), it appears that management has limited ability to effect waterfowl clutch sizes compared to other reproductive rates.

Egg Success.—Egg success (sometimes referred to as hatching success) is defined as the percentage of eggs from a full clutch that hatch in a successful nest. In the San Joaquin Valley, Anderson (1956) found egg success rates of 74% and 77% in 1953 and 1954, respectively. From successful nests, dead embryos were the highest percentage of egg failure. Anderson (1957) found egg success rates of 84% in the Sacramento Valley, and missing eggs (i.e., presumed partial depredation events) accounted for the largest percentage of egg failure. From 2003-2006, egg success rates averaged 68% in the Sacramento Valley, and approximately 3% of all nests contained complete clutches of non-viable eggs (Matchett et al. 2007).

The largest sample sizes of egg success estimates come from the Suisun Marsh. From 1985 to 2004, yearly mean egg success ranged from 77% to 100%, and averaged 84% (CWA, unpublished data). Egg success for "Second Year Hens" (84%) was no different than for "After Second Year" hens (85%; Ackerman et al. 2006). Ackerman et al. (2003) found that partial clutch depredation events typically decrease egg success to 60%, compared to completely intact nests at hatching (92%). These results indicate that much of the failure of eggs in successful nests is caused by partial clutch depredation, rather than dead or infertile eggs. Egg success averaged 81% (range: 77%–85%; Ackerman et al. 2003). In contrast, Anderson (1960) found higher egg success in the Suisun Marsh in the 1950s (100% in both 1953 and 1959, n=14 and 28, respectively).

In northeastern California, egg success appears to be consistently higher than the Central Valley. At Honey Lake Wildlife Area, Hunt and Naylor (1955) found high egg success, 93% and 83% in 1953 and 1954, respectively. Getz and Smith (1989) found egg success of 87% at Mount Meadows (Walker Lake) in northeastern California. Reinecker and Anderson (1960) found high egg success (1952: 91%; 1957: 92%) at Lower Klamath and Tule Lake National Wildlife Refuges. Egg success in northeastern California resembles other mallard populations outside of California (Hoekman et al. 2002).

Within the San Joaquin Valley, egg success rates are substantially lower than other mallard populations in North America, as well as other areas within California. Ambient temperatures increase steadily during the breeding season (monthly averages range from 74°F in April to 95°F in July). Late nesting females in the San Joaquin Valley likely have poorer egg success due to high daily temperatures impacting egg viability (Ar and Sidis 2002). Egg hatching success declined strongly with extreme temperatures (number of days eggs were incubated when temperature was ≥95°F) for mallard in the Suisun Marsh and at Conaway Ranch, Sacramento Valley. (Ackerman et al. 2011).

Egg success decreases over the nesting season in both the Sacramento and San Joaquin Valley (CWA, unpublished data). Whether upland management (i.e. vegetation height) may assist in increasing egg success, especially at the end of the nesting season, remains unknown at this time. Managing for vegetation structure and complexity to shade nests during the late breeding season (June and July) may deter predators and help increase egg success.

Nest Success.—Nest success is defined as having at least one egg hatch in a nest (Klett et al. 1986). Historically, the first nest success studies in California were completed by the Waterfowl Investigations Program of the California Department of Fish and Game (Miller and Collins 1954, Hunt and Naylor 1955, Anderson 1956, Anderson 1957, Anderson 1960, Reinecker and Anderson 1960). Concurrently, investigations evaluated the importance of mallard production in agricultural areas of California (Earl 1950), and the importance of the relationship between spring precipitation and mallard production (Mayhew 1955). In California, mallards nest in a diversity of habitats, including a variety of agricultural habitats. In a comparison of nest density between the four major breeding regions in California, the Suisun Marsh supported the highest densities of nesting mallards (McLandress et al. 1996).

A number of studies have investigated mallard nest survival in California, however, most studies have reported estimates of nest survival and nest density, and/or general biological descriptions of nesting behavior. In studies after the 1970's, Mayfield (1961) nest survival estimates became widely used for estimating nest success (Johnson 1979). Nest survival in most studies has been estimated to be above the level (15%) necessary to maintain a sustainable population in midcontinent mallard populations (Cowardin et al. 1985). Few studies have investigated the factors affecting nest survival.

The Suisun Marsh nesting studies at the Grizzly Island Wildlife Area represent the longest running studies on waterfowl nesting success in North America with more than 10,000 nests monitored. Although variable, nest success has declined over time within the Suisun Marsh, with very high estimates in the late 1980s and early 1990s (Ackerman et al. 2009, Ackerman et al. 2014). Mallard nest success was monitored from 1985 to 2004, 2008 to 2013, and 2015 and averaged 28%±17% over this time (Ackerman et al. 2009). Nest success varied dramatically among years from a low of 4% in 2004 to a high of 62% in 1985 (Ackerman et al. 2009).

Yarris and Loughman (1990) found variable nest density and survival on set-aside fields associated with rice agricultural production in the Sacramento Valley. Nest success ranged from 6% to 88% on various set-aside fields. Loughman et al. (1991) reported that mallards found winter wheat and oat fields highly desirable throughout the Sacramento and Delta regions of California. McLandress et al. (1996) found nest densities as high as 9.5 nests/acre in wheat and oat fields and 12.7 nests/acre in set-aside fields in the Sacramento Valley. Nest success averaged 26% in wheat and oat fields and 33% in set-aside and nest densities were positively correlated with early spring precipitation (McLandress et al. 1996).

In the San Joaquin Valley (Grasslands), mallards nest in upland fields associated with wetland complexes. McLandress et al. (1996) estimated nest success in the San Joaquin Valley 1987-1989 and found nest success was significantly different between years (23%, 50%, and 37%, respectively).

Nest survival is the most variable of all mallard vital rates and can be related to many variables (micro-habitat, landscape characteristics, region, density, alternative prey, date, etc.). Matchett (2005) investigated nest survival of waterfowl in the arid, high-desert region at Honey Lake Wildlife Area in northeastern California and found nest survival was positively related to microhabitat (i.e., residual height of vegetation). Ackerman (2002) suggested that mallard nest survival may be affected by individual, community, and population level effects. Partial clutch loss may significantly impact waterfowl production, reducing overall duckling production by as much as 22% (Ackerman et al. 2003). At a community level, Ackerman (2002a) found nest success among fields was positively related to the abundance of alternative prey, especially California voles (Microtus californicus) at Grizzly Island Wildlife Area in the Suisun Marsh. Using the 20-year mallard dataset in the Suisun Marsh, (J. T. Ackerman, U. S. Geological Survey, unpublished data) found that nest success is negatively density dependent among years. However, within any individual year, nest survival does not appear to be negatively related to the density or distance of either natural or simulated mallard nests (Ackerman et al. 2005). In fact, nests and their fate appear to be clustered with increased nest success at shorter nearest-neighbor distances (Ackerman et al. 2005, Ringelman et al. 2009). The lack of density dependent effects at the smaller spatial scales is consistent with most other studies, but few studies have the long-term dataset required to investigate density dependence among years (Ackerman et al. 2005).

Management of upland nesting fields has been investigated in California though little knowledge exists on how management or placement should proceed within regions of California. Further analyses on existing data sets could provide more input into possible management actions for increasing nest survival in California. A wide array of management options exists for mallards in the Central Valley, and these need to be explored in a more rigorous fashion. Newbold and Eadie (2004) investigated landscape types on mallard abundance in the Sacramento Valley and found that breeding densities of mallards were positively correlated with the amount of wetland habitat.

Duckling Survival.—Duckling survival is defined as an individual duckling surviving from hatch to a set time period (e.g. 30 days). It has been found that little mortality occurs after a 30-day period (but see Simpson et al. 2005 from the Great Lakes region), thus most studies report a 30-day survival estimate. Duckling survival has been calculated using individually marked females and corresponding duckling counts (Chouinard and Arnold 2007).

In the rice-growing region of the Sacramento Valley, Yarris (1995) estimated duckling survival in 1993 and 1994. Duckling survival was low during the beginning of the breeding season (i.e., before 1 June), but increased later in the breeding season likely due to increased vegetation height as rice matured. Early (before 1 June) ducklings had poor survival in both years (10% and 14%). Late (1 June and after) ducklings had higher survival (59%) in both years. Overall, estimates of 30-day duckling survival were 38% and 36% in 1993 and 1994, respectively. Avian predators were speculated to be the primary cause of duckling mortality in rice fields.

In the San Joaquin Valley, Chouinard and Arnold (2007) monitored individually marked ducklings and females. Duckling survival was estimated at 25% for both years (1995 and 1996) and sites (Los Banos and Salt Slough Wildlife Areas). Total brood loss was high (51%). Nearly all duckling mortality (93%) occurred during the first 12 days. Ducklings had poor 2–20 day survival rates in semi-permanent and permanent wetlands (19%) and moist-soil units (17%), as compared to reverse cycle wetlands (i.e., wetlands that are flooded from early spring through summer and dry the rest of the year; (76%). Avian predators (39%) were the primary cause of duckling mortality. Hatch date did not impact duckling survival.

In northeastern California, at Lower Klamath National Wildlife Refuge, Mauser et al. (1994a) estimated 50-day duckling survival rates over three years, 1988-1990. Duckling survival rates varied from 18% to 24%. Total brood loss varied from 37% to 81%.

