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

California mallards: a review

Cliff L. Feldheim*, Joshua T. Ackerman, Shaun L. Oldenburger, John M. Eadie, Joseph P. Fleskes, And Gregory S. Yarris

California Department of Water Resources, Suisun Marsh Branch, 3500 Industrial Blvd., West Sacramento, CA 95691 USA (CLF)

U. S. Geological Survey, Dixon Field Station, 800 Business Park Drive, Suite D, Dixon, CA 95620 USA (JTA)

California Department of Fish and Wildlife 812 9th Street Sacramento, CA 95811 USA (SLO) [1]

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

U.S. Geological Survey, Western Ecological Research Center, Dixon Field Station, 800 Business Park Drive, Suite D, Dixon, CA 95620 USA.(JPF)

California Waterfowl Association 1346 Blue Oaks Blvd., Roseville, CA 95678 USA (GSY) [2]

**Correspondent*: Cliff.Feldheim@water.ca.gov

[1]Texas Parks & Wildlife Department 4200 Smith School Rd. Austin, TX 78744 USA
[2]United States Fish and Wildlife Service, Central Valley Joint Venture, 2800 Cottage Way, Sacramento, CA 95825 USA

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

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-

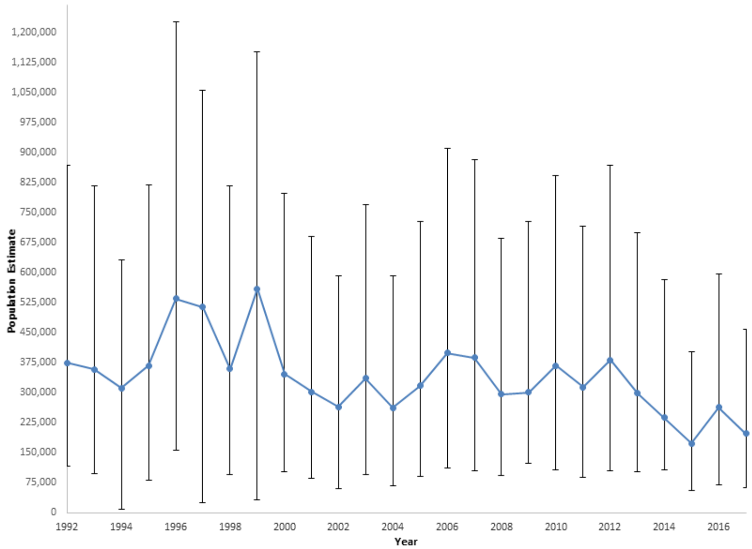

FIGURE 1.—California breeding mallard estimate with 95% confidence intervals 1992-2017.

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-

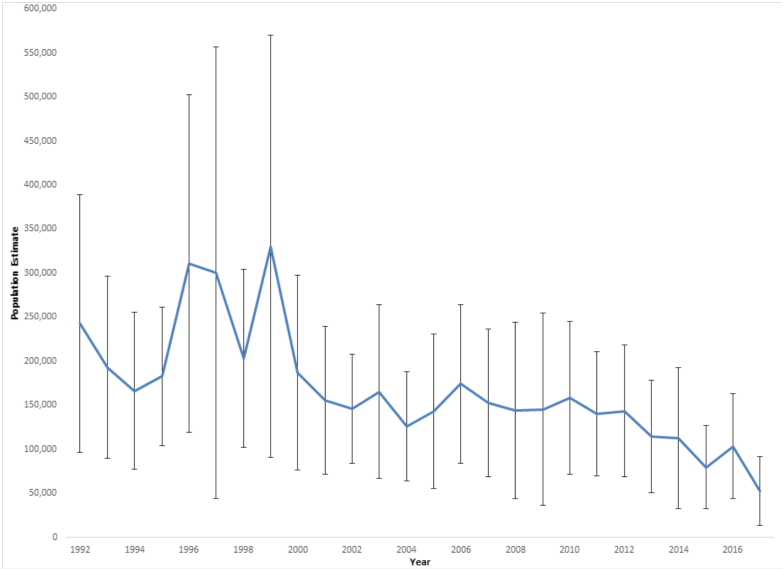

FIGURE 2.—California breeding mallard estimate with 95% confidence intervals for the Central Valley 1992-2017.

