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Notes from the Editor

This issue of the Fish and Game Journal features two full articles, a note, a book review, and an article from the archives. The first full article provides a comprehensive review and compilation of historic records detailing the distribution of longfin smelt in California, excluding the San Francisco Estuary. It cites original records and research dating back to 1889 pertaining to the geographic distribution of the species, and uses data from administrative and technical reports, including field notes to describe coast marine distribution by month, depth, and distance from mainland. The second full article presents an important analysis of the distribution and derivation of Pacific Flyway dabbling ducks, which should be of substantial use to waterfowl managers. The note being published in this issue establishes a baseline distribution for Amargosa River pupfish, extending its previously known range. The book review will be of interest to anyone who studies bighorn sheep, and the article from the archives was actually cited in the de Sobring et al., article (this issue), and provides some historical perspective related to waterfowl nesting habitat.

The New Year is quickly approaching and we still have one more issue in this volume to complete. Sadly, we will likely not have 103-4 published by the end of the year but will need to wait until January 2018, which is a significant improvement over the publish date of 102-4, which was April 2017. So, we are catching up. By the way, wintertime is a wonderful time to be with family and friends. It's also a marvelous time write up those field notes and send them to us for publication.

The Department had two notable retirements this past November. Helen Birss, most recently the Chief of the Department's Watershed Restoration Grants Branch, retired. Helen spent most of her career in the South Coast Region (Region 5), before her appointment as the Chief of the Habitat Conservation Planning Branch. Deputy Director Sandra Morey also retired in November after a long career. Sandra or Sandy, started her career in the mid-1980s with the Department as a scientific aide in the Native Plant Program, which was under the Native Heritage Division. Sandy eventually moved on to supervise both the Program and Division; the Division later became the Habitat Conservation Planning Branch. From Branch Chief, Sandy became the Regional Manager of the Central Sierra Region (Region 2), before being appointed as Deputy Director of the Ecosystem Conservation Division. Thank you both for all your contributions to the natural resources of California. Congratulations and best wishes to you both.

Armand Gonzales
Editor in Chief

California Fish and Game 103(3): 91-95; 2017

Distribution of Amargosa River pupfish *(Cyprinodon nevadensis amargosae*) in Death Valley National Park, CA

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Key words: Amargosa River pupfish, Death Valley National Park, distribution, endangered species, monitoring, intermittent streams, range

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Amargosa River pupfish (*Cyprinodon nevadensis amargosae*), is one of six recognized subspecies of Amargosa pupfish (Miller 1948) and survives in waters embedded in a uniquely harsh environment, the arid and hot Mojave Desert (Jaeger 1957). All are endemic to the Amargosa River basin of southern California and Nevada (Moyle 2002). Differing from other spring-dwelling subspecies of Amargosa pupfish (*Cyprinodon nevadensis*), Amargosa River pupfish is riverine and the most widely distributed, the extent of which has been underrepresented prior to this study (Moyle et al. 2015). Originating on Pahute Mesa, Nye County, Nevada, the Amargosa River flows intermittently, often underground, south past the towns of Beatty, Shoshone, and Tecopa and through the Amargosa River Canyon before turning north into Death Valley National Park and terminating at Badwater Basin (Figure 1). Amargosa River pupfish is data deficient with a distribution range that is largely unknown. The species has been documented in Tecopa Bore near Tecopa, Inyo County, CA (Naiman 1976) and in the Amargosa River Canyon, Inyo and San Bernardino Counties, CA (Williams-Deacon et al. 1982, Scoppettone et al. 2011). In the lower Amargosa River, pupfish were documented in the southeastern corner of Death Valley National Park south of the Inyo-San Bernardino County line (Miller 1948) and in the vicinity of Valley Springs (Sada et al. 1997; see Figure 1). These data represent occurrence of pupfish in waters flowing approximately 1.6 km northwest of Saratoga Springs (Soltz and Naiman 1978). This study identifies further downstream habitat and reports presence of Amargosa River pupfish 18 river km upstream of Badwater Basin. Though locally known to occur, Amargosa River pupfish have not previously been documented this far downstream in the lower Amargosa River.

During 2016, an extensive survey of the lower Amargosa River drainage within Death Valley National Park was conducted in the spring (April – May), prior to dry season, and in October, after dry season. The purpose was to determine the distribution of Amargosa River pupfish within Death Valley National Park and to identify suitable locations at which to establish long-term monitoring sites. Survey area was determined by identifying wetted habitat (an underestimate of actual available habitat) using 2010 Bing maps and 2010 or 2014 Google Earth aerial imagery and incorporated into Esri® ArcMAP Version

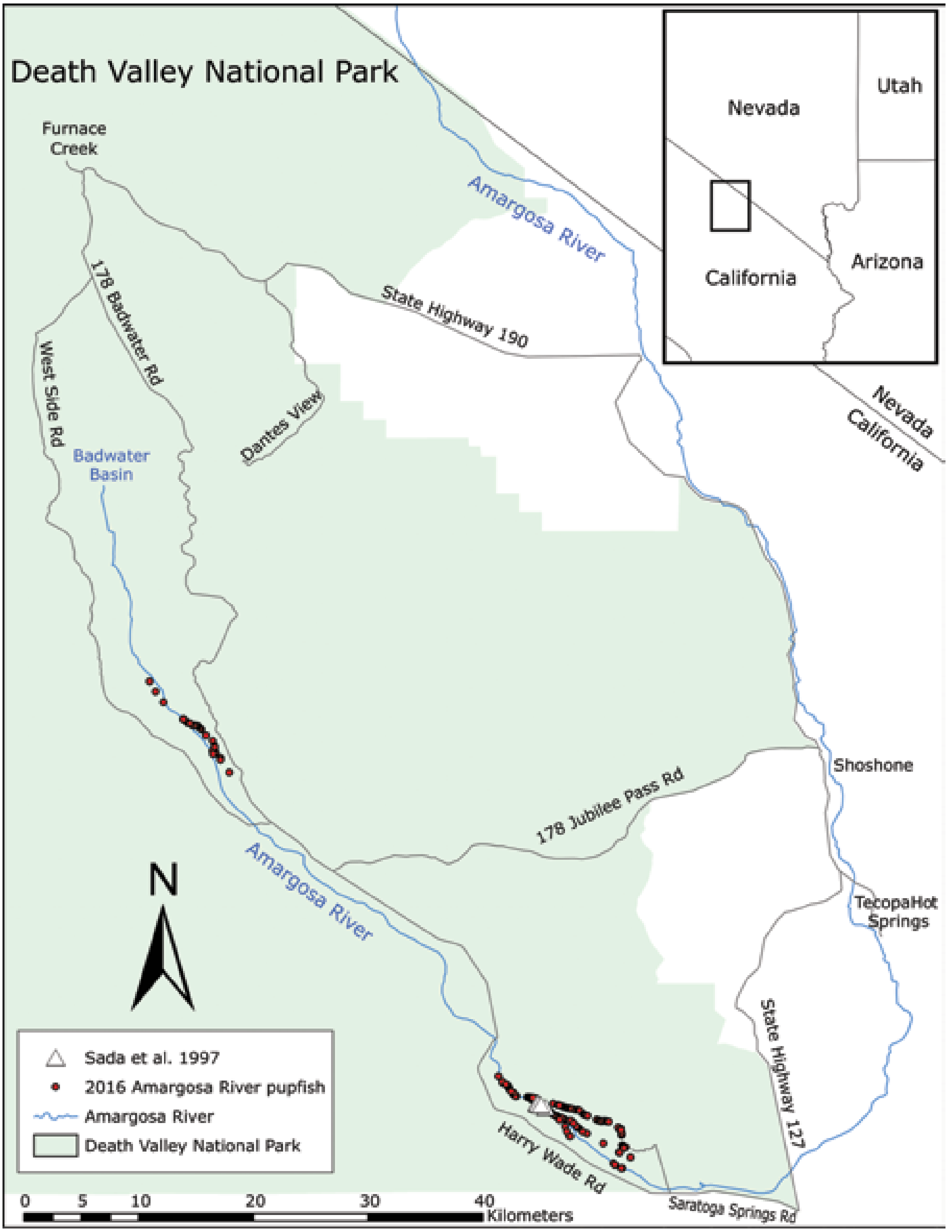

FIGURE 1.—Map of Amargosa River and drainage with wetted and ephemeral sites, upper and lower reaches, Amargosa River pupfish occurrence, and previous record of Amargosa River pupfish (Sada et al. 1997), Death Valley National Park, California, spring and autumn 2016.

10.1. In spring 2016, ground surveys of 508 pre-determined sites were conducted and 213 were sampled for Amargosa River pupfish, the latter selected based on water volume, proximity to other sample sites, and safety of accessibility. A set of three criteria, developed to target sample sites with potential for perennial water following dry season and ease of access, included minimum mean water depth of 0.2 m, minimum area of 100 m^2, and a maximum distance of 2.5 km to the nearest road. Based on these criteria, as well as supplemental pools chosen based on water volume and/or visual observation of pupfish, 53 sites were sampled for Amargosa River pupfish in autumn 2016. During all sampling events, one to three Gee minnow traps (3-mm mesh) were baited with dog food and deployed at sample sites. Water temperature, dissolved oxygen, and pH were measured with Hanna Instruments, Inc., HI9829 portable multiparameter probe. Depth was visually estimated. Biologists were selective towards vegetation and narrow channels when possible while deploying traps. Additionally, Weasel traps (3 mm mesh, 76 mm radius), constructed in-house following a U.S. Geological Survey protocol (S. Madill, U.S. Geological Survey, unpublished report), were used to target pools too shallow for a standard Gee trap. Traps were fished for 2 hr to 7.5 hr and never fished overnight to avoid potential stress to fish. Amargosa River pupfish were processed and returned to the water within 3 m of the trap deployment site. Individuals were categorized and enumerated as male, blue hue with a dark stripe along the caudal and/or anal fin distal edge; female, olive-brown with darker pigmented diamond bars laterally (Figure 2); juvenile, breeding colors not displayed; or age-0, approximate total length less than 1 cm. Other fish species encountered during site visits were identified to species, counted, and photographed.

The downstream-most location of Amargosa pupfish captured in this study extends the previously recorded geographic range approximately 49 river km to 36° 2' 53.448" N, 116° 47' 59.244" W. Totals of 3,738 and 3,424 Amargosa River pupfish were captured in spring and autumn, respectively, and one western mosquitofish (*Gambusia affinis*) was captured in spring. Mean catch per unit trap was comparable between males and females in spring, but most pupfish captured in autumn were female (78% of total catch). All age-0 fish observed in spring were recorded after 6 April 2016, suggesting an approximate spawning time. Across sample sites and seasons, temperature ranged from 13.3 to 30°C, dissolved oxygen ranged from 0.03 to 11.5 mg/L, pH ranged from 7.3 to 9.9, and depth ranged from 0.01 to 2.00 m.

FIGURE 2.—Adult female (left) and male (right) Amargosa River pupfish displaying breeding colors, Death Valley National Park, California, 8 April, 2016 and 11 March 2016, respectively.

Water flow was intermittent overall throughout the drainage system but two stretches of river, defined as the upper and lower reach and delineated by Harry Wade and West Side road crossings (see Figure 1), were consistently wetted in spring. These reaches were separated by approximately 32 km of dry or underground flowing river, offering no pupfish habitat. In contrast to spring surveys, largely dry conditions were noted during autumn with some persistent, isolated pools in both reaches and greater connectedness among pools in the lower compared to upper reach. Catch per unit trap was greater in the lower than upper reach in spring (26.3, 12.1; respectively) and opposite in autumn (3.1, 84; respectively), presumably influenced by drying conditions through summer, increasing capture probability by concentrating fish within the upper reach. Across both spring and autumn, the six sites with the largest catch rates had a mean depth of 0.5 m, both factors indicating these sites have potential for perennial water. Of the sites sampled in spring, pupfish were captured and/or observed at most sites (137; 64%) and at slightly less than half of sites sampled in autumn (25; 46%) indicating Amargosa River pupfish persist in water available to them.