Generally, 30-day duckling survival rates in California are lower than those found in both mid-continent (Krapu et al. 2006, Stafford and Pearse 2007, Simpson et al 2005) and eastern regions (Hoekman et al 2004). As indicated in Chouinard and Arnold (2007), survival rates in different habitats may vary considerably. Management may increase duckling survival in the Central Valley and Northeastern California (on refuge) by using more reverse-cycle wetlands.

Breeding Survival.—Breeding survival has been found to be an important factor in population growth rates in other mallard populations (Hoekman et al. 2002). Estimates of mid-continent breeding female survival rates range from 63% to 84%, depending on year and site (Cowardin et al. 1985, Devries et al. 2003, Brasher et al. 2006). Unfortunately, few estimates of breeding survival are available for mallards in California.

Based on signs of carcass remains in proximity to the nesting site, approximately 1% of nest failure at Grizzly Island Wildlife Area may be attributed to female mortality on the nest (California Waterfowl Association, unpublished data).

In the Sacramento Valley, depredation of hens appears to be minimal during the nesting period; however, this may vary regionally and temporally. Yarris (1995) reported 1 of

64 females was depredated during late incubation. Oldenburger (2008) found differential breeding survival estimates among age classes as second year females had an 84% survival rate versus 90% for after second year females. The breeding survival rates found in this study are substantially higher than the mid-continent and are the highest estimates of breeding survival for mallards in North America (Bielefeld and Cox 2006). This study found only one nest related mortality, caused by farming operations during harvest of a wheat field.

In northeastern California, Mauser and Jarvis (1994) found only 3 of 401 nests contained evidence of female mortality on the nest. This study found no mortalities of female mallards during the late incubation, brooding, and post-breeding periods, approximately 10 August, at Lower Klamath National Wildlife Refuge.

Molt & Survival.—Unlike many mallard populations, it appears a large percentage of male and female mallards leave the breeding areas to complete the wing molt. Although molt migrations are well-known for geese (Sterling and Szubin 1967, Zicus 1981) and sea ducks (Salomonsen 1968, King 1973), few dabbling duck populations are known to complete a molt migration. In the Suisun Marsh, Yarris et al. (1994) found that 50% of female mallards left the breeding area by mid-June. Of the 20 molt locations, 12 (60%) were located in the Klamath Basin in Oregon and northeastern California (Yarris et al. 1994). In 2004 and 2005, Oldenburger (2008) found that female mallards left the Sacramento Valley later (average = 2 July) than females in the Suisun Marsh. Oldenburger (2008) found a larger percentage of female mallards remained within the Central Valley to molt (~24%), compared to Yarris et al. (1994) who found that 10% of breeding females remained in the Suisun Marsh to molt. Both rice fields and managed wetlands were used for molting habitat in the Central Valley (Oldenburger 2008). Mauser (1991) found 72%, (n=71) of radio-marked females remained in the Klamath Basin to complete a wing molt. Important locations for molting were Lower and Upper Klamath National Wildlife Refuges, and other surrounding marshes in the Klamath Basin.

Since northeastern California is an important molting location for both northeastern (Mauser 1991) and Central Valley mallard populations, Fleskes et al. (2007) investigated molting survival at Upper Klamath, Tule Lake, and Lower Klamath National Wildlife Refuges. The percentage of female mallards that survived the flightless period (defined as the date of tagging to estimated 125 mm feather length) was much greater at Tule Lake (2001: 95-100%, 2002: 85%) and Upper Klamath (2002: 90%) than at Lower Klamath NWR (2001: 50-70% 2002: 45-65%, 2006: 14-65%). Predation and botulism were the major cause of decreased survival in molting mallards in northeastern California. It appears that molting survival at some locations may be limiting those populations. In contrast, studies from the mid-continent region have reported high (>90%) molting survival (Kirby and Cowardin 1986, Evelsizer 2002).

Fall-Winter Survival.—Fleskes et al. (2007a) monitored fall-winter survival rates (late August-March) of radio-marked after hatch year (AHY) and hatch-year (HY) mallards in the Sacramento Valley. AHY females exhibited higher survival (72%–83%) than HY females (49%–68%). The primary cause of mortality was hunting. Survival may also be influenced by recent shifts in waterfowl distributions (Ackerman et al. 2006a) and the increased amount of rice fields that are flooded in the winter for rice straw decomposition.

Recent changes in hunting pressure have caused some concern as to whether spinning-wing decoys (SWDs) are having an effect on mallards at the population level (Ackerman et al. 2006b, Eadie et al. 2002). In particular, long-lived dabbling ducks, with lower annual fecundities (such as mallards), appear to be more vulnerable to SWDs than shorter-lived dabbling ducks, with higher annual fecundities, such as green-winged teal (Ackerman et al. 2006c).

The widespread use of SWDs began in 1998. In the 1999, 2000, and 2001 hunting seasons, CDFW staff sampled hunters about whether they used SWDs on five public hunting areas. The results from nearly 23,000 hunter days showed an overall increase in mallard bag of 0.5 per day for those who used SWDs (CDFW 2014).

Eadie et al. (2002) conducted a more rigorous study during the 1999 hunting season. Hunters using SWDs shot about 2.5 times more ducks that hunters without SWDs. Early in the season hunters using SWDs shot nearly 7 times more ducks than when the same hunters did not use SWDs (as measured from 30 minute SWD on/off periods during the same hunt). Increased harvest rates while using SWDs was caused by increased risk-taking by ducks, and closer minimum approach distances (Ackerman et al. 2006c).

Beginning in the 2001 hunting season, SWDs where prohibited prior to 1 December. This regulation was intended to reduce the harvest impact from SWD's on California's local breeding mallards and young produced in California until mallards from other areas showed up in larger numbers in the state (CDFW, unpublished data).

In 2014, CDFW staff analyzed mallard harvest at public hunt areas to evaluate the effectiveness of the prohibition before 1 December. Mallard harvest was evaluated over three-time periods, 1992-1997 (pre-SWDs), 1998-2000 (Unregulated used of SWDs), and 2001-2006 (Regulated SWDs with prohibition before 1 December. The average mallard harvest during the period of the SWDs use without the 1 December prohibition was significantly higher, on average 33% greater (p=0.05), than the period before the onset of SWDs. Similarly, the average mallard harvest during the period of SWDs without the 1 December regulation was significantly higher, on average 26% greater (p=0.05) than the period with SWDs and the 1 December regulation. Based on the public hunt area results, the 1 December prohibition appears to have reduced mallard harvest to levels that are similar to pre-SWDs (a 33% increase in harvest with SWD prior to regulation and a resultant 26% decline in harvest with the 1 December regulation; CDFW 2014).

Annual Survival.—Reinecker (1990) estimated annual survival and recovery rates for mallards from different regions within California from 1948-1982. Both preseason and postseason bandings were used in the analyses. Annual survival of mallards averaged 61% for adult males, 56% for adult females, 47% for immature males, and 46% for immature females. Evidence existed for regional differences in annual survival for populations in California. Annual survival was greater for all cohorts in the Klamath Basin, as compared to the San Joaquin Valley.

Direct recoveries of mallards from Klamath Basin NWR indicated that a large majority of 3 of 4 cohorts come from northeastern California. Adult males were recovered at a higher percentage in the Sacramento Valley (42%) than northeastern California (32%). Additionally, it appears that fewer mallards from northeastern California were being harvested in the Sacramento Valley into the 1980's. In the Sacramento Valley, cohorts from Gray Lodge WA were mostly recovered (>70%) in the Sacramento Valley. In the San Joaquin Valley (Grasslands), a majority of the mallards (>65%) were recovered in the approximate area. These results emphasize that regional management may impact regional mallard harvest in California.

Information Needs

With 80%–95% of the Central Valley's wintering and breeding waterfowl habitat under private ownership (Central Valley Joint Venture 2006), the management of private lands is crucial to both breeding and wintering waterfowl in California. Understanding the link between habitats and population vital rates is needed to better assist private and public landowners and managers with maximizing wetland-dependent species benefits. Relating populations, especially California mallards, to environmental variables remains a challenge. Past authors have attempted to find a relationship among breeding populations, recruitment, and environmental variables for this population. We encourage future efforts to understand relationships among habitats and populations of mallards (e.g. Newbold and Eadie 2004), and to assist in future management, we suggest the following studies.

Experimental Assessment of Habitats.—Management of upland and wetland habitats during the breeding season should affect vital rates of mallards, such as nest success and duckling survival. However, few studies have experimentally manipulated habitats to measure bird response. Most studies have recorded bird densities in relation to habitat characteristics, but few have investigated vital rate responses to management. Although these studies would be difficult on a large scale, mallard nesting densities in California are among the highest in North America and home ranges do not extend over large areas. Thus, it is possible to measure mallard responses to relatively small-scale management in California.

Responses of vital rates to experimental habitat manipulations could provide data to determine the cost-effectiveness of producing incremental recruitment. Currently, some management practices are advised assuming an increase in waterfowl production and quality of habitat. Yet, little empirical evidence exist that measures the effectiveness of management practices. There remains a need to quantify increased recruitment from widely recommended practices, such as brood pond type and placement and nesting vegetation enhancement (including native grass and agricultural plantings) in California.

Large Scale Vital Rate Study.—California mallard vital rates have been measured at very few sites, the exception being Suisun Marsh. Current estimates of vital rates such as breeding propensity, adult breeding survival, and duckling survival, do not exist for much of the state. Population dynamics for California mallards may not be broadly applicable within or amongst regional breeding populations to develop regional estimates. Importantly, large scale studies assist in determining the effects of habitat variables on vital rates (Emery et al 2005). With habitat and vital rate information collected simultaneously, analyses may lead to understanding regional differences of mallard vital rates. Completion of a project may produce regional management plans for mallards in California and help explain the causes of stochastic processes in vital rates.