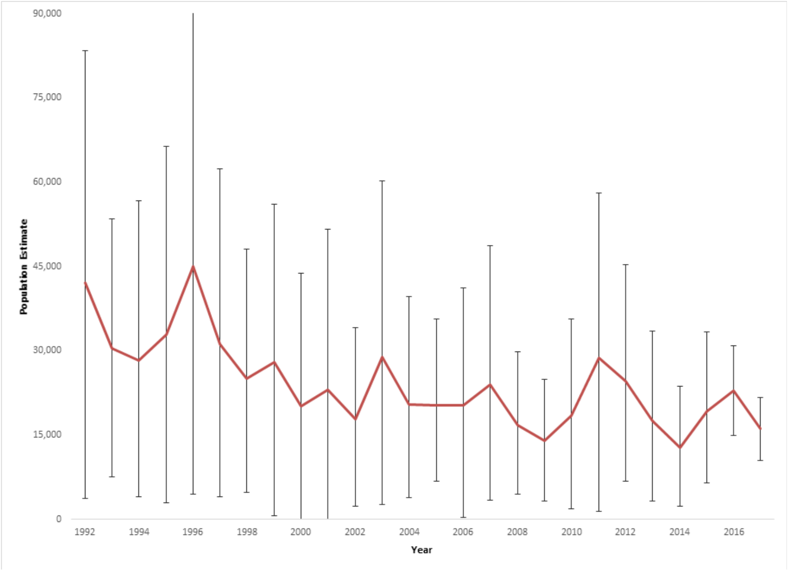

FIGURE 3.—California breeding mallard estimate with 95% confidence intervals for the Bay Delta/ Suisun Marsh 1992-2017.

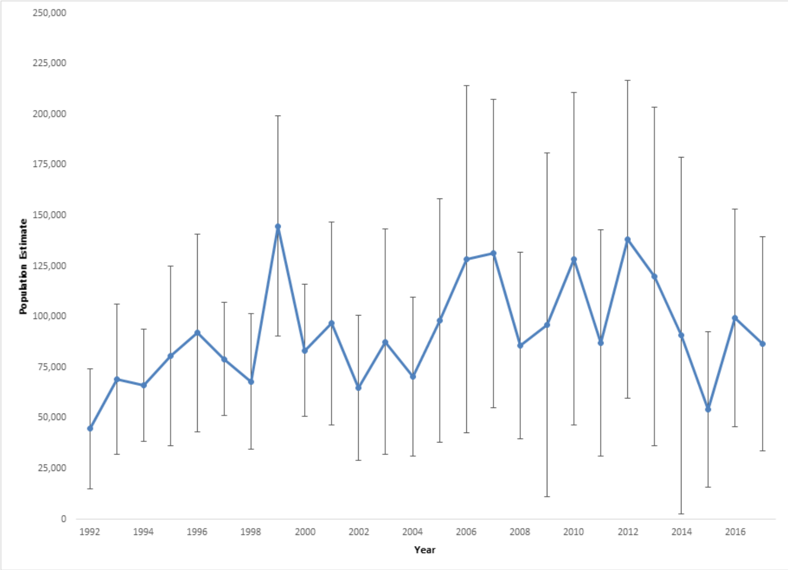

FIGURE 4.—California breeding mallard estimate for northeastern California with 95% Confidence Intervals 1992-2017.