An extreme flooding event in October 2015 dramatically altered normal flow conditions to the Amargosa River basin by increasing discharge two orders of magnitude compared to mean recorded October measurements from 1961 to 2014 (2.42 m^3/s, 0.04 m^3/s) in Tecopa, California (US Geological Survey 2016) and temporarily flooding Badwater Basin. Higher flows resulted in greater water connectivity and persistence through spring 2016 compared to normal intermittent flows not associated with flood events. Continuous water may facilitate dispersal of Amargosa River pupfish throughout the river though overall impacts of the flood event remain unknown. Under normal precipitation conditions, total wetted area is expected to decrease, diminishing connectivity and isolating habitats.

Amargosa River pupfish survival is dependent on availability of perennial pools and short reaches of flowing water, the distribution and abundance of which has been largely unknown within Death Valley National Park. In addition to aerial imagery and site surveys, these observations of pupfish occurrence provide a baseline spatial database of occupied and potential Amargosa River pupfish habitat. Such baseline data allow for comparison with future conditions in the context of stochastic factors, anthropogenic impacts, and climate change induced alterations of flora and fauna distribution patterns. Dewatering of the Amargosa Aquifer for human use alters surface water levels and may threaten Amargosa River habitat availability (Deacon 2011). Scoppettone et al. (2011) suggested that invasive saltcedar (*Tamarix sp.*), red-swamp crayfish (*Procambarus clarkii*), and western mosquitofish present in the Amargosa River Canyon may negatively impact pupfish populations. Two of the Amargosa pupfish subspecies, Tecopa (*C. n. calidae*) and Shoshone (*C. n. shoshone*) are considered extinct and Amargosa River pupfish is a Species of Special Concern in California (Moyle et al. 2015).

Acknowledgments

This work was funded and permitted by the National Park Service and we would like to thank Dr. K. Wilson and all biologists at Death Valley National Park for their cooperation and commitment to conservation. We also thank the rest of the Marsh & Associates team for their enthusiasm searching for pupfish through a very harsh environment.

Literature Cited

Deacon, J. E. 2011. Probable effects of proposed groundwater pumping by Southern Nevada Water Authority in Spring, Cave, Dry Lake and Delamar Valleys, Nevada on spring and wetland-dependent biota. Prepared for the Office of Nevada State Engineer on behalf of Great Basin Water Network, University of Nevada, Las Vegas.

Jaeger, E. C. 1957. The North American deserts. Stanford University Press, Stanford, California (USA).

Miller, R. R. 1948. The Cyprinodont fishes of the Death Valley system of eastern California and southwestern Nevada. Miscellaneous Publications Museum of Zoology, University of Michigan, No. 68.

Moyle, P. B. 2002. Inland Fishes of California. University of California Press, Berkeley and Los Angeles, California, USA.

Moyle, P. B., R. M. Quiñones, J. V. Katz, and J. Weaver. 2015. Fish Species of Special Concern in California. California Department of Fish and Wildlife. Sacramento, California, available at: www.wildlife.ca.gov

Naiman, R. J. 1976. Productivity of a herbivorous pupfish population (*Cyprinodon nevadensis*) in a warm desert stream. Journal of Fish Biology 9:125-137.

Sada, D. W., K. Pindal, D. L. Threloff, and J. E. Deacon. 1997. Spatial and temporal variability of pupfish (genus *Cyprinodon*) habitat and populations at Saratoga Springs and the Lower Amargosa River, Death Valley National Park, California. Report submitted to U.S. National Park Service, Death Valley National Park, Coop Agreement No. 8000-2-9003.

Scoppettone, G. G., M. E. Hereford, P. H. Rissler, D. M. Johnson, and J. A. Salgado. 2011. Relative abundance and distribution of fishes within an established Area of Critical Environmental Concern, of the Amargosa River Canyon and Willow Creek, Inyo and San Bernardino Counties, California. U.S. Geological Survey Open-File Report 2011-1161, 32 p.

Soltz, D. L. and R. J. Naiman. 1978. The natural history of native fishes in the Death Valley system. Natural History Museum. Los Angeles County, Science Series 30:1-76.

U.S. Geological Survey. 2016. Surface water data for the Nation: USGS Surface-Water Monthly Statistics. [Internet] Available at: https://waterdata.usgs.gov/nwis/monthly.

Williams-Deacon, C. D., T. P. Hardy, and J. E. Deacon. 1982. Distribution and status of fishes of the Amargosa River Canyon, California. Report submitted to U.S. Fish and Wildlife Service, Endangered Species Office, Sacramento, California.

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Historic and contemporary distribution of Longfin Smelt (*Spirinchus thaleichthys*) along the California coast

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Longfin smelt (*Spirinchus thaleichthys*) was listed as threatened under the California Endangered Species Act in 2009. This anadromous fish exhibits complex life history patterns, using a variety of habitats from nearshore waters, to estuaries and lower portions of freshwater streams. While consistent data collection efforts in the greater San Francisco Bay region provide much information regarding this species, little is known throughout its remaining range in California. To help address this gap in knowledge, the objectives of this review were to gather, synthesize and analyze existing data for this species from areas outside of San Francisco Bay, and to identify areas of historic and contemporary presence, and habitat use along the northern and central California coasts. Observations were gathered from existing published articles, technical reports, museum collections and field observations. Longfin smelt captures were noted dating from 1889 to 2016 in a diverse range of habitats, including coastal lagoons, bays, estuaries, sloughs, tidal freshwater streams and nearshore habitats. Longfin smelt were found throughout northern and central California in 15 watersheds spanning from Moss Landing Harbor north to Lake Earl near the northern California border. Spawning was noted in both the Eel River and in tributaries to Humboldt Bay, with pre-and post-spawn individuals observed in tributaries to Humboldt Bay in more recent years. Use of nearshore waters was also noted with most longfin smelt collected in shallow waters relatively close to shore in the vicinity of known spawning areas. This paper provides a comprehensive look at the existing information available for this species along the California coast, highlights current data gaps, and identifies additional information needed to improve management and enhance recovery of the species within the State.

Key words: Anadromous, California Endangered Species Act, Habitat, Humboldt Bay, Longfin Smelt, Osmeridae

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Members of the family Osmeridae are distributed throughout the cool waters of the northern hemisphere and currently consist of 15 recognized species (Eschmeyer 2006).

These "true smelts" include marine (5), anadromous (6), freshwater (3), and estuarine (1) species, though life history plasticity is common in this family. For example, many species of smelt can tolerate a wide range of salinities, with some anadromous species such as the European smelt (*Osmerus eperlanus*) and the rainbow smelt (*Osmerus mordax*) having self-sustaining freshwater landlocked populations (Baby et al. 1991; Lischka and Magnuson 2006; Tulp et al. 2013). For most species of Osmerids, spawning predominately takes place over coarse gravels or on sandy substrates (Rupp 1965; Hirose and Kawaguchi 1998; de Groot 2002; Stables et al. 2005; Lischka and Magnuson 2006). For example, spawning takes place on beaches for surf smelt (*Hypomesus pretiosus*), and in freshwater streams for species such as eulachon (*Thaleichthys pacificus*), rainbow smelt and wakasaki (*Hypomesus nipponensis*) (de Groot 2002; Stables et al. 2005; Rice 2006). As Osmerids can be found in large numbers in the coastal marine environment, many species are important forage fish and contribute to a variety of commercial and recreational fisheries (Leet et al. 2001).

Seven recognized species of Osmerids occur in California including the longfin smelt (*Spirinchus thaleichthys*), an anadromous species found along the central and northern California coast north to central Alaska (Moyle 2002). Once harvested commercially in San Francisco Bay, this species is currently listed as threatened by the State of California (Leet et al. 2001; CDFW 2009). However, *S. thaleichthys* was found to be "warranted but precluded" from listing under the federal Endangered Species Act in part of its range by the U.S. Fish and Wildlife Service in part due to genetics and the lack of information on populations outside of San Francisco Bay (USFWS 2012). Like other species of Osmerids, population declines are likely due to habitat degradation and loss (de Groot 2002; CDFG 2009). The longfin smelt is a relatively small (to 150 mm TL) fish that exhibits a two-year life history (Leet et al. 2001; Moyle 2002; Rosenfield 2010). Though little is known regarding spawning, it is thought longfin smelt may spawn over coarse gravel or sandy substrates similar to other Osmerids (Moulton 1974; Martin and Swiderski 2001; Rosenfield 2010). This species also inhabits various depths depending on the time of day and life history stage, with adults inhabiting deeper areas close to the bottom during the day and becoming more associated with surface waters at night (Chigbu et al. 1998). Newly hatched larvae (5 mm SL) are associated with the surface waters and can move vertically in the water column once the swim bladder reaches inflation (Bennett et al. 2002; Hobbs et al. 2006).

Much of the existing demographic information on longfin smelt comes from either San Francisco Bay, or from a landlocked population in Lake Washington, WA (Moulton 1974; Stevens and Miller 1983; Chigbu and Sibley 1994; Baxter et al. 1999; Bennett et al. 2002; Rosenfield and Baxter 2007; Merz et al. 2013) with limited information collected in other areas throughout its range (Misitano 1977; McCabe et al. 1983; Robards et al. 1999; Abookire and Piatt 2005; Harding et al. 2011). In California, little is known regarding longfin smelt in areas outside of San Francisco Bay. Longfin smelt were categorized as "common" in surveys of the Klamath River estuary spanning from 1979 to 1989 and Humboldt Bay in the late 1960's (Eldridge and Bryan 1972; Sopher 1974; Kisanuki et al. 1991). However, an extensive fish study conducted in Humboldt Bay from 2000 to 2001 sampled few longfin smelt, consistent with the declines seen in San Francisco Bay, athough the study was not designed to replicate the earlier efforts (Gleason et al. 2007).

The purpose of this comprehensive data review was to gather, synthesize and analyze all available contemporary and historic information on longfin smelt distribution and habitat associations in areas of California outside of San Francisco Bay.

Materials and Methods

Longfin smelt catch data from published studies, technical reports, thesis and museum collections were evaluated for validity and integrated into a spatial database (Appendix 1). The review included sampling efforts conducted within bays, estuaries, the stream-estuary ecotone, lower reaches of freshwater streams, and nearshore waters of California, excluding catches within San Francisco Bay which had its longfin smelt range described by Merz et al. (2013). Museums with longfin smelt records included the California Academy of Sciences (CAS), Humboldt State University (HSU), Harvard University Museum of Comparative Zoology (MCZ), University of Kansas Biodiversity Institute and Natural History Museum Ichthyology Collection (KU and KUIT), Los Angeles County Natural History Museum (LACM), and Stanford University (SU). If available, the information gathered included: location, date, depth, sex, length, method of collection, number collected, and spawning condition. For convenience, observations were lumped into two categories, historic (1999 or earlier) or current. Fish >20 mm were categorized as larvae, juveniles between 20 and 88mm total length (TL), while fish >88 mm TL or >70 mm standard length (SL) were considered adults (Simonsen 1977; Emmett et al. 1991; Rosenfield 2010). Geographic locations were from stated latitude and longitude, specific written descriptions including landmarks and depths, or maps. Locations that were not included, or were too general (e.g. just "Humboldt Bay"), were not placed on the maps, though the observations were reported in Appendix 1.

Results

Longfin smelt observations were noted from 1889 to 2016, with a total of 189 capture locations documented (Appendix 1 and Figure 1). Geographically, longfin smelt were reported from Moss Landing Harbor in central California, north to Lake Earl near the northern California border (Figure 1), encompassing a total of 15 watersheds either with historic or current observations (Figures 1-3). Longfin smelt were captured using a variety of fish sampling gear, with the most common methods being trawls and seines, though individuals were also captured using boat electrofishing and a variety of net types (Appendix 1).