Duckling Survival in Relation to Wetland Management.—In the Sacramento Valley, ducklings produced early in the season are heavily dependent on a limited number of wetlands or irrigation ditches prior to the establishment of emergent cover in rice fields and wetlands. Since duckling survival is low during the early part of the breeding season (Yarris 1995, Oldenburger 2008), additional information is needed to understand management options that may increase recruitment during the first half of the breeding season. Increasing spring-summer flooded wetlands through landowner incentive programs may play an important role in increasing recruitment in this region. Currently, few wetlands are being managed as reverse-cycle wetlands in California.

Mitigating Evolving Issues in Wetland Management.—Wetland management in California will face many challenges, which will require habitat managers to adapt and develop new and innovative ways to maintain an adequate quantity and quality of wetlands to support mallards and all wetland-dependent species. Climate change will likely limit water available for wetland management while increasing human population will increase competition for water. Costs and management associated with wetland management such as mosquito abatement will reduce budgets as diseases both old (e.g., West Nile) and new (e.g., Zika), threaten human populations. In California, methylmercury contamination threatens to alter historic wetland management. Without knowledge of the increased bird response to wetland management, we may not adequately manage existing lands dedicated to breeding waterfowl as resources become limited in the future.

Molting Study.—A large percentage of female mallards molt migrate from breeding locations within the Central Valley to northeastern California (Yarris et al. 1994, Oldenburger 2008). Fewer female mallards perform a molt migration in northeastern California (Mauser 1991). Molting survival appears high in other populations (Evelsizer 2002), but molting survival is variable among sites in the Klamath Basin. The complete distribution of molting birds still remains unknown for mallards in California. Recent analyses (Oldenburger 2008) found non-breeding survival to be one of the most limiting factors on population growth rates of mallards in the Central Valley. Since non-breeding survival includes molting survival, it may be possible that molt survival is a limiting factor for the breeding population. Identifying major molting locations for mallards in California may assist in future design of molting habitat and alter habitat management in those areas to increase molting survival.

Breeding Population and Density Estimates.—The rising risk of habitat loss, coupled with increased demand on scarce resources for conservation means dollars need to be invested wisely to have a disproportionate impact on mallard populations. It is critically important to develop robust models and planning tools to guide habitat conservation and other management actions. Spatial tools have been employed by conservation planners across a diversity of landscapes and species and provide important guidance for future breeding duck conservation actions. The "Thunderstorm Map" which incorporates data from the U. S. Fish and Wildlife Service's Four-Square-Mile breeding waterfowl survey, developed by the Habitat and Population Evaluation Team (HAPET), is one such tool which describes upland nesting habitat accessibility to breeding ducks (Cowardin et al. 1995). Because of the known breeding duck populations utilizing various habitats, managers can employ an entire suite of prescriptive remedies to conserve and enhance habitat and develop management strategies. The Prairie Pothole Joint Venture (PPJV) uses this and other spatial tools and models to develop short and long-term conservation goals as well as develop step down plans to optimize duck production. Developing a similar tool and Four-Square-Mile type survey for California would help identify priority areas for the conservation and management of habitat for California's breeding ducks.

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Abundance, habitat and occupancy of Roosevelt Elk in the Bald Hills of Redwood National Park

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Fundamental to species management is understanding the factors that determine distribution or occupancy. We estimated occupancy in an area with two Roosevelt elk (*Cervus elaphus roosevelti*) herds that differed in abundance and hypothesized that habitat type (meadow, forest), herd, or both, influenced elk occupancy. Data were gathered from 12 repeated surveys of 47 stations conducted from May to August. At each 1-ha sign station, we surveyed for the presence or non-presence of elk sign 0–4 days old, recorded habitat type as forest or meadow, and noted which herd occupied the area. We tested the assumption of constant residence status and examined the influence of habitat and abundance on occupancy with nine single- and multi-season occupancy models. The most parsimonious model was a multi-season model where both herd and habitat type influenced occupancy and extinction. Both herds had lower occupancy of forest but complete occupancy of meadow. The herd with lower abundance had lower occupancy of forest, with occupancy declining over the 12 weeks. Roosevelt elk abundance likely influenced occupancy of forest but not meadow because forest provided less forage.

Keywords**:** abundance, California, *Cervus elaphus,* occupancy, forest, meadow, Roosevelt elk

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Abundance is often used to make inferences about population persistence, however, estimates of abundance are usually costly. Therefore, some have suggested that estimating distribution or occupancy can be used as a surrogate for abundance (MacKenzie et al. 2002, 2003, 2006; Royle et al. 2005). Though it seems intuitive that larger abundances should result in higher occupancy rates, there is limited research on this relationship (Gaston et al. 2000; Freckleton et al. 2005). In spite of the limited information on abundance-occupancy relationships there is evidence that occupancy is linked to abundance but the relationship might be complicated by habitat (Freckleton et al. 2005; McLoughlin et al. 2006).

Habitat type may influence species occupancy (Gaston et al. 2000; Freckleton et al. 2005; MacKenzie et al. 2002, 2003, 2006). Thus, any consideration of the relationship between occupancy and abundance must also consider the relationship between occupancy and habitat use of a given species. An increasing abundance may increase occupancy of marginal or lower quality habitat merely because high quality habitat is already occupied (Battin 2004; McLoughlin et al. 2006). A relationship of this nature will result in marginal habitats occupied at higher rates at high abundance and at lower rates at low abundance.

Roosevelt elk (*Cervus elaphus roosevelti*) in the Bald Hills of Redwoods National Park in northern California present an opportunity for exploring abundance and habitat influences on occupancy. Two elk herds of differing abundances occur along a north to south gradient in the Bald Hills (Starns et al. 2015; Kolbe and Weckerly 2015). In addition, Weckerly (2005) and Weckerly and Ricca (2000) reported that elk occupy meadows more frequently than forests presumably because meadows contain most of the forage in north coastal California. Yet, abundance was not considered in either study. Our objective was to estimate the influence of habitat type and abundance on occupancy by Roosevelt elk.

Materials and Methods

Study Area.—The Bald Hills area of Redwood National Park, Humboldt County, California (41˚ 11' N, 123˚ 56' W), was grazed by domestic livestock while under private ownership from about 1850 until 1977-1978 when it was acquired by the National Parks Service (Mandel and Kitchen 1979). The Bald Hills had a mild, continental climate with cool, wet winters and dry, warm summers broken by occasional fog (Weckerly and Ricca 2000; Kolbe and Weckerly 2015; Starns et. al 2015). Rain was the predominant form of precipitation with mean annual precipitation varying between ~1,200 and 1,800 mm (Weckerly and Ricca 2000). Additional precipitation was in the form of winter snow that can persist for 1–2 weeks and reach depths up to 40 cm (Starns et al. 2015). The mean summer and winter temperatures ranged from 24 ˚C to 27˚C and 3˚C to 5˚C respectively (Kolbe and Weckerly 2015).

The Bald Hills are a diverse landscape of forests and meadows. The region was approximately 4,000 ha in size (Weckerly and Ricca 2000). Meadows of 10–300 ha make up about 1,000 ha of the region while, oak woodlands, second growth, and old growth redwood (*Sequoia sempervirens*) conifer make up 76% of habitat (Weckerly and Ricca 2000; Kolbe and Weckerly 2015). The habitat in the Bald Hills generally varied with elevation which ranged from 360–930 m. Meadows generally occurred along ridgetops and contained several herbaceous species such as deervetch (*Lotus micranthus*), English plantain (*Plantago lanceolata*), California oatgrass (*Danthonia californica*), and sweet vernal grass (*Anthoxanthum odoratum*) (Weckerly and Ricca 2000; Kolbe and Weckerly 2015; Starns et. al 2015). Oak woodlands were dominated by white oak (*Quercus garryana*) and black oak (*Q. kelloggii*) while coast redwood and Douglas fir (*Pseudotsuga menziesii*) dominated second growth and old-growth redwood conifer forests (Weckerly and Ricca 2000; Kolbe and Weckerly 2015; Starns et. al 2015).

Roosevelt elk were non-migratory in the Bald Hills (Weckerly and Ricca 1995; Weckerly and Ricca 2000). In January, 2003, 204 elk were counted in the Bald Hills during systematic surveys and divided into two herds (Kolbe and Weckerly 2015; Starns et. al 2015). One herd was distributed in the northern Bald Hills while the other was distributed in the southern Bald Hills (Kolbe and Weckerly 2015). The northern herd had approximately 56 elk while the southern herd had about 148 elk (see Starns et al. 2015 for estimation methods). These herds consisted of adult females, juveniles, and sub-adult males (Kolbe and Weckerly 2015).

Methods.—Forty seven sign stations were surveyed weekly from the late May to early August, 2003, for a total of 12 surveys. All surveys were conducted by the same surveyor. Sign stations were 1-ha circular plots along roads with ≥0.8 km between stations (Weckerly and Ricca 2000). Thirteen sign stations included the area occupied by the southern herd and 34 included areas inhabited by the northern herd (Kolbe and Weckerly 2015). Oak woodlands, second growth and old growth confer stands were grouped into one habitat type, forest. There were 31 stations in forest habitat of which six were in areas that could be used by the southern herd and 25 that could be used by the northern herd. There were 16 stations in meadow habitat, seven stations in areas that could be used by the southern herd and nine stations that could be used by the northern herd. It took two days to survey all sign stations.