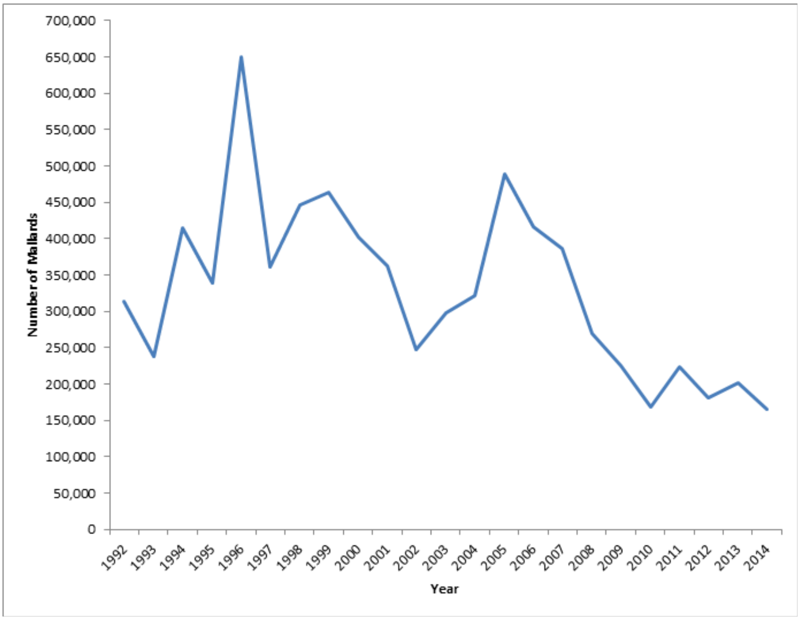

FIGURE 5.—California Midwinter Survey Index for Mallards 1992-2015.

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.

Acknowledgments

We would like to thank all those that attended the "mallard meeting" in August, 2007, in Chico, California, including E. Burns, R. Capriola, M. Carpenter, J. Kwoek, M. Miller, C. Santere, and D. Woolington. We thank R. Holbrook, E. Jeu, D. Kwasny, D. Loughman, E. Machett, D. Mauser, J. Messerli, M. Miller, P. Perrine, D. Skalos, D. Yparraguirrie, and

M. Wolder for providing critical reviews of earlier versions of this paper. We'd like to thank the three reviewers and journal editor who made valuable comments and made this a better manuscript. California Department of Fish and Wildlife, California Waterfowl Association, and Central Valley Joint Venture provided monetary and logistic support for the completion of the meeting and this paper. The use of trade, product, or firm names in the publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Literature Cited

Ackerman, J. T., M. P. Herzog, G. S. Yarris, M. L. Casazza, E. W. Burns, And J. M. Eadie. 2014. Waterfowl ecology and management. Pages 103–132 in P. B. Moyle, A. Manfree, and P. L. Fiedler, editors. Suisun Marsh: Ecological history and possible futures. University of California Press, Berkeley, California, USA.

Ackerman, J. T., M. P. Herzog, L. Salas, T. Gardali, G. Ballard, D. Loughman, G. Yarris, And J.M. Eadie. 2011. Avian Breeding Demographic Response to Climate Change: A Multi-Species and Multi-Landscape Approach to Synthesizing Risk Factors. Summary Report, U. S. Geological Survey, Western Ecological Research Center, Davis, CA; PRBO Conservation Science, Petaluma, CA; California Waterfowl Association, Sacramento, CA; University of California, Davis, California, USA.

Ackerman, J. T., J. Kwolek, R. Eddings, D. Loughman, And J. Messerli. 2009. Evaluating upland habitat management at the Grizzly Island Wildlife Area: effects on dabbling duck nest density and nest success, year 1 baseline report. Administrative Report, U. S. Geological Survey, Western Ecological Research Center, Davis, CA and California Waterfowl Association, Sacramento, California, USA.

Ackerman, J. T, J. M Eadie, S. L. Oldenburger, G. S. Yarris, D. L. Loughman, And M. R. Mclandress. 2006. Age related reproductive success of mallards in California. Fourth North American Duck Symposium, Bismarck, North Dakota, USA.

Ackerman, J. T., J. Y. Takekawa, D. L. Orthmeyer, J. P. Fleskes, J. L. Yee, And K. L. Kruse. 2006a. Spatial use by wintering greater white-fronted geese relative to a decade of habitat change in California's Central Valley. Journal of Wildlife Management 70(4): 965-976.

Ackerman, J. T., J. M. Eadie, M. L. Szymanski, J. H. Caswell, M. P. Vrtiska, A. H. Raedeke, J. M. Checkett, A. D. Afton, T. G. Moore, F. D. Caswell, R. A. Walters, D. D. Humburg, And J. L. Yee. 2006b. Effectiveness of spinning-wing decoys varies among dabbling duck species and locations. Journal of Wildlife Management 70(3):799-804.

Ackerman J. T., J. M. Eadie, and T. G. Moore. 2006c. Does life history predict risk-taking behavior of wintering dabbling ducks? Condor 108:530-546.

Ackerman, J. T, A. L. Blackmer and J. M. Eadie. 2005. Is predation on waterfowl nests density dependent: a test at three spatial scales. Oikos 107: 128-140.