Longfin smelt were observed in a wide variety of habitats throughout its range in coastal California. Populations of longfin smelt spanned much of the central and northern California coastline with individuals collected in both small and large estuaries, over a wide range of flow regimes, and a variety of habitat complexities. For instance, longfin smelt were collected throughout Humboldt Bay, which has multiple small tributaries and extensive slough and brackish areas, but were also collected in areas with minimal off-channel estuarine habitats and waters dominated by freshwater flows (e.g. Russian River, Mad River and Klamath River). The broad use of estuary types by this species highlights the considerable plasticity in the life history and habitat use among Osmerids.

Most longfin smelt occurrences were from the Humboldt Bay or Eel River areas, nearby in nearshore waters, or in lower reaches of tributaries to the Bay, likely reflecting the higher sampling effort in this region (Appendix 1; Figure 2). In Humboldt Bay, longfin smelt were noted in all of the major tributaries including Mad River Slough, Jacoby Creek, Freshwater Slough (also known as Eureka Slough in its lower reaches), Elk River and Salmon Creek (Appendix 1). These observations represent most of the contemporary cap-

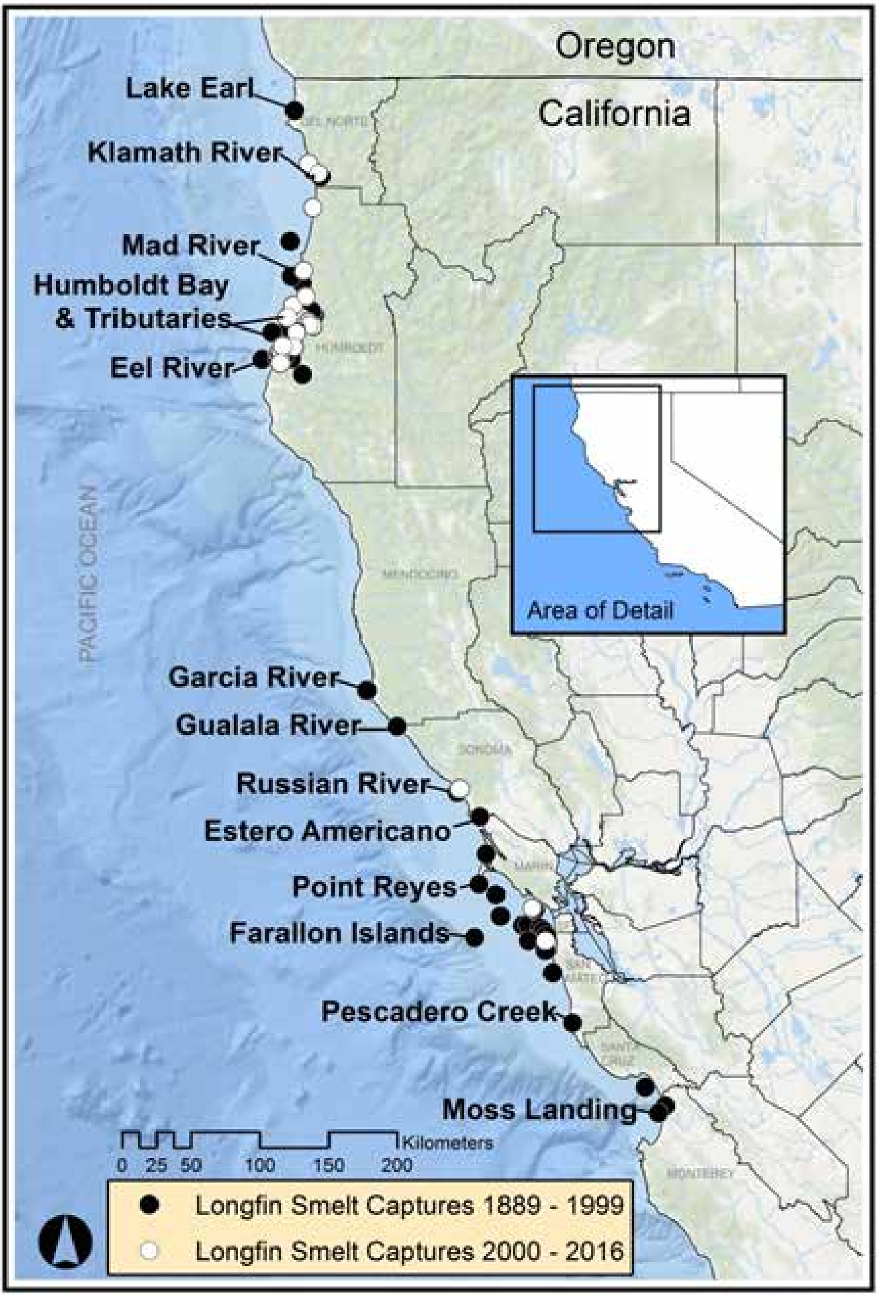

FIGURE 1.—Locations for all longfin smelt (*Spirinchus thaleichthys*) observations identified in this study from 1889 to 2016 (see Appendix 1 for a list of citations). Observations were from California, but did not include captures from San Francisco Bay.

tures of longfin smelt throughout the study area. Since 1999, 23 observations of longfin smelt were documented in waters of Humboldt Bay, its tributaries or in nearshore waters with observations ranging from 1-17 individuals per sampling event. Longfin smelt were found year-round in the waters of Humboldt Bay and ranged in size from 4 to 150 mm (Appendix 1).

Longfin smelt were observed in many areas throughout the Eel River estuary and the mainstem portions of the coastal plain (Figure 2). The Eel River is the third largest watershed in California, with an extensive tidally influenced estuary containing many slough channels and brackish areas (Monroe et al. 1974). Most of the longfin smelt data collected in the Eel River estuary came from two studies, Puckett (1977) and Cannata and Hassler (1995). Both studies used beach seines to sample the lower estuary for approximately one year. Given the large size of the Eel River estuary, much of the estuary was not sampled, though detections of longfin smelt appear to be relatively frequent in areas with consistent sampling (Puckett 1977; Cannata and Hassler 1995). Longfin smelt utilized a wide range of the lower river/estuary with individuals sampled 5.7 km from the mainstem of the river in slough waters, and as far as 20 km upriver from the mouth in alluvial portions well outside the brackish zone (Puckett 1977; Jensen 1957). Both Puckett (1977) and Cannata and Hassler (1995) observed longfin smelt in samples taken in late fall through early spring, though neither detected them in January. This is likely due to the difficulty sampling during high flow events that are common on the Eel River during this month. All longfin smelt observations from the Eel River occurred from late fall through early spring with some observations during summer months (Appendix 1).

Dominated by freshwater flows, the Russian River is a large river system with an estuary that closes periodically cutting off the river from the ocean. Closing and breaching events generally occur from late summer through fall (Sonoma County Water Agency 2001). Trawl surveys were conducted from summer or early fall through mid-November in the lower Russian River over four years (Merritt Smith Consulting 1998; 1999; 2000; Sonoma County Water Agency 2001). Longfin smelt were detected near the mouth of the river with detections occurring in late August through early November. Three individuals were also collected in June. Longfin smelt were not detected in the upstream stations also trawled during the study. In addition, while longfin smelt were captured in trawl surveys, they were not detected in the corresponding shallow water beach seine collections in the lower estuary (Merritt Smith Consulting 1998; 1999; 2000; Sonoma County Water Agency 2001). This indicates longfin smelt were utilizing the deeper, cooler, more saline waters of the estuary. The timing of observations in the Russian River estuary indicates individuals were staging in the estuary prior to spawning, though it is unclear where spawning might occur in the watershed.

Longfin smelt were also collected in two coastal lagoons, Abbotts Lagoon and Lake Earl, using gill nets (McLeod 1989; Saiki and Martin 2001). Abbotts Lagoon and Lake Earl, the largest lagoon on the West Coast of the United States, are frequently disconnected from the ocean by sand bars that commonly form during the summer months (Monroe et al. 1975; Saiki and Martin 2001). These lagoons are dominated by brackish waters for most of the year and also have limited connectivity to freshwater stream habitats. Similar to these coastal lagoons, longfin smelt were also collected in rivers and streams with mouths that close to the ocean for most or part of the year. These included the Gualala River, Russian River, Estero Americano, and Pescadero Creek (Appendix 1).

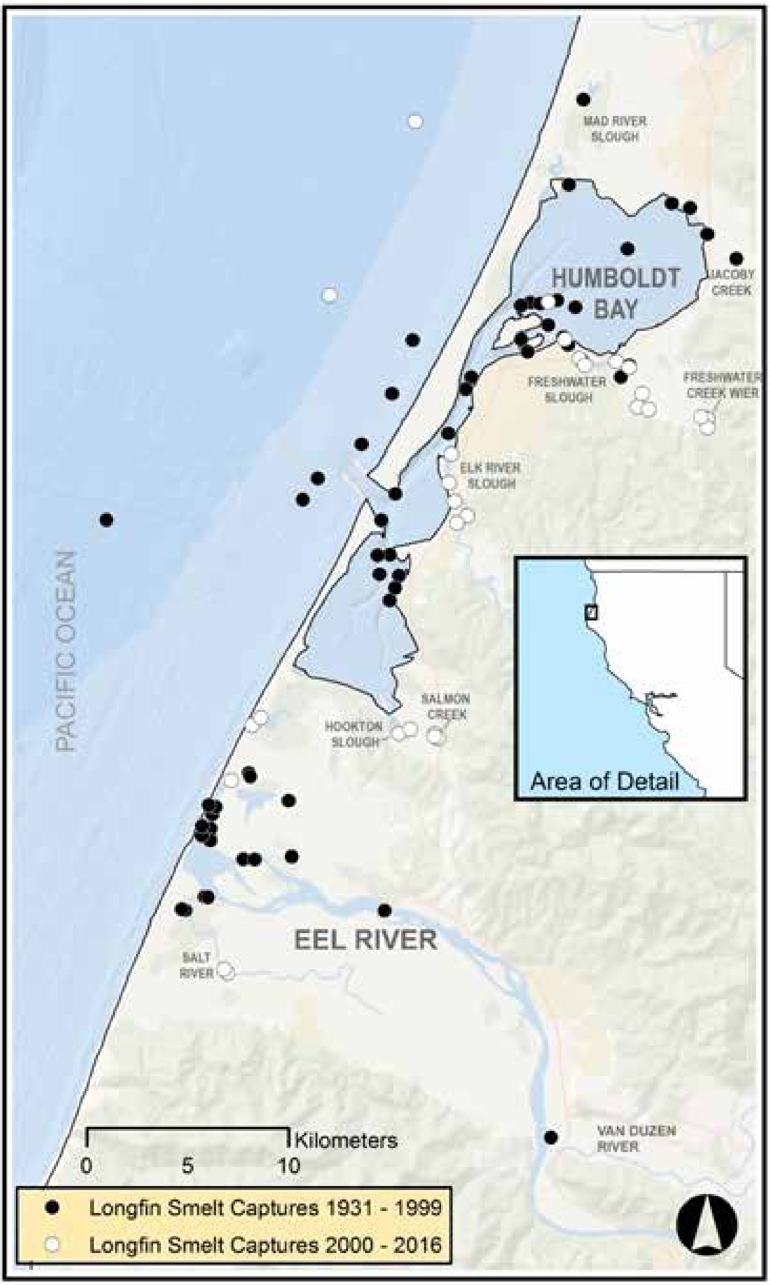

FIGURE 2.—Locations for Longfin Smelt (*Spirinchus thaleichthys)* observations in Humboldt Bay, its tributaries, in the Eel River and offshore waters from 1931 to 2016.