The surveyor searched for elk sign that was either hoof prints or feces between 0–4 days old. Sign that was ≤4 days old reduced errors in classifying sign as recent or old (Weckerly and Ricca 2000). Feces that were 0–4 days old were odious and moist and tracks that were 0–4 days old had limited plant detritus and track definition that had not be degraded by wind and moisture.

We estimated occupancy with nine single- and multi-season models in program PRESENCE (Hines 2014). We considered the entire 12 surveys a season in single-season models. To test the assumption of constant resident status, (i.e. no extinction or colonization across all surveys) we also considered multi-season models where the primary seasons were months and the secondary seasons were the four surveys conducted in each month (MacKenzie et al. 2006; Longoria and Weckerly 2007). We treated habitat as a binomial covariate where meadow was the reference category. We also considered abundance to be a binomial covariate with sign stations in the more abundant herd (the southern herd) coded as the reference category. Detection probability was kept constant in each of the nine models. The detection probability was the estimated probability of detecting elk sign during a survey when elk had actually visited the station. A preliminary analysis indicated that neither habitat type nor abundance influenced detection of sign. Colonization was set to zero in the multi-season models because no sign was detected in a primary season that had not been detected in a previous primary season. We considered five single-season models where habitat, abundance, both or neither influenced occupancy. We then considered these influences on occupancy in four multi-season models. We assessed model fit by ΔAIC_C where AIC_C was Akaike's Information Criterion corrected for small sample size (Burnham and Anderson 2002). The ΔAIC_C was the difference in AIC_C between a given model and the model with the smallest AIC_C.

Results

We selected the multi-season occupancy model where habitat and herd influenced both occupancy and extinction (Table 1). All other multi-season and single-season models had $\Delta AIC_C > 3.0$ AIC_C units. In both herds meadows were completely occupied (1.0) throughout the 12 weeks (Table 2, Figure 1). Forest occupancy by the southern herd in the first month was similar to meadow occupancy but then declined in remaining months. The northern herd had lower forest occupancy that declined from the first to last month. The estimated detection probability was 0.36 (SE = 0.03).

Table 1. Model selection summary for occupancy by Roosevelt elk in the Bald Hills of Redwood National Park, Humboldt County, California, USA. Parameters estimated were occupancy ($\hat{\psi}$), extinction ($\hat{\varepsilon}$), and detection probability ($\hat{p}$). Covariates were habitat and herd. Reported in the table are the model parameters, number of parameter estimates (*k*), deviance (-2 log-likelihood), and ΔAICc for each model.

Model	*k*	-2 Log-likelihood	ΔAIC_c
$\hat{\psi}$(Herd[1] + Habitat[2]), $\hat{\varepsilon}$(Herd + Habitat), $\hat{p}$(.)	7	577.11	0.00
$\hat{\psi}$(Herd + Habitat),$\hat{\varepsilon}$(.),$\hat{p}$(.)	5	584.15	3.04
$\hat{\psi}$(Habitat),$\hat{\varepsilon}$(.),$\hat{p}$(.)	4	589.16	6.05
$\hat{\psi}$(Herd),$\hat{\varepsilon}$(.),$\hat{p}$(.)	4	591.21	8.10
$\hat{\psi}$(Herd + Habitat), $\hat{p}$(.)	4	591.90	8.79
$\hat{\psi}$(Habitat), $\hat{p}$(.)	3	597.10	11.99
$\hat{\psi}$(.),ε(.),$\hat{p}$(.)	3	597.94	12.83
$\hat{\psi}$(Herd),$\hat{p}$(.)	3	599.24	14.13
$\hat{\psi}$(.),$\hat{p}$(.)	2	606.39	19.28

Table 2. Untransformed parameter estimates and standard errors (SE) of the selected multi-season occupancy model of Roosevelt elk in the Bald Hills of Redwood National Park, Humboldt County, California, USA. Parameters in the multi-season model were occupancy ($\hat{\psi}$), extinction ($\hat{\varepsilon}$), and detection probability ($\hat{p}$). Covariates were habitat type and herd. Reference categories were meadow habitat and the more abundant herd. The $\hat{\beta}_0$ is the constant or intercept.

Coefficients	Estimate	SE
$\hat{\Psi}_{\hat{\beta}_0}$	61.973	1.634
$\hat{\Psi}_{Herd}$	-31.891	2.493
$\hat{\Psi}_{Habitat}$	-29.538	2.528
$\hat{\varepsilon}_{\hat{\beta}_0}$	-42.236	18.732
$\hat{\varepsilon}_{Herd}$	0.995	1.237
$\hat{\varepsilon}_{Habitat}$	40.208	18.768
$\hat{p}_{\hat{\beta}_0}$	-0.561	0.110

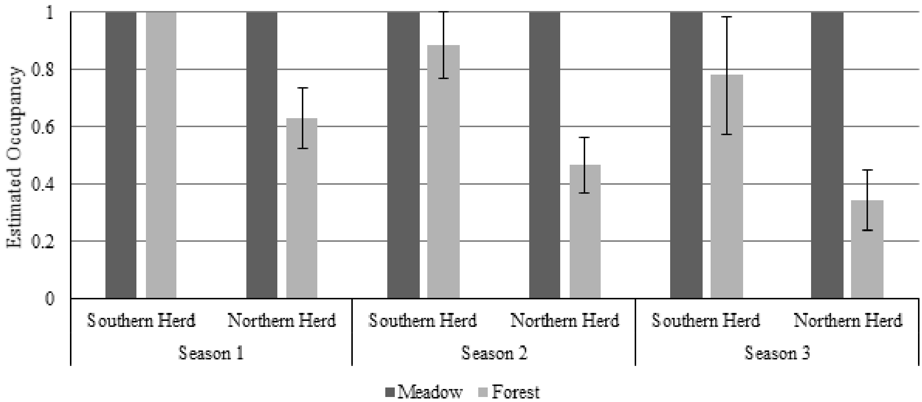

FIGURE 1.—Estimates of occupancy from sign surveys conducted for Roosevelt elk in the Bald Hills of Redwood National Park, Humboldt County, California, USA. Reported are the three secondary-season occupancy estimates with SE bars. Estimates are divided into northern and southern herds that had different abundances. The southern herd had the highest abundance. The dark gray bars are meadow and light gray bars are forest.

DISCUSSION

Our results suggest that Roosevelt elk occupancy is influenced by abundance and habitat type. Occupancy was highest in meadows and lowest in forests. Meadows were occupied by elk at the highest possible rate (1.0) although abundance differed greatly. Forest habitat was occupied at a lower rate than meadow habitat and at an even lower rate when abundance was low. Thus, elk occupy marginal habitat when quality habitat is already occupied but it is conditional on elk abundance. Elk occupied forest more frequently when abundance was high. Our results contrasted with those of Gaston et al. (2000), who suggested that differences in habitat quality would not influence abundance-occupancy relationships at large spatial scales. However, this may be a product of the study taxa. Gaston et al. (2000) discussed abundance and occupancy relationships of songbirds not elk. In Europe individual *C. elaphus* used habitat in a manner consistent with an ideal-free distribution (McLoughlin et al. 2006) whereas songbirds generally follow an ideal-despotic distribution (Holmes et al. 1996). The smaller body size and despotic behavior displayed by songbirds might affect habitat use in relation to abundance differently than elk. Elk range over a larger area and often occupy multiple kinds of habitat with marginal habitat used more frequently during high abundance. Songbirds often use one kind of habitat and adjust territory size according to habitat quality (Warren et al. 2013). In high quality habitat territory size is smaller than in marginal habitat. The result can be that songbird occupancy is similar in low and high quality habitat.

Occupancy of forest habitats by elk decreased in both herds across the 12 weeks of surveys, a period when food resources in forests may have declined. Meadows, in contrast, maintained the same occupancy throughout the 12 weeks. The heterogeneity in occupancy across months suggests that elk distribution can change across months (MacKenzie et al.

2006; Longoria and Weckerly 2006). The higher occupancy rate and lower extinction rate in meadows is in line with previous studies of habitat influences on Roosevelt elk distribution (Weckerly and Ricca 2000; Weckerly 2005; Starns et al. 2015; Kolbe and Weckerly 2015). Extinction may have been influenced by abundance as it was in the top model; however, the standard error of the herd coefficient was high. The imprecision of extinction coefficients might be affected by the small sample size in relation to the number of parameters estimated by the model.

The estimated probability of detection (0.36) was surprisingly low. Weckerly and Ricca (2000) reported an estimated detection probability (0.96) that was almost three times higher. Our surveys were conducted in the summer and not winter when other sign surveys were conducted (Weckerly and Ricca 2000; Weckerly 2005). Weckerly and Ricca (2000) also did not estimate the detection probability using occupancy estimators. Nonetheless, the warm, dry climate of the Bald Hills in the summer could have dried the feces resulting in misclassifications (i.e., 0-4 day old feces classified as >4 day old feces). Similarly hoof prints made in moist substrate in winter are likely to be readily detectable, while hoof prints on a dry substrate may be less detectible and denude more quickly. Thus the difference in our estimated detection probability could be a product of missing sign and misclassifying young sign as old. If error in aging sign did occur then it might have been more extensive in forests than in meadows. Forests receive less direct sun light and are generally moister than meadows. The misclassification in age of sign would not negate our findings, however, because the misclassification would likely result in estimates that were biased low in meadows and high in forests. Yet, we still estimated lower occupancy in forests. Future studies that consider summer occupancy of elk should consider measuring covariates such as precipitation, number of dry days, and weekly average wind speeds because they might denude signs and make them less likely to be detected.