Ackerman, J. T. And J. M. Eadie. 2003. Current versus future reproduction: an experimental test of parental investment decisions using nest desertion by mallards (*Anas platyrhynchos*). Behavioral Ecology and Sociobiology 54: 264-273

Ackerman, J. T., J. M. Eadie, D. Loughman, G. S. Yarris and M. R. McLandress. 2003. Cues for investment: nest desertion in response to partial clutch depredation in dabbling ducks. Animal Behavior 66: 871-883.

Ackerman, J. T. 2002. From individuals to populations: the direct and indirect effects of predation on waterfowl nest success. Ph.D. Dissertation, University of California, Davis, California, USA.

Ackerman, J. T. 2002a. Of mice and mallards: positive indirect effects on coexisting prey on waterfowl nest success. Oikos 99:469-480.

Anderson, W. 1960. A study of waterfowl nesting in the Suisun Marshes. California Fish and Game 46:217-226.

Anderson, W. 1957. A waterfowl nesting study in the Sacramento Valley, California. 1955. California Fish and Game 43:71-90.

Anderson, W. 1956. A waterfowl nesting study on the Grasslands, Merced County, California. California Fish and Game 42:117-130.

AR, A. and Y. Sidis. 2002. Nest microclimate during incubation. In: Avian incubation, D. C. Deeming, editor. Oxford, Oxford University Press, United Kingdom.

Arnold, T W., D. Shizuka, B.E. Lyon, J.T. Pelayo, K. R. Mehl, J.J Traylor, Reed, W.L., and C.L. Amundson, 2011. Use of Nape Tags for Marking Offspring of Precocial Waterbirds. Papers in Ornithology. 84.

Bellrose, F. C. 1980. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

Bielefeld, R. R. and R. R. Cox, Jr. 2006. Survival and cause-specific mortality of adult female mottle ducks in east-central Florida. Wildlife Society Bulletin 34:388-394.

Brasher, M. G., T. W. Arnold, J. H. Devries, and R. M. Kaminski. 2006. Breeding-season survival of male and female mallards in Canada's prairie-parklands. Journal of Wildlife Management 70:805-811.

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. United States Fish and Wildlife Service. Sacramento, California, USA.

California Department of Fish and Wildlife. 2014. Final Environmental Document, Migratory Gamebird Hunting, Waterfowl, Coots, Moorhens. State of California Resources Agency, Sacramento, California, USA.

Chouinard, M. P., Jr. and T. W. Arnold. 2007. Survival and habitat use of mallard (*Anas platyrhynchos*) broods in San Joaquin Valley, California. Auk 124:1305-1316.

Cowardin, L. M., D. S. Gilmer, and C. W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildlife Mongraphs 92.

Devries, J. H., J. J. Citta, M. S. Lindberg, D. W. Howerter, and M. G. Anderson. 2003. Breeding-season survival of female mallards in the prairie pothole region of Canada. Journal of Wildlife Management 67:551-563.

De Sobrino, C. N. T W. Arnold, and C. L. Feldheim. 2017. Distribution and derivation of dabbling duck harvests in the Pacific Flyway, California Fish and Game 103(3): 118-137.

Eadie, J. M., T. G. Moore, and J. T. Ackerman. 2002. Experimental evaluation of the effect of amechanical decoy (moto-duck) on hunting success and waterfowl response in California 1999-2000. Final report to the California Waterfowl Association. University of California, Davis, California, USA.

Earl, J. P. 1950. Production of mallards on irrigated land in the Sacramento Valley, California. Journal of Wildlife Management 14:332-342.

Emery, R. B., D. W. Howerter, L. M. Armstrong, M. G. Anderson, J. H. Devries, and B. L. Joynt. 2005. Seasonal variation in waterfowl nesting success and its relation to cover management in the Canadian prairies. Journal of Wildlife Management 69:1181-1193.

Evelsizer, D.D. 2002. Management of avian botulism and survival of molting mallards. M.S. Thesis, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.

Fleskes, J.P., D. M. Mauser, and G. S. Yarris. 2007. Survival of female mallards molting on Klamath Basin National Wildlife Refuges: Project Update 2007. 2007 Adminstrative Report. U. S. Geological Survey, Western Ecological Research Center, Sacramento, California, USA.