While longfin smelt presence has been documented in nearshore waters, their use of these areas is not well described. Observations compiled from areas outside of rivers and estuaries in nearshore coastal waters generally occurred near watersheds having longfin smelt, with frequent detections adjacent to Humboldt Bay, the Eel River, and San Francisco Bay (Figures 2 & 3). For example, observations in nearshore waters were generally in depths less than 40 m ranging from the shoreline (collected in a beach seine) off of Trinidad Head (HSU Fish Collection #3694), to depths of 55 m in waters offshore of Drakes Bay (B. MacFarlane, National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center, Fisheries Ecology Division, unpublished data). Most were also collected within 10 km of the mainland, with some taken as far as 36 km offshore near the Farallon Islands (CAS Fish Collection #34742). Reported lengths for longfin smelt collected in coastal marine waters using bottom trawls consisted of late juvenile through adult individuals, with sizes ranging from 84 to 145 mm TL. Observations in epipelagic waters off the coast of San Francisco Bay found longfin smelt ranging from young-of-the-year through adult individuals, measuring from 36 to 120 mm SL (B. MacFarlane, unpublished data). Data provided here show longfin smelt utilize waters close to shore and in relatively shallow depths year-round, from juveniles through adult stages, with most sampled as adults from late summer through late fall (Appendix 1). Limited observations in other parts of their range along the west coast show similar findings. Samples taken off the shores of the Columbia River estuary noted longfin smelt in nearshore shallow waters, with benthic samples taken in shallow waters ranging from 9.4 to 18.6 m deep (Hinton and Emmet 1994; Litz et al. 2014). Longfin smelt were also taken using trawls off of Tillamook Bay, Oregon in nearshore shallow waters (Emmet and Hinton 1992). Observations compiled here show longfin smelt were taken frequently with epi-benthic trawl gear (Appendix 1). However, large observations of longfin smelt in the nearshore waters of California and Washington were collected with both epi-pelagic and epi-benthic sampling methods (Hinton and Emmet 1994; Harding et al. 2011; B. MacFarlane, unpublished data).

Spawning populations (i.e. individuals in spawning and post-spawning condition, spawning aggregations, and the presence of early larval stages in freshwater habitats) were also identified in the Eel River and tributaries to Humboldt Bay. In the Eel River, spawning was noted in the Eel River Estuary by Puckett (1977), though the specific location was not reported. Additionally, individuals in spawning condition (i.e. eggs extruded from females with the addition of pressure and milt flowing from males) were collected 7.2 km upstream of the mouth of the Eel River (Jensen 1957). In the Humboldt Bay region, early larvae were observed in Freshwater Creek/Slough as well as in Humboldt Bay (Eldridge and Bryan 1972; Chamberlain 1988). Individuals in spawning condition (i.e. adult sized individuals in areas thought to be used for spawning and with eggs or milt extruded with little pressure) have also been observed in Freshwater Creek from December through February (C. Anderson, Sponsored Programs Foundation, Humboldt State University, personal communication; J. Ray, California Department of Fish and Wildlife, personal communication). Individuals in post-spawn condition (i.e. individuals with elongated pectoral and anal fins, in areas thought to be used for spawning, but with concave abdomens and no eggs or milt upon exerting pressure) were sampled in February in Salmon Creek (M. Wallace, California Department of Fish and Wildlife, personal communication) and in mid-March in Freshwater Creek (J. Garwood, California Department of Fish and Wildlife, personal communication). In addition, individuals with ripe gonads were noted in north Humboldt Bay in November and December (Sopher 1974).

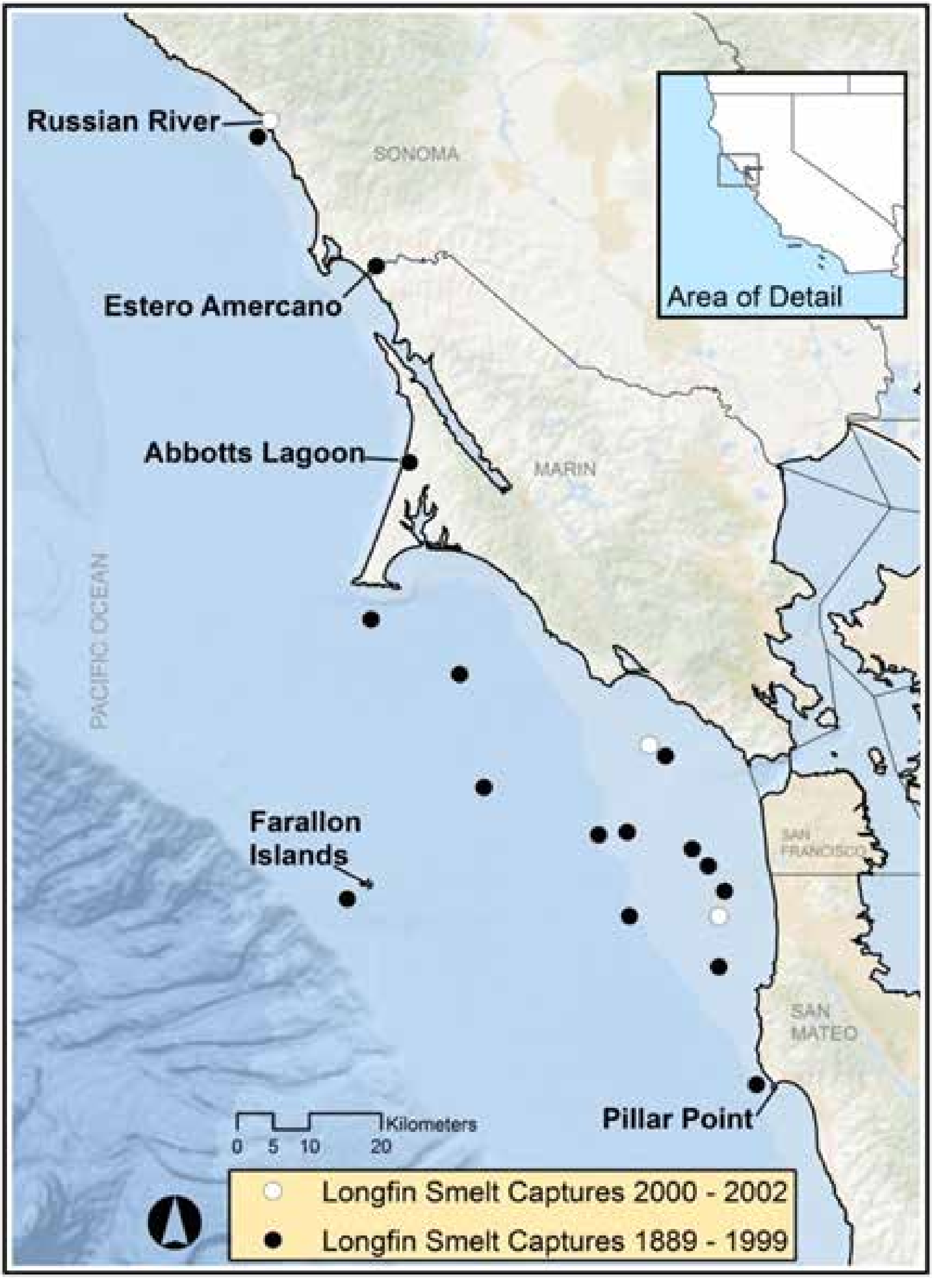

FIGURE 3.—Locations for Longfin Smelt (*Spirinchus thaleichthys*) collections from the Russian River to Pillar Point, CA from 1889 to 2002. Collections from San Francisco Bay were not included in this study.

Information regarding spawning behavior of longfin smelt was also noted in association with salmonid migrant trapping in Freshwater Creek, a tributary to Humboldt Bay. Among the data gathered, a single sex aggregation of longfin smelt was collected at the Freshwater Creek weir in late December 2015 (J. Ray, personal communication). All of the individuals (n=8) sampled on that occasion were pre-spawn males, indicating staging for spawning was segregated by sex. This corresponds with the findings from Moulton (1974) who found male longfin smelt from a landlocked population in Lake Washington, WA., arriving before females in tributary rivers. This is also similar to observations of other Osmerids such as eulachon and rainbow smelt, with males arriving at spawning locations before females and staying at sites longer (Murawski et al. 1980; Moyle 2002).

Females were also documented at spawning grounds for protracted periods. One fin clipped female longfin smelt was recaptured at the Freshwater Creek weir a minimum of 25 days (maximum = 44 days) after initial capture in February 2016 (C. Anderson, personal communication). As the mark was not unique to an individual, the spawning condition at the first capture is unclear though she was noted to be in pre-spawn condition at the time of recapture. This observed recapture interval was longer than reported for female rainbow smelt in the Parker River estuary in Massachusetts, which recorded a maximum period of recapture at spawning grounds to be 14 days (Murawski et al. 1980).

Discussion

This review provides a synthesis of the available data for longfin smelt along the California coastline. However, these data likely underestimate the spatial and temporal distributions and habitat utilization of this species. For example, no longfin smelt were documented in the Smith River. While there are records of longfin smelt in harbor seal scat sampled at the mouth of the Smith River (Gemmer 2002), it is unknown if the fish eaten were from the Smith River, in the waters offshore, or an adjacent watershed. There are also anecdotal records of longfin smelt presence in the Smith River (Fry 1973), though no direct observations of the species in the river were located. In addition, despite the presence of available habitat, no observations of longfin smelt were found in the multitude of streams along the southern Humboldt County coast through southern Mendocino County (Figure 1). While some field observations from this area documented "smelt" or surf smelt, no observations identifying longfin smelt were noted. In addition, in summer and fall longfin smelt may orient toward deep riverine and estuarine channels where shore oriented sampling for salmonids may miss them (Rosenfield and Baxter 2007).

Common among the watersheds longfin smelt were documented to occur, is the significant degradation or loss of tidal wetland habitat and freshwater flows (Moyle et al. 2011; Katz et al. 2013). This degradation of habitat quantity and quality has likely contributed to population declines. To help recover longfin smelt, restoration of natural freshwater flows and former wetlands are needed in areas such as Humboldt Bay and the Eel River estuary, as these areas include both available habitat and extant populations of longfin smelt. There have been a few recent examples of former tidelands, once diked and drained, that have undergone restoration efforts and have subsequently observed longfin smelt use. For example, the Salt River, a major tributary to the lower Eel River estuary, underwent a large restoration project in the summer of 2013 with over 4 km of river channel excavated, widened and deepened (Manning and O'Shea 2015). In the winter of 2014, adult longfin smelt were detected over 4.5 km up-stream in the restored areas (M. Wallace, personal communication). Longfin smelt were also sampled in slough channels connected to McNulty Slough in the lower portion of the Eel River that were restored to tidal access after a levee breach (M. Wallace, unpublished data). In Salmon Creek, a tributary to Humboldt Bay, longfin smelt were detected in January 2012 in areas that had received extensive restoration during the previous year (M. Wallace, unpublished data). In San Francisco Bay, longfin smelt were also documented in salt ponds restored to tidal flow (Hobbs et al. 2012). These restoration projects highlight that longfin smelt can rapidly utilize restored areas once marine connectivity is re-established or enhanced.

This data review synthesizes a wide variety of information for longfin smelt along the northern and central California coast. However, to enhance the management of this species and guide habitat protection and restoration efforts, systematic studies are needed throughout its range in California. While there are ongoing data collection efforts in San Francisco Bay, there is currently little work being done on populations outside of that area. In Humboldt Bay, most contemporary observations were taken incidental to ongoing salmon monitoring efforts by the California Department of Fish and Wildlife using beach seines in the tributaries to the Bay, or at the salmon weir on Freshwater Creek. Of highest importance is a systematic effort designed specifically for longfin smelt to determine the current presence of this species in watersheds along the California coast most likely to have longfin smelt, especially those having no available data or unclear occupancy. This type of effort could likely be accomplished with new methods such as environmental DNA (eDNA) currently being utilized to detect other listed cryptic aquatic species (Ficetola, et al. 2008; Thomsen et al. 2012; Schmelzle and Kinziger 2016). This would provide a comprehensive and contemporary view of longfin smelt presence to prioritize research and habitat restoration needs for the species (Roni et al. 2002). Future investigations should also determine spatial and temporal habitats and areas important to the species, especially in known watersheds with longfin smelt present such as Humboldt Bay and the Eel River estuary. For example, specific spawning and rearing areas, as well as potential restoration opportunities, should be determined within watersheds. In coastal marine areas, use by longfin smelt should be investigated to ensure important late juvenile and early adult habitats are fully understood and identified. In conclusion, while this review provides a comprehensive look at the known data for this species along the coast of California, focused designed-based studies are needed to determine all extant California populations and their associated limiting factors for population recovery.