Our analysis suggests that Roosevelt elk occupancy is driven by both habitat type and abundance. Our findings are in accord with the ideal-free distribution. Roosevelt elk use habitats of high quality most often and low quality habitat less often. Roosevelt elk habitat use is analogous to the findings of McLoughlin et al. (2006) who found that as density increased red deer selected a wider range of habitats. In the same way, Bald Hill forests were occupied at a higher rate by the more abundant southern herd than by the northern herd. In contrast, the higher quality meadows were occupied at the same rate for both herds. Additionally, Kolbe and Weckerly (2015) found that the home-ranges of the two Bald Hills herds were similar in size. Yet, the southern herd had an abundance that was roughly 3 times greater than the northern herd. One way for both herds to have similar home range sizes is for the more abundant herd to occupy marginal habitat more often. Our study suggests that abundance and habitat influence occupancy of Roosevelt elk.

Logistical burdens are usually high when estimating elk abundance because population surveys often are conducted from aircraft or by intense ground surveys. We have shown that sign surveys, which are relatively less costly, present a viable alternative for monitoring elk populations. Moreover, occupancy or distribution of elk can be estimated accommodating imperfect detection of sign. Because elk are distributed in the manner of an ideal-free distribution, changes in occupancy of quality and marginal habitat should also shed insight into changes in elk abundance.

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Using citizen science to estimate the Coastal Rainbow Trout population of Grass Valley Creek Reservoir

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Native trout and other salmonid populations worldwide are in decline due to overfishing, drought, and altered flow regimes. The successful recovery of these species requires both population monitoring and stakeholder involvement. This study engaged citizen scientists in a continuous census mark and recapture survey to estimate the population of Coastal Rainbow Trout (*Oncorhynchus mykiss irideus*) in Grass Valley Creek Reservoir. Fish were caught using hook-and-line sampling, marked via adipose fin removal, measured for fork length, and assessed for physical abnormalities. Population size was estimated as 1,924 fish (95% confidence interval: 1,443-2,780), mean fish size was 283.9 mm (SD=57.1 mm) and 95% of the sampled population had no physical abnormalities. These methods can be broadly applied to lake habitats throughout California because they are straightforward, reproducible, and easily implemented by citizen scientists who are experienced anglers.

Key words: citizen science, CPUE, Grass Valley Creek Reservoir, mark recapture, *Onchorhynchus mykiss irideus*, Rainbow Trout, Schnabel population estimate

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Anthropogenic habitat modifications and the onset of climate change have created challenging environmental conditions that have affected a wide range of organisms (Mantyka-Pringle et al. 2012). Impacts on freshwater species are of particular concern because their dispersal is limited by hydrographic constraints, and freshwater habitats have already been heavily impacted by climate change and anthropogenic stressors (Woodward et al. 2010). Though freshwater habitats cover less than 1% of our planet's surface, they support nearly 6% of known species, meaning that degradation of these habitats can have a disproportionately large effect on biodiversity (Dudgeon et al. 2006).

In California, human activities have had sizeable, negative effects on fish populations (Moyle and Williams 1990, Yoshiyama et al. 1998, Katz et al. 2013, Moyle et al. 2013). Beginning in the late 19th century, many fish populations saw marked declines in response to overfishing. The construction of dams in the 20th century fragmented much of California's riverine habitats, blocking off hundreds of miles of river and significantly changing habitat downstream of the dams. Agricultural practices have diverted water, increased siltation, introduced pesticides, and removed riparian vegetation that provides cover and temperature regulation. Logging has had similar effects, increasing siltation and reducing habitat complexity. Introduced species have preyed on native species and competed with them for resources. These activities have contributed to the status of the 25 fish taxa in California that are currently listed as endangered or threatened under the federal or state endangered species acts, including multiple species of native trout (Katz et al. 2013).

The California Fish and Game Commission established the Wild Trout Program in 1971, which was subsequently expanded in 1998 to include the Heritage Trout Program. The goals of the California Heritage and Wild Trout Program are to protect and monitor California's wild and native trout resources, conduct research and evaluate angling regulations, engage the public, and recommend new waters for designation as Wild Trout Waters (California Department of Fish and Wildlife 2017a). Currently there are 55 waters that are designated as Wild Trout Waters (California Department of Fish and Wildlife 2017b). Twelve of these waters have received the additional designation as Heritage Trout Waters, which is reserved for streams or lakes that support populations that best represent native trout populations within their historic drainage. California Senate Bill 384 (Fish and Game Code Section 1726 et seq.), passed in 2007, requires the California Heritage and Wild Trout Program to routinely inventory wild trout fisheries, and provide annual recommendations for inclusion in the program to the California Fish and Game Commission (California Department of Fish and Wildlife 2017c).

Time and resource limitations can be major obstacles to effectively monitoring wildlife populations. Given these constraints, citizen science can be an effective tool for collecting data on a species or population of particular concern (Tulloch et al. 2013). Citizen science recruits interested members of the public to contribute to scientific inquiry, including the establishment of baseline data and subsequent population monitoring (Dickinson et al. 2012). Much of citizen science focuses on observational studies, which require minimal training and equipment. A challenge in fisheries biology is that target species are often not accessible through simple observation, which necessitates specialized expertise and equipment. In fisheries research, early studies that used citizen science focused on observational methods or post-mortem sampling (Fairclough et al. 2014), but recent work has shown that recreational anglers possess the skills needed to participate in more sophisticated sampling techniques utilizing catch-and-release fishing (Williams et al. 2015).

Mark-recapture, a commonly used technique to estimate population size, can be conducted through a variety of field collection methods. In small or remote mountain lakes, hook-and-line fishing is the preferred method of sampling due to logistical problems associated with transporting gear such as electroshock units and seines (Gresswell et al. 1997). This approach also provides opportunities for skilled recreational anglers to participate in monitoring efforts as citizen scientists, providing a dual benefit to resource management agencies and the public-at-large.

The goal of this study was to use citizen science to assess the wild Coastal Rainbow Trout (*Oncorhynchus mykiss irideus*) population of Grass Valley Creek Reservoir (GVCR), a body of water that is currently under consideration for future designation under the California Heritage and Wild Trout program (M. Dege, California Department of Fish and Wildlife, personal communication). Participants collected mark-recapture data to establish a baseline population estimate, as well as condition metrics such as size and physical appearance. Many anglers already possess an interest in conservation; providing a mechanism for them to participate in a process that results in cost-effective data collection, and serves as an important interface between agency managers and stakeholders.

Methods

Study System.—Behnke (1992) describes Coastal Rainbow Trout as a cold water salmonid fish species whose native range historically spanned Pacific coast streams from Alaska to Mexico. These fish exhibit both freshwater-resident and anadromous forms. Residents complete their entire lifecycle in freshwater lakes and streams, while the anadromous form, commonly called Steelhead, migrates to the ocean as a juvenile and returns to freshwater as adults to spawn. Resident Coastal Rainbow Trout typically spawn during the spring as water temperatures rise. During this time of year, the reseident trout will spawn in tributary streams and inlets (Behnke 1992). In the case of GVCR, the resident trout spawn in Grass Valley Creek as it is the lone tributary of GVCR

Grass Valley Creek Reservoir is a manmade reservoir located in eastern Trinity County, California, adjacent to the Shasta-Trinity County line and California State Route 299W. It is approximately 40 kilometers west-northwest of Redding, California, located at 40º 37' 26″N and 122º 45' 30″W (Figure 1) with a dam crest elevation of 858 meters (United States Bureau of Reclamation 2017). Historically, Grass Valley Creek supported resident and migratory populations of Coastal Rainbow Trout. The Grass Valley Creek population became landlocked by the construction of the Buckhorn Sediment Dam, which was completed in 1991 without a fish bypass structure (e.g., fish ladder). As a consequence, fish from GVCR can no longer migrate to and from the Pacific Ocean (M. Dege, California Department of Fish and Wildlife, personal communication). Currently, angling regulations allow a two fish bag limit, regardless of size, for those who wish to harvest fish from the reservoir.

Citizen Scientist Selection and Training.—Six citizen scientists were recruited based on their fly-fishing experience in general, and specifically, their many years experience in fishing at GVCR. Opportunities were advertised via word-of-mouth, including announcements at local fly-fishing shops. Prior to data collection, all anglers received training on how to mark, measure, and assess the fish for physical abnormalities. Fin clipping instruction was done on fish that were purchased from a local market and each citizen scientist had the opportunity to perform a fin clip. Anglers were also trained on what fork length represented and how to make the measurement.