Fleskes, J. P., J. L. Yee, G. S. Yarris, M. R. Miller, and M. L. Casazza. 2007a. Pintail and mallard survival in California relative to habitat, abundance, and hunting. Journal of Wildlife Management 71:2238-2248.

Getz, V. K., and J. R. Smith. 1989. Waterfowl reproduction on artificial islands in Mountain Meadows Reservoir, California. California Fish and Game 75:132-140.

Hoekman, S. T., S. T. Gabor, M. J. Petrie. 2006. Population dynamics of mallards breeding in agricultural environments in eastern Canada. Journal of Wildlife Management 70:121-128.

Hoekman, S. T., T. S. Gabor, R. Maher, H. R. Murkin, and M. S. Lindberg. 2006a. Demographics of breeding female mallards in southern Ontario, Canada. Journal of Wildlife Management 70:111-120.

Hoekman, S. T., S. T. Gabor, R. Maher. 2004. Factors affecting survival of mallard ducklings in southern Ontario. Condor 106:485-495.

Hoekman, S. T., L. S. Mills, D. W. Howerter, J. H. Devries, and I. J. Ball. 2002. Sensitivity analyses of the life cycle of midcontinent mallards. Journal of Wildlife Management 66:883-900.

Hunt. E. G. and A. E. Naylor. 1955. Nesting studies of ducks and coots in Honeylake Valley. California Fish and Game 41:295-314.

Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.

Johnson, D. H. and L. M. Cowardin. 1987. A model of the productivity of the mallard duck. Ecological Modelling 38:257-276.

King, J.G. 1973. A cosmopolitan duck moulting resort; Takslesluk Lake, Alaska. Wildfowl 24:103-109.

Kirby, R. E. and L. M. Cowardin. 1986. Spring and summer survival of female Mallards from north central Minnesota. Journal of Wildlife Management 50:38–43.

Krapu, G. L., P. J. Pietz, D. A. Brandt, and R. R. Cox, Jr. 2006. Mallard brood movements, wetland use, and duckling survival during and following a prairie drought. Journal of Wildlife Management 70:1436-1444.

Klett, A. T., H. F. Duebbert, C. A. Faanes, and K. F. Higgins. 1986. Techniques for studying nest success of ducks in upland habitats in the Prairie Pothole Region. U.S. Fish and Wildlife Service Resource Publication 158.

Loughman, D., G. Yarris, and R. McLandress. 1991. An evaluation of waterfowl production in agricultural habitats of the Sacramento Valley. Final report to California Department of Fish and Game. California Waterfowl Association, Sacramento, California, USA.

Matchett, E. L. 2005. Nesting ecology of waterfowl in a western Great Basin ecosystem. M. S. Thesis. University of Nevada Reno, Reno, Nevada, USA.

Matchett, E, L, D. L. Loughman, J. A. Laughlin, and R. D. Eddings. 2007. Factors that influence nesting ecology of waterfowl in the Sacramento Valley: an evaluation of the Conservation Reserve Enhancement Program. Final report to California Department of Fish and Game. California Waterfowl Association. Sacramento, California, USA.

Mauser, D. M, 1991. Ecology of Mallard ducklings on Lower Klamath National Wildlife Refuge, California. PhD dissertation. Oregon State University, Corvallis, Oregon.

Mauser, D. M. and R. L. Jarvis. 1994. Mallard recruitment in northeastern California. Journal of Wildlife Management 58:565-570.

Mauser, D. M., R. L. Jarvis, and D. S. Gilmer. 1994a. Survival of radio-marked mallard ducklings in Northeastern California. Journal of Wildlife Management 58:82-87.

Mayhew, W. W. 1955. Spring rainfall in relation to mallard production in the Sacramento Valley, California. Journal of Wildlife Management 19:36-47.

Mayfield, H. F. 1961. Nest success calculated from exposure. Wilson Bulletin 73:255-261.

Mclandress, M. R., G. S. Yarris, A. E. H. Perkins, D. P. Connelly, and D. G. Raveling. 1996. Nesting biology of mallards in California. Journal of Wildlife Management 60:94-107.

Miller, A. W. and B. D. Collins. 1954. A nesting study of ducks and coots on Tule Lake and Lower Klamath National Wildlife Refuges. California Fish and Game 40:17-37.