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Literature Cited

Abookire, A. A., and J. F. Piatt. 2005. Oceanographic Conditions Structure Forage Fishes into Lipid-Rich and Lipid-Poor Communities in Lower Cook Inlet, Alaska, USA. Marine Ecology Progress Series 287:229-240.

Baby, M., L. Bernatchez, and J. Dodson. 1991. Genetic Structure and Relationships Among Anadromous and Landlocked Populations of Rainbow Smelt, Osmerus Mordax, Mitchill, as Revealed by MTDNA Restriction Analysis. Journal of Fish Biology 39(Sa):61-68.

Baxter, R., K. Hieb, S. Deleon, K. Fleming, and J. Orsi. 1999. Report on the 1980-1995 Fish, Shrimp, and Crab Sampling in the San Francisco Estuary. James Orsi, Editor. The Interagency Ecological Program for the Sacramento-San Joaquin Estuary, Technical Report 63, Stockton, California.

Bennett, W. A., W. J. Kimmerer, and J. R. Burau. 2002. Plasticity in Vertical Migration by Native and Exotic Estuarine Fishes in a Dynamic Low-Salinity Zone. Limnology and Oceanography 47(5):1496-1507.

California Department of Fish and Game (CDFW). 2009. A Status Review of the Longfin Smelt (*Spirinchus Thaleichthys*) in California. Sacramento, California.

Cannata, S., and T. Hassier. 1995. Juvenile Salmonid Utilization of the Eel River Estuary. California Cooperative Fishery Research Unit. Humboldt State University. Arcata, California.

Chamberlain, R. 988. Fish Use of a Mitigation Salt Marsh. M.S. Thesis. Humboldt State University, Arcata, California.

Chamberlain, R., and R. Barnhart. 1993. Early Use by Fish of a Mitigation Salt Marsh, Humboldt Bay, California. Estuaries 16(4):769-783.

Chigbu, P., and T. Sibley. 1994. Relationship Between Abundance, Growth, Egg Size and Fecundity in a Landlocked Population Of Longfin Smelt, *Spirinchus Thaleichthys*. Journal Of Fish Biology 45(1):1-15.

Chigbu, P., T. Sibley, and D. Beauchamp. 1998. Abundance and Distribution of Neomysis Mercedis and a Major Predator, Longfin Smelt *(Spirinchus Thaleichthys)* in Lake Washington. Hydrobiologia 386:167-182.

Cole, M. 2004. Distribution of Fish Species in Humboldt Bay, Humboldt County, California, USA: A GIS Perspective. M.S. Thesis. Humboldt State University, Arcata, California.

Degeorges, A. 1972. Feasibility of Artificial Reefs in Intertidal Waters. M.S. Thesis. Humboldt State University, Arcata, California.

De Groot, S. 2002. A Review of the Past and Present Status of Anadromous Fish Species in the Netherlands: is Restocking the Rhine Feasible? Pages 205-218 In P. H. Nienhuis and R. D. Gulati, Editors. Ecological Restoration of Aquatic and Semi-Aquatic Ecosystems in the Netherlands. Hydrobiologia 478:1-6.

Eldridge, M. 1970. Larval Fish Survey of Humboldt Bay. M.S. Thesis. Humboldt State University, Arcata, California.

Eldridge, M., and F. Bryan. 1972. Larval Fish Survey of Humboldt Bay, California. National Oceanic Atmospheric Administration, Technical Report SSRF-665.

Emmett, R., and S. Hinton. 1992. Benthic and Epibenthic Invertebrates, Demersal Fishes, and Sediment Structure off Tillamook Bay, Oregon, September 1990, With Comparisons to Previous Surveys. Coastal Zone and Estuarine Studies Division, Northwest Fisheries Science Center. Seattle, Washington.

Emmett, R., S. Hinton, S. Stone, and M. Monaco. 1991. Distribution and Abundance of Fishes and Invertebrates in West Coast Estuaries. Volume II: Species Life History Summaries. Elmr Report No. 8. NOAA/NOS Strategic Environmental Assessments Division, Rockville, Maryland.

Emmett, R., R. Llansó, J. Newton, R. Thom, M. Hornberger, C. Morgan, C. Levings, A. Copping, and P. Fishman. 2000. Geographic Signatures of North American West Coast Estuaries. Estuaries 23(6):765-792.

Eschmeyer, W. 2006. Catalogue Of Fishes. [Internet]. California Academy of Sciences, San Francisco. Available From: http//www.calacademy.org/Research/Ichthyology/Catalog. Accessed 28 September, 2015.

Ficetola, G. F., C. Miaud, F. Pompanon, and P. Taberlet. 2008. Species Detection Using Environmental DNA From Water Samples. Biology Letters 4(4):423-425.

Fry, D. 1973. Anadromous Fishes of California. California Department of Fish & Game Booklet. Sacramento, California. USA.

Gemmer, A. 2002. Ecology of Harbor Seals, *Phoca Vitulina*, in Northern California. M.S. Thesis. Humboldt State University, Arcata, California.

Gleason, E., T. Mulligan, and R. Studebaker. 2007. Fish Distribution in Humboldt Bay, California: A GIS Perspective By Habitat Type. Current Perspectives on the Physical and Biological Processes of Humboldt Bay. Pages 105-169 In S. C. and R. Rasmussen. Editors. Current Perspectives on the Physical and Biological Process of Humboldt Bay. California Sea Grant. Eureka, California.

Harding, J., A. Ammann, and R. Macfarlane. 2011. Regional and Seasonal Patterns of Epipelagic Fish Assemblages From the Central California Current. Fishery Bulletin 109(3):261-281.

Hill J., and L. Hendrickson. 1991. Haematozoa of Fishes in Humboldt Bay. Journal of Wildlife Diseases 27(4):701-705.

Hinton, S., and R. Emmett. 1994. Benthic Infauna, Sediment and Fish Offshore From the Columbia River, July 1992. Coastal Zone and Estuarine Studies Division, Northwest Fisheries Science Center. Seattle, Washington.

Hirose, T., and K. Kawaguchi. 1998. Spawning Ecology of Japanese Surf Smelt, *Hypomesus Pretiosus Japonicus* (Osmeridae), in Otsuchi Bay, Northeastern Japan. Environmental Biology of Fishes 52(1-3):213-223.

Hobbs, J., W. Bennett, and J. Burton. 2006. Assessing Nursery Habitat Quality For Native Smelts (Osmeridae) in the Low-Salinity Zone of the San Francisco Estuary. Journal of Fish Biology 69:907-922.

Hobbs, J., P. Moyle, and N. Buckmaster. 2012. Monitoring the Response of Fish Communities to Salt Pond Restoration: Final Report. University of California, Davis. Davis, California.

Jensen, P. 1957. An Extension of the Range of the Long-Finned Smelt. California Department of Fish and Game Bulletin 43(1):99.

Katz, J., P. B., Moyle, R. M. Quiñones, J., Israel, and S. Purdy. 2013. Impending Extinction of Salmon, Steelhead, and Trout *(Salmonidae)* in California. Environmental

Biology of Fishes 96(10-11):1169-1186.

Kisanuki, T., J. Polos, and D. Wills. 1991. Annual Report - Klamath River Assessment Program. U.S. Fish and Wildlife Service, Coastal California Fisheries Fishery Resource Office, Aff1-Fro-91-14. Arcata, California

Leet, W. S., Dewees, C. M., Klingbeil, R., and E. J. Larson. 2001. California's Living Marine Resources: A Status Report. The Resources Agency, California Department of Fish and Game. University of California, Agriculture and Natural Resources Publication Sg01-11, Sacramento, California..

Lischka, S., and J. Magnuson. 2006. Timing and Site Selection of Spawning in a Landlocked Population of Rainbow Smelt in Wisconsin. Environmental Biology of Fishes 76(2-4):413-418.

Litz, M., R. Emmett, P. Bentley, A. Claiborne, and C. Barceló. 2014. Biotic and Abiotic Factors Influencing Forage Fish and Pelagic Nekton Community in the Columbia River Plume (USA) Throughout the Upwelling Season 1999–2009. ICES Journal of Marine Science: Journal du Conseil 71(1):5-18.

Manning, S., and D. O'shea. 2015. Post Construction Eelgrass Survey Report, Year 2-2015. Prepared For: The Humboldt County Resource Conservation District, Eureka, California.

Martin K., and D. Swiderski. 2001. Beach Spawning in Fishes: Phylogenetic Test of Hypotheses. American Zoology 41:526-537.

Mccabe Jr, G. T., W. D. Muir, R. L. Emmett, and J. Durkin. 1983. Interrelationships Between Juvenile Salmonids and Nonsalmonid Fish in the Columbia River Estuary. Fishery Bulletin 81(4):815-826.

Merz, J. E., P. S. Bergman, J. F. Melgo, and S. Hamilton. 2013. Longfin Smelt: Spatial Dynamics and Ontogeny in the San Francisco Estuary, California. California Fish and Game 99(3):122-148.

Merritt Smith Consulting. 1998. Biological and Water Quality Monitoring in the Russian River Estuary, 1997 - Second Annual Report. Prepared for the Sonoma County Water Agency. Lafayette, Ca.

Merritt-Smith Consulting. 1999. Biological and Water Quality Monitoring in the Russian River Estuary, 1998 - Third Annual Report. Prepared for the Sonoma County Water Agency, Lafayette, Ca.

Merritt-Smith Consulting. 2000. Biological and Water Quality Monitoring in the Russian River Estuary, 1999 - Fourth Annual Report. Prepared for the Sonoma County Water Agency, Lafayette, California.

Misitano, D. 1977. Species Composition and Relative Abundance of Larval and Post-Larval Fishes in Columbia River Estuary, 1973. Fishery Bulletin 75(1):218-222.

Monroe, G., B. Mapes, P. Mclaughlin, B. Browning, D. Rogers, R. Warner, and J. Speth. 1975. Natural Resources of Lake Earl And Smith River Delta. California Department of Fish and Game, Eureka, California.

Monroe, G., Reynolds, F., B. Browning and J. Speth. 1974. Natural Resources of the Eel River Delta. California Department of Fish and Game, Eureka, California.

Moulton, L. 1974. Abundance, Growth, and Spawning of the Longfin Smelt in Lake Washington. Transactions of the American Fisheries Society 103(1):46-52.

Moyle, P. B. 2002. Inland Fishes of California. University of California Press. Berkeley, California. USA.

MOYLE, P. B., J. KATZ, AND R. QUIÑONES. 2011. Rapid Decline of California's Native Inland Fishes: A Status Assessment. Biological Conservation 144(10):2414-2423.

MURAWSKI, S., G. CLAYTON, R. REED, AND C. COLE. 1980. Movements Of Spawning Rainbow Smelt, Osmerus Mordax, In A Massachusetts Estuary. Estuaries 3(4):308-314.

PINNIX, W., T. SHAW, K. ACKER, AND N. HETRICK. 2005. Fish Communities In Eelgrass, Oyster Culture And Mudflat Habitats Of North Humboldt Bay, California, Final Report. Us Fish And Wildlife Service, Arcata, California Technical Report Number Tr2005-02.

RICE, C. 2006. Effects Of Shoreline Modification On A Northern Puget Sound Beach: Microclimate And Embryo Mortality In Surt Smelt (*Hypomesus Pretiosus*). Estuaries And Coasts 29(1):63-71.

ROBARDS, M. D., J. F. PIATT, A. B. KETTLE, AND A. A. ABOOKIRE. 1999. Temporal and Geographic Variation In Fish Communities Of Lower Cook Inlet, Alaska. Fishery Bulletin 97(4):962-977.