Field Methods.—Field methods were designed to collect data for a continuous Schnabel mark-recapture analysis (Schnabel 1938, Carpenter et al. 2001, Pine et al. 2003, Hansen et al. 2008). The study was completed over 13 sampling days from 01 October 2016 through 29 January 2017. A seven person team, made up of citizen scientists and the lead author (D.C.H.), caught, marked, and released fish in GVCR. Anglers fished from float tubes (a type of an inner tube used by recreational anglers) with fly rods that were equipped with sinking, intermediate sinking, or floating fly lines. Anglers used flies that imitated the nymph stage of aquatic and terrestrial insects. Hook sizes varied from size 8 to 20 (4.8 mm to 1.5 mm) and were single and barbless, in accordance with California Freshwater Sport Fishing

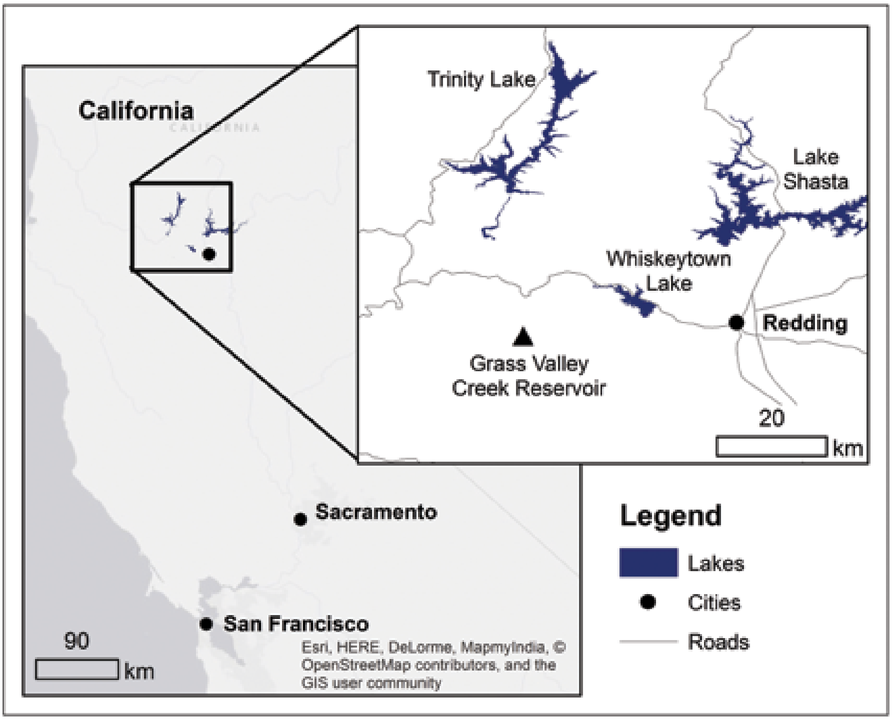

FIGURE 1.—Location map for Grass Valley Creek Reservoir, California.

Regulations (2016-2017). Landing nets were used to minimize the stress and handling time of individual fish. All fishing took place during daylight hours, generally between 0800 and 1600 hours. Each angler was required to have a California State fishing license and follow all state fishing regulations. Data were collected under California Department of Fish and Wildlife Scientific Collecting Permit #13568.

Fish sampling methods were chosen to maximize ease of data collection for citizen scientists. After capture, fish were marked by clipping their adipose fin with surgical scissors, as close to the backbone as possible, without taking any flesh from the fish. Adipose fin clips have not previously been used in GVCR, meaning that all recaptures with a clipped adipose fin originated from our study. Fish fork length was measured to the nearest ¼ inch from the tip of the nose to fork in the caudal fin, and converted to millimeters for analysis. Anglers assessed the physical appearance of each fish by counting the number of physical abnormalities present. For the purpose of our study, physical abnormalities were defined as lesions, sores, parasites, missing or damaged fins, missing or damaged eyes, gill and opercular damage, or any abnormalities caused by attempted predation. Upon completion of any mark-recapture population estimate, all captured individuals are returned to the population without being marked. Therefore, on the final day of sampling, we returned 10 fish to the water unmarked since the study had concluded.

Analyses.—The Schnabel function, in the fishmethods package for R-studio, was used to conduct a continuous Schnabel mark-recapture analysis that estimated population size with 95% *CI* (R Core Team 2013, Nelson 2017). The Schnabel population estimate is shown in the equation:

$$N = \frac{\sum_{i=1}^{s}(M_i C_i)}{\sum_{i=1}^{s} R_i}$$

where s is the number of sampling events, M_i is the number of previously marked individuals in the population at sampling event i, C_i is the total number of fish caught during sampling event i, and R_i is the total number of recaptures during sampling event i.

This method is commonly used in fisheries mark-recapture studies (Schnabel 1938, Carpenter et al. 2001, Pine et al. 2003, Hansen et al. 2008) and assumes that (1) the population is closed, (2) all fish have an equal probability of being caught, (3) marking fish does not affect their probability of recapture, (4) tags are not lost between capture events, and (5) all tags are reported during recaptures. To increase confidence that these assumptions were met, we plotted the total number of fish that had been previously marked after each sampling period against the proportion of fish in each sample that had been previously marked, and examined the linearity of this relationship using a Pearson correlation coefficient. A non-linear relationship could be caused by violations of the method's assumptions (Sutherland 2006).

Summary statistics were created to describe fish size class, condition, and catch-per-unit-effort (CPUE). Fish size class was summarized by binning the data into approximately 25 millimeter bins. Condition was calculated as the percent of fish with a given number of physical abnormalities. For these metrics, we used data recorded during the first capture. CPUE was calculated as the average number of fish caught per angler each hour.

In order to ensure consistency between citizen scientists, we excluded data from any angler whose individual CPUE fell more than one standard deviation away from the overall mean CPUE for the study. Two anglers met this criteria; thus, the results reported here reflect data collected by five anglers. We do note, however, that exclusion of these anglers had a negligible effect on our final population estimate.

Results

During the study, 421 fish were captured. Of those, 39 fish were recaptures and 372 were marked (Table 1). These numbers were used in a continuous Schnabel mark-recapture analysis, which estimated the population size of Coastal Rainbow Trout to be 1,924 fish (95% confidence interval: 1,443-2,780). There was a linear relationship between total number of fish that had been previously marked after each sampling period and the proportion of fish in each sample that had been previously marked (Pearson Correlation: $r = 0.617$, $p = 0.025$, $n = 13$), increasing our confidence that the model's assumptions were met.

Over the course of 360 hours of fishing, the CPUE per angler was calculated as 1.17 fish per hour (Table 2). Due to variation in the number of anglers and the number of hours sampled per day, the daily average CPUE differed slightly and was calculated as 1.22 (*SD* = 0.68) fish per hour.

Total length of the fish in this study ranged from 152.4 - 457.2 mm. Mean total length of the sample population was 283.9 mm (*SD* = 57.1 mm) (Figure 2). Ninety five percent of the 382 sampled fish had no physical abnormalities. Fifteen exhibited one physical abnormality (3.93%), and two fish exhibited two physical abnormalities (0.52%). No fish had more than two physical abnormalities.

TABLE 1—Daily sampling data for the number of fish caught (Ci), recaptured (Ri), newly marked and previously marked (Mi) for the continuous Schnabel population estimate of Rainbow Trout in the Grass Valley Creek Reservoir

		Population Estimate		
Sample Date ($_i$)	**Caught (C_i)**	**Recaptures (R_i)**	**Newly Marked**	**Previously Marked (M_i)**
10/01/2016	59	0	59	0
10/02/2016	36	0	36	59
10/09/2016	44	5	39	95
10/15/2016	36	3	33	134
10/22/2016	68	7	61	167
10/29/2016	38	4	34	228
11/06/2016	36	2	34	262
11/11/2016	24	5	19	296
11/20/2016	23	1	22	315
12/03/2016	9	1	8	337
12/10/2016	14	4	10	345
12/17/2016	23	6	17	355
01/29/2017	11	1	0	372
Totals	**421**	**39**	**372**	

TABLE 2.—The catch per unit effort (CPUE) for each sampling day. CPUE was calculated as the number of fish caught per angler each hour fished.

Date	Anglers	Hours Fished	Total Caught	CPUE
10/01/2016	5	37	59	1.59
10/02/2016	2	16	36	2.25
10/09/2016	5	40	44	1.10
10/15/2016	2	14	36	2.57
10/22/2016	5	40	68	1.70
10/29/2016	3	24	38	1.58
11/06/2016	4	32	36	1.13
11/11/2016	4	32	24	0.75
11/20/2016	4	32	23	0.72
12/03/2016	3	24	9	0.38
12/10/2016	3	24	14	0.58
12/17/2016	3	24	23	0.96
01/29/2016	3	24	11	0.52
2016-2017	**5**	**360**	**421**	

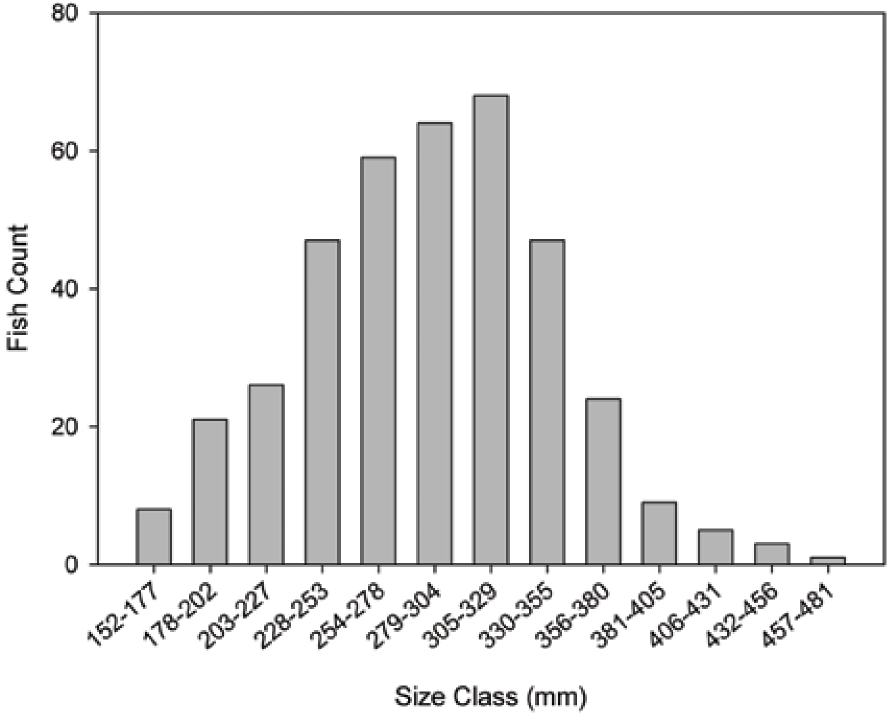

FIGURE 2.—Size class distribution (in millimeters) of Coastal Rainbow Trout in Grass Valley Creek Reservoir. Data from recaptures are excluded.