Munro, R. E. and C. F. Kimball. 1982. Population ecology of mallard: VII. Distribution and derivation of the harvest. U. S. Fish and Wildlife Service Resource Publication No. 147. Washington D. C. USA.

Naylor, L. W. 2002. Evaluating moist-soil seed production and management in Central Valley wetland to determine needs for waterfowl. M. S. Thesis. University of California Davis, Davis, California, USA.

Newbold, S. and J. M. Eadie. 2004. Using species-habitat models to target conservation: a case study with breeding mallards. Ecological Applications 14: 1384-1393.

Oldenburger, S. L. 2008. Breeding ecology of mallards in the Central Valley of California. M. S. Thesis. University of California Davis, Davis, California, USA.

Olson, S. M. and R. E. Trost. 2013. 2013 Pacific Flyway databook. United States Fish and Wildlife Service, Portland, Oregon, USA.

Ringleman, K.M., J.T. Ackerman, J.M. Eadie, and J. Kwolek. 2009. Duck nest monitoring at Grizzly Island Wildlife Area: 2009 report. Administrative Report, U. S. Geological Survey, Western Ecological Research Center, Davis, CA and California Waterfowl Association, Sacramento, California, USA.

Rivere, R. 1999. Mallard use of wetland and agricultural habitats during the breeding season in California's San Joaquin Valley Grasslands. M. S. Thesis. University of Missouri, Columbia, Missouri, USA.

Rienecker, W. C. 1990. Harvest, distribution, and survival of mallards banded in California, 1948-82. California Fish and Game 76:14-30.

Rienecker, W. C. and W. Anderson. 1960. A waterfowl nesting study on Tule Lake and Lower Klamath National Wildlife Refuges. California Fish and Game 46:481-506.

Rowher, F. C. 1992. The evolution of reproductive patterns in waterfowl. in Ecology and management of breeding waterfowl. Batt, B. D. J., A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, editors. University of Minnesota Press, Minneapolis, Minnesota. USA.

Salomonsen, F. 1968. The molt migration. Wildfowl 19:5-24.

Simpson, J. W., T. J. Yerkes, B. D. Smith, and T. D. Nudds. 2005. Mallard duckling survival in the Great Lakes region. Condor 107:898-909.

Skalos, D., and M. Weaver. 2017. 2017 California Waterfowl Breeding Population Survey. CA Department of Fish and Wildlife, Sacramento, California, USA.

Smith, W. D., G. L. Rollins, and R. L. Shinn. 1996. A guide to wetland habitat management in the Central Valley. California Department of Fish and Game, Sacramento, California, USA.

Stafford, J. D. and A. T. Pearse. 2007. Survival of radio-marked mallard ducklings in South Dakota. Wilson Journal of Ornithology 119:585-591.

Sterling, T. and A. Szubin. 1967. Canada Goose molt migration to the Northwest Territories. Transactions North American Wildlife Natural Resources Conference 32:355-373.

Williams, B. K., M. D. Koneff, and D. A. Smith. 1999. Evaluation of waterfowl conservation under the North American Waterfowl Management Plan. Journal of Wildlife Management 63:417-440.

Yarris, G. S. and D. L. Loughman. 1990. An evaluation of waterfowl production on set-aside lands in the Sacramento Valley, California. Final report to the California Department of Fish and Game and the National Fish and Wildlife Foundation. California Waterfowl Association, Sacramento, California, USA.

Yarris, G. S., M. R. McLandress and A. E. H. Perkins. 1994. Molt migration of post-breeding female mallards from Suisun Marsh, California. Condor 96:36-45.

Yarris, G. S. 1995. Survival and habitat use of mallard ducklings in the rice-growing region of the Sacramento Valley, California. Final report to California Department of Fish and Game. California Waterfowl Association, Sacramento, California, USA.

Zicus, M.C. 1981. Molt migration of Canada geese from Crex Meadows, Wisconsin. Journal of Wildlife Management 45:54-63.

Zuwerink, D. A. 2001. Changes in the derivation of mallard harvest from the northern U. S. and Canada. MS. Thesis. Ohio State University, Columbus, Ohio, USA.

Received 20 June 2017
Approved 25 August 2017
Associate Editor was D. Skalos