RONI, P., T. BEECHIE, R. BILBY, F. LEONETTI, M. POLLOCK, AND G. PESS. 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds. North American Journal of Fisheries Management 22(1):1-20.

ROSENFIELD, J. A. 2010. Life History Conceptual Model And Sub-Models For Longfin Smelt, San Francisco Estuary Population. Report Submitted To The Sacramento-San Joaquin Delta Regional Ecosystem Restoration Implementation Plan (Drerip). Aquatic Resources Consulting, Sacramento, California.

ROSENFIELD, J. A., AND R. BAXTER. 2007. Population Dynamics and Distribution Patterns of Longfin Smelt in the San Francisco Estuary. Transactions of the American Fisheries Society 136(6):1577-1592.

RUPP, R. 1965. Shore-Spawning And Survival of Eggs of the American Smelt. Transactions of the American Fisheries Society 94(2):160-168.

SAIKI, M., AND B. MARTIN. 2001. Survey of Fishes and Environmental Conditions In Abbotts Lagoon, Point Reyes National Seashore, California. California Fish and Game 87(4):123-138.

SAMUELSON, C. 1973. Fishes Of South Humboldt Bay, Humboldt County, California. M.S. Thesis. Humboldt State University, Arcata, California.

SCHMELZLE, M., AND A. KINZIGER. 2016. Using Occupancy Modelling To Compare Environmental Dna To Traditional Field Methods For Regional-Scale Monitoring Of An Endangered Aquatic Species. Molecular Ecology Resources. Molecular Ecology Resources 16(4):895-908.

SIMONSEN, M. 1977. The Use of Discriminate Function Analysis in the Identification of Two Species of Larval Smelt, *Spirinchus Thaleichthys* and *Hypomesus T. Transpacificus*, in the Sacramento-San Joaquin Estuary, California. MS Thesis. University of the Pacific, Stockton, California.

SONOMA COUNTY WATER AGENCY. 2001. Biological and Water Quality Monitoring in the Russian River Estuary, 2000 - Fifth Annual Report. Prepared for Sonoma County Water Agency by J. Martini-Lamb. Lafayette, California.

SOPHER, T. 1974. A Trawl Survey of the Fishes of Arcata Bay, California. M.S. Thesis. Humboldt State University, Arcata, California.

Stables, T., C. Perrin, and M. Rosenau. 2005. Acoustic and Trawl Surveys to Locate Eulachon Aggregations in the Lower Fraser River, British Columbia. North American Journal of Fisheries Management 25(2):675-688.

Stein, R. 1972. Identification of Some Pacific Cottids. M.S. Thesis. Humboldt State University, Arcata, California.

Stevens, D., and L. Miller. 1983. Effects of River Flow on Abundance of Young Chinook Salmon, American Shad, Longfin Smelt, and Delta Smelt in the Sacramento-San Joaquin River System. North American Journal of Fisheries Management 3(4):425-437.

Thomsen, P. F., J. Kielgast, L. L. Iversen, P. R. Møller, M. Rasmussen, and E. Willerslev. 2012. Detection of a Diverse Marine Fish Fauna Using Environmental DNA From Seawater Samples. Plos One 7(8):E41732.

Tulp, I., M. Keller, J. Navez, H. Winter, M. De Graaf, and W. Baeyens. 2013. Connectivity Between Migrating and Landlocked Populations of a Diadromous Fish Species Investigated Using Otolith Microchemistry. Plos One 8(7):E69796.

US Fish and Wildlife Service (USFWS). 2012. Notice of 12-Month Petition Finding (Longfin Smelt). Docket No. FWS-R8-Es-2008-0045.

Waldvogel, J. 1977. Age, Maturity, and Distribution of Northern Anchovy, *Engraulis Mordax*. M.S. Thesis. Humboldt State University, Arcata, California.

Wallace, M. 2006. Juvenile Salmonid Use of Freshwater Slough and Tidal Portion of Freshwater Creek, Humboldt Bay, California 2003. Annual Report. California Department of Fish and Game. Arcata, California.

Young, J. 1984. Identification of Larval Smelt (*Osteichthyes: Salmoniformes: Osmeridae*) From Northern California. M.S. Thesis. Humboldt State University, Arcata, California.

Zuspan, M. and M. Sparkman. 2002. CDFG Annual Report, Mad River Winter-Run Adult Steelhead Run-Size Estimate, 2000-2001 Season. Project 1A3. Arcata, California.

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Appendix 1.—Longfin smelt (Spirinchus thaleichthys) observations compiled for this study from 1889 to 2016. All observations were from coastal California, not including areas east of the Golden Gate Bridge. Observations are listed from north to south.

Area	Location	Month	Year	Number	Size (mm, TL)	Gear[a]	References (Document #)[g]
Del Norte County	Lake Earl (lagoon)	4	1989	1	UNK	GN	McLeod 1989
Klamath River	Estuary	UNK	1979-1989	"common"	UNK	VAR	Kisanuki et al. 1991
		11, 12	1992	≥2	UNK	S; BE	M. Wallace, California Department of Fish and Wildlife, unpublished data
		3	2001	UNK	150	BE	M. Wallace, unpublished data
		7	2003	UNK	UNK	BE	M. Wallace, unpublished data
Offshore	Gold Bluffs Beach	UNK	2005-2007	1	128	OT	Mulligan and Lomeli 2008
Offshore	False Klamath Cove	UNK	2005-2007	3	132-145	OT	Mulligan and Lomeli 2008
Offshore	Offshore of Big Lagoon	11	1968	5	95-116	UNK	LACM Fish Collection #37766.002
Near the Beach	Trinidad	9	2004	2	UNK	UNK	HSU Fish Collection #3694
Offshore	Trinidad	8, 9	1969	125	UNK	OT	Quirollo 1969
Mad River	Estuary	Winter	2002	1	UNK	S	Zuspan & Sparkman 2002; M. Sparkman, California Department of Fish and Wildlife, unpublished data
Offshore	Offshore of North Spit Humboldt Bay	10	2010	7	91-140	OT	Mulligan and Jones 2011
		9	1992	UNK	UNK	OT	Pequegnat and Mondeel-Jarvis 1995
	Offshore of Humboldt Bay	3, 5	1960	51	UNK	OT	Allen 1964
		7	1961	4	UNK	OT	Allen 1964
		1	1962	9	UNK	OT	Allen 1964
	Offshore of South Humboldt Bay	11	1968	5	86-114	T	LACM Fish Collection #30763.003

Appendix 1 continued

Area	Location	Month	Year	Number	Size (mm, TL)	Gear[a]	References (Document #)[g]
Humboldt Bay	Eureka, CA	1931	1931	3	UNK	UNK	MCZ Fish Collection #32743
Humboldt Bay	Entrance Channel	UNK	1974-1976	UNK	UNK	S	Waldvogel 1977
	Throughout	UNK	2000-2001	11	120-131	VAR	Cole 2004; Gleason et al. 2007
		11, 12	1979	9	UNK	PN	Young 1984
		1	1980	4			Young 1984
		1-12	1969	713	4-51	PN	Eldridge 1970; Eldridge and Bryan 1972
	Bay Entrance, North Bay, Jacoby Creek, Freshwater Slough	2-5	1971	687	UNK	UNK	Stein 1972
	UNK	UNK	1983-1984	14	UNK	OT	Hill and Hendrickson 1991
	North Humboldt Bay	12	2014	1	118	LA	J. Ray, California Department of Fish and Wildlife, unpublished data
		1-12	1968	1,586	50-150	OT	Sopher 1974
	North Humboldt Bay	UNK	2003-2005	12	UNK	VAR	Pinnix et al. 2005
	North Humboldt Bay	2-7	1972	110	UNK	S	DeGeorges 1972
	North Humboldt Bay	2	1961	1	UNK	UNK	HSU Fish Collection #2465
	Off Woodley Island	7-11	1981	7	UNK	OT	Chamberlain 1988
		3	1982	10	UNK	OT	Chamberlain 1988
		1	1982	2	Juvenile/ larval	PN	Chamberlain 1988
	South Humboldt Bay	1	1965	72	UNK	OT	Samuelson 1973
	South Humboldt Bay	4	1970	43	UNK	OT	Samuelson 1973
		10	1964	1	UNK	OT	Samuelson 1973
		10	1968	4	UNK	OT	Samuelson 1973

Area	Location	Month	Year	Number	Size (mm, TL)	Gear[a]	References (Document #)[g]
Humboldt Bay (cont.)		11	1963	5	UNK	OT	Samuelson 1973
		11	1968	25	UNK	OT	Samuelson 1973
	Freshwater Slough	4, 7	2003	UNK	UNK	S	M. Wallace, unpublished data; Wallace 2006
	Freshwater Slough (cont.)	3	2005	UNK	UNK	S	M. Wallace, unpublished data
		1-3	2006	UNK	UNK	S	M. Wallace, unpublished data
		4	2007	UNK	UNK	S	M. Wallace, unpublished data
		1	2008	UNK	UNK	S	M. Wallace, unpublished data
	Second Slough	12	1981	7	UNK	CN	Chamberlain 1988
		3, 4	1982	9	UNK	CN	Chamberlain 1988
		11	1981	1	UNK	OT	Chamberlain 1988
		2	1982	2	UNK	OT	Chamberlain 1988
	3rd Slough	7	2003	UNK	UNK	S	M. Wallace, unpublished data
	Park Street Mitigation Marsh	2	1981	7	UNK	CN	Chamberlain 1988
		1-3	1981	72	Juvenile/Larval	PN	Chamberlain 1988
		11	1981	3	UNK	OT	Chamberlain 1988
	Freshwater Creek Weir	3	2009	7	108-124[b, e]	W	J. Garwood, California Department of Fish and Wildlife, unpublished data
		12	2012	4	UNK	W	C. Anderson, Sponsored Programs Foundation, HSU, unpublished data
		12	2015	8	123-131[b, d]	W	J. Ray, unpublished data
		1	2016	3	107-132[b, d]	W	C. Anderson, unpublished data
		2	2016	3	130-135[d]	W	C. Anderson, unpublished data

Appendix 1 continued

Area	Location	Month	Year	Number	Size (mm, TL)	Gear[a]	References (Document #)[g]
Humboldt Bay (cont.)	Above Freshwater Creek Weir	12	2014	17	UNK	S	M. Wallace, unpublished data
	Elk River Slough	2, 3	2005	UNK	UNK	S	M. Wallace, unpublished data
		1-3	2006	UNK	UNK	S	M. Wallace, unpublished data
		1	2008	UNK	UNK	S	M. Wallace, unpublished data
	Salmon Creek	2	2006	UNK	UNK	S	M. Wallace, unpublished data
		1	2012	UNK	UNK	S	M. Wallace, unpublished data
		1	2014	UNK	UNK	S	M. Wallace, unpublished data
		2	2015	UNK	UNK	S	M. Wallace, unpublished data
		2	2016	1	114b, [e]	S	M. Wallace, unpublished data
	Hookton Slough	1	2006	UNK	UNK	S	M. Wallace, unpublished data
Offshore of the Eel River		8	1971	4	84-108	OT	LACM #31955.006
Eel River Estuary	Hawk Slough	4	1974	1	121	S	Puckett 1977a[f]; L. Puckett, California Department of Fish and Game (Retired), unpublished field notes
		2, 3	1995	8	112-128	S	Cannata and Hassler 1995
	Quill Slough	4	1974	1	114	S	Puckett 1977a; 1 L. Puckett, unpublished field notes
	North Bay	12	1973	2	130-139	S	Puckett 1977a; L. Puckett, unpublished field notes
	North Bay	6, 12	1994	78	NA	S	Cannata & Hassler 1995
	North Bay	2, 3	1995	3	NA	S	Cannata & Hassler 1995
	Cutoff Slough	2	1974	1	128	S	Puckett 1977a; L. Puckett, unpublished field notes