DISCUSSION

This study has provided data that can potentially aid in the management and sustainability of Grass Valley Creek Reservoir Coastal Rainbow Trout fishery. The study also demonstrates that the utilization of experienced anglers as citizen scientists can contribute to more advanced studies and improved data collection. While this study is narrow in its scope, taking place at one mid-altitude reservoir in northern California, the methods are easily applied to other lake systems making the study broad in its application.

The Schnabel population estimate has several inherent assumptions built into the model (Schnabel 1938, Sutherland 2006). First, it assumes that the population has negligible births, deaths, emigration, and immigration. We placed signs along trails and access roads asking the public to release all fish caught during the study, with the goal of reducing the number of fish leaving the population. Second, it assumes that all fish have an equal probability of being caught. A limitation of this study is that angling is an effective sampling method only for a certain range of fish sizes. In addition to being gape-limited, ontogenetic shifts in diet may mean that smaller fish are not attracted to the types of flies that were used in this study. Likewise, larger fish may shift to larger prey items to maximize energetic intake relative to foraging effort (Townsend and Winfield 1985). Because of this, our population estimate likely estimates a limited number of size classes. Third, the Schnabel estimate assumes that marking fish does not affect their probability of recapture. In order to decrease behavioral changes that may affect this assumption, we took steps to minimize stress and handling time. Fin clipping was conducted as quickly as possible to minimize air exposure. In circumstances where handling time may have been increased, fish were placed in the water to rest and recover prior to completion of marking and data collection. Fourth, the model assumes that tags are not lost between capture events. Since our marking method was the removal of the adipose fin, we are confident that this assumption was met. Finally, it assumes that all tags are reported during recapture. Experienced anglers can easily recognize fin clips, and our team was actively monitoring clips of recaptured fish for signs of infection. Given this, it is unlikely that any marked fish went unreported during resampling.

Thompson and Blankenship (2011) examined adipose fin regeneration after clipping in Coho salmon (*Oncorhynchus kisutch),* a species that is closely related to Coastal Rainbow Trout. They found that when the adipose fin was completely removed, it showed no regeneration after 24 months. Because of this, adipose fin clips cannot be reliably used in subsequent mark-recapture studies at GVCR because it would not be possible to determine how many fish with a missing adipose fin are in the reservoir at the onset of the study. Therefore, we recommend that future studies at GVCR utilize a different marking method, such as a hole punch to the caudal fin. Previous work has shown that caudal hole-punches regenerate over time, allowing differentiation between marking events from different seasons (Allison 1963).

A strategic goal of the California Fish and Game Commission, which established the California Heritage and Wild Trout Program, is to "Increase public participation and representation in Commission decision-making processes and operations." Citizen science engages the public and increases stewardship (Dickinson et al. 2012), making it an excellent way to support this goal. However, there has been some concern that data collected by citizen scientists is more error-prone than data collected by professional scientists. For example, several studies on volunteer-based monitoring programs have found a "learner" effect, where the quality of the data collected by citizen scientists improves over time (Sauer et al. 1994, Kendall et al. 1996, Jiguet 2009). Other studies have found that datasets are largely reliable when citizen scientists are given proper training (Done et al. 2017, Palmer et al. 2017). We argue that experienced recreational anglers, such as the citizen scientists who participated in our study, are likely to have surpassed this learning curve because they already have many hours of experience angling, identifying species, and handling fish. We chose a simple and inexpensive marking technique, fin clipping, and the citizen scientists received training on this methodology prior to the onset of sampling, likely leading to a decrease in errors in our population estimation. Another benefit that comes with citizen science is that it can help offset the budget and resource constraints that plague many monitoring programs. Gardiner et al. (2012) did a cost-benefit analysis of implementing citizen science programs. They found that, despite requiring an initial investment, citizen science was more cost effective per dollar than traditional data collection methods over time. The authors acknowledge that there may be an increase in data collection errors but argue that, in many cases, this is counterbalanced by the ability to collect a larger dataset in a cost-effective manner.

CDFW conducted a *Fish for Science* program at GVCR from 1994-1997, and again in 2011, which used CPUE of participants as an estimate of fish abundance. This approach assumes a proportional relationship between CPUE and overall fish abundance, but has been criticized as a metric for estimating fish abundance (Harley et al. 2001, Maunder et al. 2006). However, it is still widely used in assessing fishery stocks in large ocean basins (McCluskey and Lewison 2008). While most published criticisms of CPUE focus on ocean systems, some criticisms are applicable to freshwater systems. Specifically, CPUE can easily be influenced by environmental conditions that influence fish appetite and behavior, such as seasonal variations or differences between years (Lucas and Baras 2000, Hilborn and Walters 2013), making the validity of comparing different sampling periods questionable. Despite this, we believe that CPUE can be a valuable tool to engage citizen scientists as long as it is interpreted with these limitations in mind. While the results from mark-recapture methods such as the Schnabel estimate are not readily accessible to anglers during the sampling period, CPUE provides anglers with a real-time, albeit rough, metric that can help keep them engaged throughout the study.

We recommend that citizen scientists be incorporated into future fish population studies when possible. Incorporating experienced anglers as citizen scientists facilitated a larger dataset and met the goals of the California Fish and Game Commission. Our straightforward methods were chosen so that they were easily understood and applied by citizen scientists. These experienced anglers were able to collect important data on a fish population, while taking care to reduce handling time and stress to fish. The methods employed make this study reproducible in the future at GVCR, as well as other diverse lake habitats across California.

Acknowledgments

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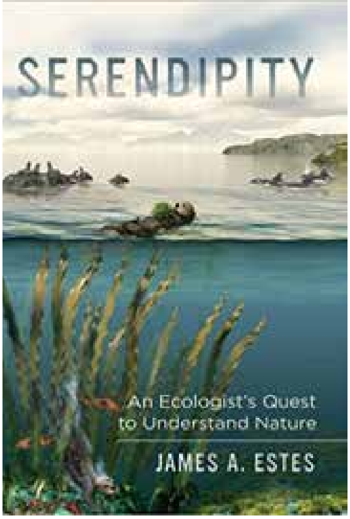
Book Review:
Serendipity: an ecologist's quest to understand nature

James A. Estes. 2016. University of California Press, Oakland, USA. 276 pages (hard cover). $29.95. ISBN: 978-0-520-28503-3



With publication of *Serendipity: an ecologist's quest to understand nature*, an extremely competent and highly respected scientist provides readers with a detailed review of his life's work exploring marine ecosystems. Most of James Estes' investigations were conducted in the northern Pacific Ocean and, more specifically, in the Aleutian Archipelago of southwest Alaska, but also included work elsewhere in the Pacific Ocean and in the southern hemisphere. Key subjects in Estes' life-long research have been sea otters, kelp, sea urchins and, almost fortuitously, the unintended consequences of human actions. During a career spanning nearly 50 years, Estes has been a leading proponent of discovering the linkages between, and consequences of, ecosystem perturbations. In this book he recounts, largely in chronological order, the observations, experiments, serendipitous happenings, setbacks, discoveries, and successes that have characterized his efforts.

Dr. Estes' work has involved large numbers of collaborators, among which have been graduate students, academics, agency scientists, and technicians, all of who contributed to his successes. In reviewing the acknowledgments, I noted that four employees of the California Department of Fish and Game added in meaningful ways to his work, and I also am privileged to have worked closely with three of them during my 34 years with that agency. It is gratifying to see the efforts of agency personnel acknowledged as major contributors to, or facilitators of, research of the magnitude and import described in Serendipity.

While space does not permit a detailed description of the work conducted or the importance of the results, the book can be succinctly described as one scientist's efforts to understand the relevance of top-down forcing, its implications for ecosystem function, and the consequences of anthropogenic perturbations and their role in, and implications for, ecosystem change. The work described in Serendipity had its origins with an early emphasis on food webs and the ecological linkages among sea otters, kelp, and sea urchins, and evolved into an exploration of top-down forcing, keystone species, and trophic cascades, all of which are discussed in detail by the author.

The book consists of 16 chapters, each dedicated to some aspect of the long-term research conducted by Dr. Estes, and each chapter generally builds on knowledge gained, observations made, or results of efforts described in the preceding chapter. In Chapter 15, Estes identifies the goals of the book as being to (1) recount knowledge gained over a research career spanning roughly 50 years; (2) describe broadly how predators and prey interact with one another (and the consequences thereof); and, (3) explain how the science he conducted actually happened. After identifying these goals, he presents what he identifies as the seven conceptual high-points of his five-decade adventure with creatures ranging in size from the great whales to phytoplankton, and the role that the actions of Homo sapiens played in providing grist for much of the research described. These seven high points are identified and discussed as (1) the importance of perturbations; (2) generality and variation [of results]; (3) state shifts and hysteresis; (4) the far-reaching influences of trophic cascades; (5) coevolution; (6) inter-ecosystem connectivity; and, (7) serendipity.