Area	Location	Month	Year	Number	Size (mm, TL)	Gear[a]	References (Document #)[g]
Eel River Estuary (cont.)	Morgan Slough	3	1974	3	120-130	S	Puckett 1977a; L. Puckett, unpublished field notes
	Salt River	11	1973	3	116-133	S	Puckett 1977a; L. Puckett, unpublished field notes
	Salt River (cont.)	12	2014	1	130	S	M. Wallace, unpublished data
		2	2015	3	UNK	S	M. Wallace, unpublished data
	Main Channel Eel River Estuary	12	1973	2	140; 142	S	Puckett 1977a; L. Puckett, unpublished field notes
	Near Cock Robin Island	12	1952	1	UNK	UNK	CAS Fish Collection #212337
	McNulty Slough	2	2007 & 2009	2	UNK	S	M. Wallace, unpublished data
		7	2007	50-100	UNK	S	M. Wallace, unpublished data
Eel River	20 km from mouth of River	12	1955	23	105c	FN	Jensen 1957 & HSU Fish Collection #240
	Mouth of the Van Duzen River	11	1956	7	UNK	UNK	HSU Fish Collection #2534
Gualala River	River mouth	4	1973	1	UNK	UNK	J. Hopelain, California Department of Fish and Game, unpublished data
Garcia River	UNK	UNK	1973-1977	UNK	UNK	UNK	J. Hopelain, unpublished data
Russian River	Estuary	6, 11	1997	12	UNK	OT	Merritt Smith Consulting 1998
		8, 9	1998	5	UNK	OT	Merritt Smith Consulting 1999
		10, 11	1999	4	UNK	OT	Merritt Smith Consulting 2000
		10	2000	2	UNK	OT	Sonoma County Water Agency 2001
	Offshore	8	1971	1	102	OT	LACM Fish Collection #31982.01
Estero Americano	Estuary	UNK	1988-1990	8	UNK	OT	Hickey et al. 2007
Point Reyes	Abbotts Lagoon	UNK	1999	1	UNK	GN	Saiki and Martin 2001
Point Reyes	Offshore of Lighthouse	10	1971	1	UNK	UNK	CAS Fish Collection #28362

Appendix 1 continued

Area	Location	Month	Year	Number	Size (mm, TL)	Gear[a]	References (Document #)[g]
Offshore of San Francisco Bay	Offshore of North San Francisco Bay	2	2002	54	74-120[c]	NRT	Harding et al. 2011; MacFarlane, B. NOAA SWFSC Fisheries Ecology Division, unpublished data
		3	1999	1162	63-110[c]	NRT	Harding et al. 2011; MacFarlane, B., unpublished data
		6	2000	7	80-95[c]	NRT	Harding et al. 2011; MacFarlane, B., unpublished data
		7	2001	1	99[c]	NRT	Harding et al. 2011; MacFarlane, B., unpublished data
		9	1936	2	UNK	UNK	CAS Fish Collection #63975
Offshore of San Francisco Bay	Offshore of North San Francisco Bay	10	2001	2	69; 72[c]	NRT	Harding et al. 2011; MacFarlane, B., unpublished data
		11	1998	33	63-73[c]	NRT	Harding et al. 2011; MacFarlane, B., unpublished data
	Farallon Islands	10	1973	30	UNK	UNK	CAS Fish Collection #34742
	Offshore of South San Francisco Bay	3	1889	1	UNK	BT	SU Fish Collection #56118
	Offshore of South San Francisco Bay (cont.)	3	1999	17	75[c]	NRT	Harding et al. 2011; MacFarlane, B., unpublished data
		5	1999	34	36-109[c]	NRT	Harding et al. 201; MacFarlane, B., unpublished data
		6	1999	48	42-97[c]	NRT	Harding et al. 2011 ; MacFarlane, B., unpublished data
		6	2002	1	108[c]	NRT	Harding et al. 2011 ; MacFarlane, B., unpublished data
	Offshore of South San Francisco Bay	7	1973	2	UNK	T	CAS Fish Collection #34785
		10	1912	2	UNK	VAR	CAS Fish Collection #12190

Area	Location	Month	Year	Number	Size (mm, TL)	Gear[a]	References (Document #)[g]
Offshore of San Francisco Bay (cont.)		10	1973	12	UNK	T	CAS Fish Collection #34750
		10	1973	1	UNK	T	CAS Fish Collection #34806
		11	1949	2	UNK	T	CAS Fish Collection #63976
Pescadero Creek	Butano Creek		UNK (possibly 12/1893)	1	UNK	UNK	SU Fish Collection #2556
Monterey Bay	Offshore of Santa Cruz	3	1890	4	UNK	BT	SU Fish Collection #5215
Moss Landing	Near Entrance	1	1980	1	UNK	NA	CAS Fish Collection #45425
Monterey Bay	Offshore North of Monterey	7	1993	5	UNK	UNK	KU Fish Collection #9335; #548; #9336; #9337 & #23732

[a]Gear used: BT=Beam Trawl; CN= Channel Net; GN=Gill Net; LA=Lampara Net; NRT= epipelagic 264 Nordic Rope Trawl; S=Seine; OT=Otter Trawl; T=Trawl; W=Weir; FN= Fyke Net; PN=Plankton Net; BE= Boat Electrofisher; UNK=Unknown Gear Type; VAR=Various.

[b]Measurements taken in fork length.

[c]Measurements taken in standard length.

[d]Specimens noted to be in pre-spawn condition.

[e]Specimens noted to be in spawned out condition.

[f]Spawning observed in this study, though the specific location was not reported.

[g]References for unpublished reports

Allen G. 1964. An oceanographic study between the points of Trinidad Head and the Eel River, California State Water Quality Control Board. Arcata, California

Hickey, P., L., Hulette, L. Pozzi, and J. Heck. 2007. The Estero Americano Watershed Management Plan. Prepared by the Gold Ridge Resource Conservation District.

Hopelain, J. 1997. Unpublished Report. Draft final report Dingell-Johnson Coastal Steelhead Study of Gualala and Garcia Rivers- data collection 1973-1977

McLeod, D. 1989. Field Note: Lake Earl, Del Norte County. CDFW Field Archives, Arcata, California.

Mulligan, T., and M. Jones. 2011. PG&E Wave Connect Project Final Report Baseline Fisheries Studies. Report to PG&E. Humboldt State University. Arcata, California.

Mulligan, T., and M. Lomeli. 2008. Redwood National and State Parks Subtidal Fish Survey Final Report. Report to Redwood National and State Parks. Humboldt State University. Arcata, California.

Pequegnat, J., and D. Mondeel-Jarvis. 1995. 301(m) monitoring program annual report on sediment characteristics, benthic infauna, demersal fish and macroinvertebrates sampled September 1994. Humboldt State University.

Puckett, L. 1977A. The Eel River estuary-observations on morphometry, fishes, water quality, and invertebrates. CDFG Memorandum Report. Eureka, California.

Quirollo, L. 1969. Field Notes: offshore collections. CDFW Field Archives, Arcata, California.

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Distribution and derivation of dabbling duck harvests in the Pacific Flyway

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Hunters in the Pacific Flyway harvest a wide diversity of dabbling ducks, and better knowledge of the origins of these birds could assist in both harvest and habitat management. We used abundance, banding, and harvest data from throughout the Pacific Flyway and other important source areas in the Central Flyway to estimate the distribution and derivation of Pacific Flyway dabbling duck harvests during 1966–2013. Although most of the combined Pacific Flyway dabbling duck harvest was derived from Alaskan and Canadian sources, each Pacific Flyway state relied extensively on within-state production for at least some species, especially mallards (*Anas platyrhynchos*), gadwalls (*Mareca strepera*), cinnamon teal (*Spatula cyanoptera*), and wood ducks (*Aix sponsa*). Harvest from California was especially diverse, including large proportions of ducks produced in California in addition to migrants from throughout the Pacific and Central Flyways. Although the Pacific Flyway has long been recognized as a critical wintering area for dabbling ducks, our analyses indicate it is also an important production area for several species. Sustaining future waterfowl harvests will require continued recognition of the diverse production origins of waterfowl that winter in the Pacific Flyway.

Key words: band recoveries, California, dabbling ducks, derivation, distribution, harvest, Pacific Flyway, waterfowl

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Management of migratory waterfowl benefits from reliable knowledge of the connections between production (i.e., breeding) and harvest areas (Osnas et al. 2014). Distribution of harvest describes where birds from a specific production area are harvested, and given extended hunting seasons, such harvest can occur on breeding, migration, or wintering areas. Distribution of harvest can be estimated based on the relative proportion of band recoveries from a given production area, assuming reporting rates are equal among potential harvest areas (Henny and Burnham 1976). Derivation of harvest describes the production origins of birds harvested by hunters in a specific region, and in addition to band recovery data, requires abundance estimates from each production area for estimating relative banding effort (Munro and Kimball 1982). Methods for estimating harvest distribution and derivation were first developed by Geis et al. (1971) using data from American black ducks (*Anas rubripes*). Munro and Kimball (1982) further refined these methods, using population surveys, band recoveries, and harvest information to describe patterns of harvest distribution and derivation for North American mallards (*Anas platyrhynchos*) during 1961−1975. Their work was subsequently used to help describe boundaries for Eastern, Mid-continent, and Western mallard populations and aided in the development of adaptive harvest management (AHM) protocols (U.S. Fish and Wildlife Service 1999). Klimstra and Padding (2012) used derivation of harvest information to improve harvest management of four populations of Canada geese (*Branta canadensis*) wintering in the Atlantic Flyway. Their analysis showed that early harvest was comprised almost entirely of geese from an overabundant resident population, thus enabling development of special early seasons to exploit resident geese with minimal risk to less abundant migratory populations (Klimstra and Padding 2012). More recently, Szymanski and Dubovsky (2013) described connectivity between production and harvest areas for blue-winged teal (*Spatula discors*). Their analysis further demonstrated the effectiveness of the Conservation Reserve Program at improving blue-winged teal production throughout the Dakotas. Hence, analyses of waterfowl harvest distribution and derivation have helped identify important regions for both harvest and habitat management. From 2008−2016, AHM protocols for mallards in the Pacific Flyway relied on abundance estimates from California, Oregon, and Alaska. Abundance estimates from Washington and British Columbia were included beginning with the 2017 hunting season (U.S. Fish and Wildlife Service 2016), but breeding populations from Idaho, Nevada, and Utah are still excluded, as are populations from production areas located in the Mid-continent, especially Alberta (Alisauskas et al. 2014). Since 2010, a separate AHM protocol has guided bag limits for northern pintails (*Anas acuta*), but harvest strategies for most other dabbling ducks in the Pacific Flyway follow recommendations arising from the AHM western mallard population model (U.S. Fish and Wildlife Service 2016). It is therefore important to understand how harvest distribution and derivation for other important duck species compare to those of mallards. Our objectives were to describe the distribution and derivation of harvest for the nine most commonly harvested dabbling ducks within the Pacific Flyway: mallards, northern pintails, green-winged teal (*Anas crecca*), American wigeons (*Mareca americana*), gadwalls (*M. strepera*), northern shovelers (*Spatula clypeata*), cinnamon teal (*S. cyanoptera*), blue-winged teal, and wood ducks (*Aix sponsa*; we treat *Aix* as a dabbling duck for our analysis, but acknowledge that their taxonomic affinity remains uncertain).

Materials And Methods

Study area—North American waterfowl flyways are both ecological and administrative constructs (U.S. Fish and Wildlife Service 2015). Ecologically, the Pacific Flyway includes portions of North America that support waterfowl populations that winter primarily west of the Continental Divide. Administratively, the Pacific Flyway includes Alaska, Washington, Oregon, California, Idaho, Nevada, Utah, and Arizona, and western portions of Montana, Wyoming, Colorado, and New Mexico (Figure 1). Although they do not vote on U.S. regulation-setting decisions, British Columbia and Yukon Territory are also members of the Pacific Flyway, as are Baja California, Baja California Sur, Sonora, and Sinaloa, Mexico. For our analyses of harvest distribution and derivation, we included British Columbia and all U.S. states located wholly within the Pacific Flyway except Arizona, which had insufficient band recoveries for analysis.