Although Serendipity was written by a scientist and recounts the history of numerous ideas and subsequent discoveries, it is a very reader-friendly work. With the end of each chapter, I found myself wanting to continue with the next, and sometimes found myself reading well into the evening. The text is clear, the messages are of great interest, and the conclusions are fascinating and have implications both for conservation and management. The text is presented in a manner that is easy reading for researchers, students, and interested members of the public. Although the material is technical in many ways, Estes has taken the opportunity to provide explanations and definitions throughout the book, which includes a detailed glossary and a thorough list of citations. Moreover, Serendipity is exceedingly well-written and carefully edited, and I noted only one error in the text. On pages 72 and 73, reference is made to, "… the late-1990s through the end of the first decade of the twentieth century…". Surely, the author had intended to refer to the first decade of the twenty-first century.

In the final chapter Estes writes, "Living with large predators means rethinking the spatial scales of conservation and management. Small protected areas simply won't do, as they cannot maintain viable populations of large predators, especially large predatory mammals. We will need landscapes and seascapes that are managed and protected at large enough scales to maintain these animals at ecologically effective population densities." I couldn't agree more with those thoughts. As noted elsewhere (Bleich 2016), many recent North American efforts to ensure continuation of ongoing ecological and evolutionary (E&E) processes appear to have been established as the result of desires to please special interest groups, and the perceived benefits of political expediency. To the dismay of many, however, such areas have been established largely in the absence of ecological forethought and at scales too small to ensure the continuation of E&E processes (Bleich 2016). Instead, proponents of many recently protected areas have emphasized the sociological or recreational benefits, rather than ecological benefits, of such areas, and increasing rates of visitation further confound the efficacy of such areas (Sarmento and Berger 2017). Perhaps the continuing advocacy of James Estes and other scientists of his caliber will yield changes in the ways that efforts to conserve viable ecosystems occur in the future.

Another review (Ball et al. 2017) was published just as I completed this review, and it generally was positive. Nevertheless, those authors described what they felt were several weaknesses and I must disagree with them on one issue raised in their comments. Ball et al. (2017) described the tone used by Estes when referring to his major scientific discoveries and subsequent publications in prestigious journals as "casual," and described references to submitting concepts to the National Science Foundation and the apparent ease in receiving funding as "glib." The authors of that review voiced concern that Estes' descriptions of those activities were "somewhat cavalier" and that they could "even be discouraging to graduate students who are struggling to establish themselves as scientists." I view such criticism as unfortunate and unnecessary, but note the review was prepared as part of a graduate seminar. Rather than finding such statements discouraging, I would prefer to think that at least some of those students, by having read Serendipity, will be motivated to strive for the level of success achieved by Jim Estes during his stellar career.

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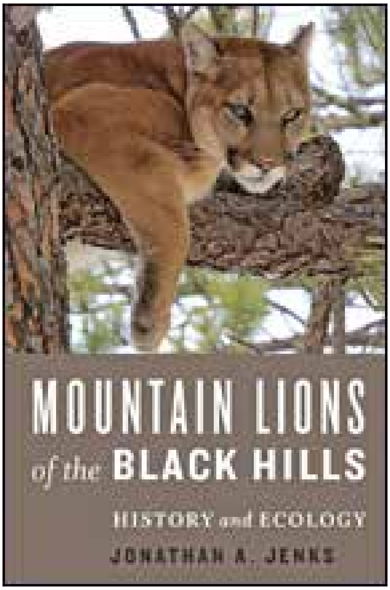
Book Review:
Mountain lions of the Black Hills: history and ecology

Jonathan A. Jenks. 2018. Johns Hopkins University Press, Baltimore, Maryland, USA. 144 pages (hard cover). $75.00.
ISBN: 978-1-4214-2442-2



In 1999 Jon Jenks had the good fortune to begin a long-term investigation of mountain lions (*Puma concolor*) occupying a small, isolated range of mountains in western South Dakota. The Black Hills are surrounded largely by vast expanses of flat prairie (or agricultural lands that formerly were prairie), and little information regarding mountain lions in that region was available. Jon became involved very early in studying what has turned out to be the natural reestablishment of a keystone predator in the Black Hills and has pursued investigations of the population ecology of those cryptic felids for 15 years. He and his students have published on the predator-prey relationships, population dynamics, population ecology, behavior, and genetics of this population in numerous professional journals. In *Mountain Lions of the Black Hills,* Jenks provides a first-person account of their long-term effort to better understand the ecology of one of North America's most intriguing carnivores, and summarizes the results of that research succinctly and in a way that is readily understood by the reader.

This book traces the recent history of mountain lions in the Black Hills in a logical order. In the first two chapters, Jenks discusses some of the early history of the region and an overview of the general ecology of the Black Hills and surrounding area. Chapter 3 centers largely on introducing the reader to mountain lions in general, as well as the methods used during this long-term and classic investigation. The following chapters discuss the results of the vast amount of research conducted in the area, including demography (Chapter 4), disease (Chapter 5), nutritional ecology (Chapter 6), and population genetics (Chapter 7). In each of these chapters the author delves deeply into the subject matter and provides, with ample credit to the students working with him, detailed summaries and interpretations of the results that are the basis for this book.

Chapter 8 addresses some of the perceptions held by the citizens of South Dakota during investigations recounted in the book, and some of the changes in public opinion that occurred over time. Jon further notes that the conservative population estimates generated during the research led some to conclude that he and his students developed a protectionist attitude regarding mountain lions. Others seized upon those conservative estimates, ultimately leading animal rights groups, both inside and outside of South Dakota, to challenge harvest recommendations proposed by the South Dakota Department of Game, Fish and Parks. As Jenks explained, however, his mentors had emphasized conservative approaches to harvest objectives, thereby ensuring that overharvest was unlikely. The court ultimately dismissed those challenges, and the first mountain lion hunting season occurred in 2005 and has since then been an annual event and with little opposition. The unbiased and objective approach to investigating mountain lions in the Black Hills was instrumental in the decision to open a hunting season.

In an epilogue, Dr. Jenks expresses appreciation for having had the opportunity to explore what essentially was the recolonization of the Black Hills by an apex predator. From what must have been very few individuals in the 1990s, that small population increased in numbers and expanded its distribution throughout the Black Hills. As much, if not more, is now known about that population than most other populations of that secretive felid, and in large part because of the efforts of Jenks and his colleagues. Not only were they fortunate to have been involved with this investigation since the population was very small, they have been able to investigate the ecology of the population as it expanded and as animals dispersed. As he notes in the penultimate sentence, "I have confidence that with continued management the species will thrive and provide future generations the thrill of seeing this charismatic critter in its natural environment."

In the book, Jon uses two terms that were new to me in context, but for which I have an appreciation. Rather than use the term corridor for areas that immigrant or emigrant lions use when moving between areas of atypical mountain lion habitat, he uses the term 'conduit', the implication being that movement occurs, but without limitation on or knowledge of, the actual routes travelled. From a conservation perspective, the maintenance of conduits is preferable to maintenance of corridors when addressing interpopulation movements, and I suggest it is a useful term with application both to dispersing carnivores and migratory ungulates. In lieu of using the term carrying capacity to describe the ability of an area to support mountain lions, Jon uses the term 'saturated' to describe the maximum number or maximum density of mountain lions likely to occur in any given area over time. I suspect we will see that term increasingly in the literature as additional investigators become familiar with it.

I read this book in just a couple of days; it is well written, easily understood even by non-scientists, and takes the reader into the field with the investigators. I noted only two (only two!) minor typographical errors, both of which could be missed easily by even the most experienced copy editor or proof-reader. All in all, this book is a good read, and provides a first-person account of one of the longest running and most detailed investigations of mountain lions yet conducted. Jon has provided readers with a thorough description of the recolonization of an area by a top carnivore, the trials and tribulations associated with research and the management of that species and, perhaps more importantly, with an optimistic view of its future.—*Vernon C. Bleich, Department of Natural Resources and Environmental Science, University of Nevada Reno* and *Eastern Sierra Center for Applied Population Ecology, Bismarck, North Dakota.*

California Fish and Game 104(2): 91; 2018

Information for Contributors

California Fish and Game is a peer-reviewed, scientific journal focused on the biology, ecology, and conservation of the flora and fauna of California or the surrounding area, and the northeastern Pacific Ocean. Authors may submit papers for consideration as an article, note, review, or comment. The most recent instructions for authors are published in Volume 97(1) of this journal (Bleich et al. 2011), and are accessible through the California Department of Fish and Wildlife website (www.wildlife.ca.gov/publications). Planning is in progress to provide an avenue for authors to submit manuscripts directly through the website, and to enable restricted and confidential access for reviewers. In the meantime, manuscripts should be submitted by e-mail following directions provided by Bleich et al. (2011). The journal standard for style is consistent with the Council of Science Editors (CSE) Style Manual (CSE 2006). Instructions in Bleich et al. (2011) supersede the CSE Style Manual where differences exist between formats. Authors of manuscripts that are accepted for publication will be invoiced for charges at the rate of $50 per printed page at the time page proofs are distributed. Authors should state acceptance of page charges in their submittal letters. The corresponding author will receive a PDF file of his or her publication without additional fees, and may distribute those copies without restriction. Plans are underway to make the complete series of *California Fish and Game* available as PDF documents on the California Department of Fish and Wildlife website.

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Front.—Drake mallard (*Anus platyrhynchos*) taking flight. CDFW file photo.

Rear.—Bull Roosevelt elk (*Cervus Canadensis roosevelti*). CDFW Photo © Jim Mahmens.

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