Previous studies of harvest derivation (e.g., Munro and Kimball 1982) used banding reference areas (Anderson and Henny 1972) to delineate breeding populations. However, population surveys, banding data, and harvest data are typically organized by geopolitical boundaries, and states and provinces manage much of their own waterfowl habitat and set their own hunting regulations (subject to federal frameworks), so we used states and provinces as both source and harvest areas for our analyses (see also Szymanski and Dubovsky 2013). Because banding data were particularly sparse in northern Canada, we combined

FIGURE 1.—Map of North America illustrating the four waterfowl flyways.

Yukon and Northwest Territories (hereafter Yukon/NWT) and treated aggregated data as if they were from the Central Flyway (~90% of enumerated waterfowl were from NWT; Appendix 1). We also analyzed non-flyway sources of harvest from Alberta, Saskatchewan and Manitoba (pooled together), and Montana, North and South Dakota (pooled as Prairie U.S.). We initially summarized data from Colorado and Wyoming, but found that they contributed only 2-3% of the annual gadwall and mallard harvest for Utah and trace amounts (<0.2%) for other species and jurisdictions, so we excluded them from further consideration. Although we included mid-continent sources in our analysis, our estimates of harvest distribution were based solely on Pacific Flyway recoveries (e.g., we excluded ducks banded in Alaska that were harvested in the Central, Mississippi, and Atlantic Flyways).

Breeding population estimates—We estimated annual abundance (Nt) for each species (s) and production area (i) using data from three existing surveys: 1) the federal Waterfowl Breeding Population and Habitat Survey (WBPHS, U.S. Fish and Wildlife Service 2015); 2) state waterfowl surveys (Olson 2014); and 3) the Breeding Bird Survey (BBS; Sauer et al. 2011). The WBPHS primarily covers source areas outside the Pacific Flyway, including Prairie U.S., Prairie Canada, and Northwest Territory, but also includes portions of Yukon Territory and Alaska. State waterfowl surveys have been conducted since 1959 in Nevada, 1979 in Washington, 1990 in Utah, 1992 in California, 1994 in Oregon, and 2006 in British Columbia (Olson 2014, U.S. Fish and Wildlife Service 2015). The Breeding Bird Survey began coverage in western North America in 1968 (Sauer et al. 2011); however, coverage in northern regions of Canada and Alaska was limited, especially in early years. For Breeding Bird Survey data, we used state or province-level annual summaries of mean ducks per BBS route. Given 50 survey stops of 0.4 km (0.25 mile) radius, a single BBS route covers 25.1 km^2, and we extrapolated average route-specific BBS estimates to the entire landmass of each state or province (Zimmerman et al. 2015).

For states or provinces with two concurrent surveys, we paired data from BBS and WBPHS surveys (AK, YK, NT, AB, SK, MB, MT, ND, and SD) or BBS and state-specific surveys (WA, OR, CA, NV, and UT) and used Bayesian state-space models (Kéry and Schaub 2012) run in reverse time (2013-1966) to estimate joint population trajectories for each data set. We modeled a common growth rate (r_{sit}) for each population (e.g., $\log[N_{si(t-1)})] = \log[N_{sit}] + r_{sit})$, where r_{sit} was drawn from a normal distribution with vague priors (μ_r=0, σ_r^2=1000). Because log[0] is undefined, we assigned 0.5 ducks to one survey route during survey years when no ducks were detected during BBS surveys, and we assumed that BPOP surveys had counted one half of the minimum ducks observed during years with non-zero counts. We modeled annual observation error in each data set using log-transformed estimates of survey precision for WBPHS data (σ_{WBPHS}), but for BBS and state surveys we treated observation error as an unknown parameter with a vague prior distribution ($\sigma_{\log(N)}$ ~Uniform(0-3)) and for BBS data we further assumed that survey precision ($\sigma^{-2}_{\log BBS}$) was correlated with the number of BBS routes conducted each year. During periods when both surveys were operating, population trajectories were driven primarily by data from dedicated waterfowl surveys, but our joint modeling approach allowed us to estimate population sizes during earlier time periods when only BBS data were available (e.g., California: 1968−1991).

In states or provinces with both BPOP surveys and BBS routes, mean long-term estimates from the two surveys were positively correlated (r^2=0.67), and this correlation was stronger when we excluded BPOP surveys with fewer than 5,000 birds (r^2=0.77, Figure 2). However, BPOP surveys detected 7.8 times more ducks than did BBS surveys, averaged over all species and survey areas (Appendix 2). Species with widespread breeding populations in the southern Pacific Flyway (i.e., mallards, gadwalls, cinnamon teal, and wood ducks) had lower adjustment factors (3.6 BPOP:BBS) than did species with primarily boreal or mid-continent breeding distributions (i.e., pintails, wigeons, green-winged teal, northern shovelers, and blue-winged teal; 10.2 BPOP:BBS). We therefore used a 3.6× adjustment factor for BBS estimates from Pacific Flyway jurisdictions that only had BBS data (Idaho), or had insufficient BPOP data for joint modeling (British Columbia). Although Nevada and Utah both have dedicated BPOP surveys, BPOP estimates were consistently smaller than unadjusted BBS indices (Appendix 2). We therefore used adjusted BBS population estimates for both Nevada and Utah. Harvest derivation uses population estimates as regional weighting factors (Munro and Kimball 1982, Szymanski and Dubovsky 2013) and it is not critical that population estimates are unbiased so long as they function as constant proportion indices of spatiotemporal variation.

Banding and recovery data—We compiled preseason banding data from just over 3.4 million normal, wild-caught dabbling ducks banded in the Pacific Flyway and neighboring jurisdictions during 1966−2013 (Appendix 3). We included ducks banded as locals (i.e., flightless young of the year) or hatch years (flight-capable young of the year) in a combined juvenile category, but excluded birds of unknown age or sex at banding. We included birds marked with a single federal band, including those captured by spotlighting, but excluded birds that were marked with auxiliary markers (e.g., nasal tags, patagial tags)

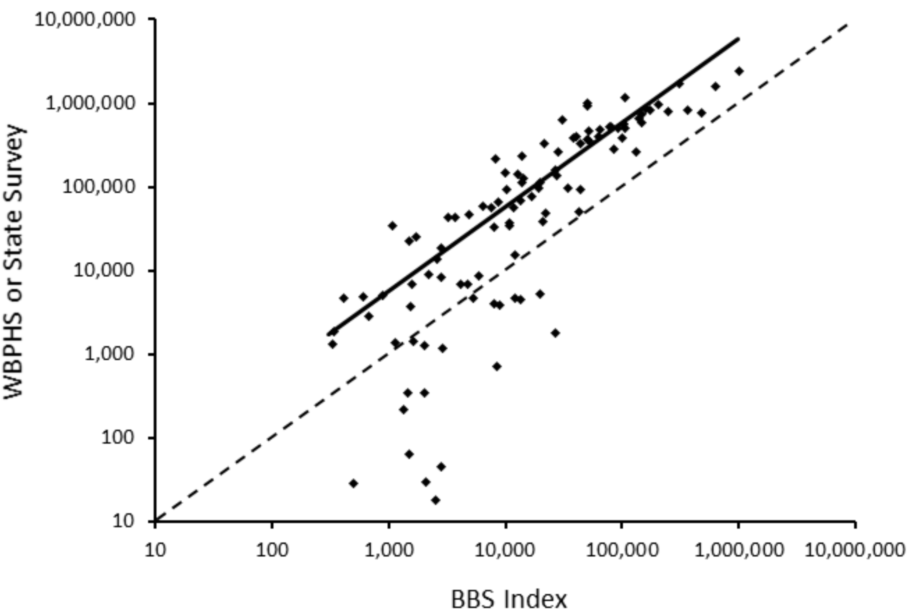

FIGURE 2.—Relationship between federal (WBPHS) or state waterfowl surveys and estimates based on the Breeding Bird Survey (BBS). Each data point represents a pair of estimates from a single state, province, or territory for a single species of dabbling duck (mallard, northern pintail, American green-winged teal, American wigeon, gadwall, northern shoveler, blue-winged teal, cinnamon teal, or wood duck). The correlation was 0.82 over all data and 0.88 for survey estimates >5,000. The dashed line indicates parity between estimate pairs, whereas the solid line represents the observed relationship where federal or state surveys observed 5.8-fold more ducks on average than the BBS survey.

because auxiliary-marked birds often have higher reporting rates (Arnold et al. 2016). Banding location was assumed to represent breeding location, but ducks banded in early fall can include migrants from other areas (Szymanski and Dubovsky 2013). Consequently, we used two different banding windows to account for variation in fall migration patterns and help eliminate early migrants from the data. For species known to migrate early (e.g., pintails, shovelers, blue-winged and cinnamon teal) we used bandings from 1 June to 31 August. For later migrants, including mallards, gadwalls, wigeons, and wood ducks, we extended the preseason banding window to 15 September to take advantage of the large number of birds that were banded during early September.

For each species (*s*), cohort (*c*; adult male, adult female, juvenile male, juvenile female), year (*t*), and banding region (*i*), we summarized total preseason banding effort (B_{scti}) and we then used direct band recoveries (R′=73,972, Appendix 3), defined as birds shot between 1 September and 31 January during the first fall or winter after banding, to estimate source-specific direct recovery rates from each harvest region (*j*):

$$\hat{f}'_{sctij} = R'_{sctij} / B_{scti}$$

This represents a source- and destination-specific index of annual harvest rate for each species, but because annual data were too sparse for analysis, we aggregated bandings and recoveries over the entire time period (1966−2013). We excluded species with 25 or fewer recoveries from state-specific analyses, but we included these data in regional summaries for the entire Pacific Flyway. For mallards, pintails, and gadwalls, which had more recovery data, we also estimated recovery rates separately for the first (1966−1989) and second halves of our study (1990−2013). Reporting rates are currently available only for mallards and eastern populations of wood ducks (Boomer et al. 2013, Garrettson et al. 2014); however, reporting rates are treated as constants in calculations of harvest derivation, so we omitted reporting rate adjustments from our analyses.

Harvest derivation resembles a Horvitz-Thompson estimator (Horvitz and Thompson 1952), except the number of birds banded from each production region (B_{scti}) is replaced by the estimated total population size for the source region ($\hat{N}_{scti}$) to account for unbanded birds in the harvest. For example, California's (CA) proportional harvest of adult male (AM) northern pintails (NOPI) from Alaska (AK) during 1966-2013 is estimated as:

$$= (\hat{N}_{sct,AK} * \hat{f}_{sct,AK,CA}) / \sum_{i=1}^{I} (\hat{N}_{scti} * \hat{f}_{scti,CA})$$

where the subscript sct = NOPI,AM,1966−2013 and 1 to I indicates all potential source areas contributing to California's pintail harvest (including Alaska).

Harvest data—Harvest estimates for the United States were obtained from the U.S. Harvest Information Program (Raftovich and Wilkins 2013). Harvest in British Columbia was obtained from the Canadian National Harvest website (Gendron and Smith 2015). Total harvest was partitioned into appropriate age and sex cohorts based on data from the Parts Collection Survey (Raftovich and Wilkins 2013). Parts that were incompletely identified to age or sex were assigned to cohorts using observed ratios from identified parts (Szymanski and Dubovsky 2013). The Parts Collection Survey cannot differentiate cinnamon teal from blue-winged teal (Carney 1992), but Szymanski and Dubovsky (2013) found that <1% of banded blue-winged teal from the mid-continent area were harvested in the Pacific Flyway. For our analyses, we combined data from both species and interpreted species composition based on production origins; teal derived from Prairie Canada or Prairie U.S. were presumed to be primarily blue-winged teal, whereas teal derived from California or the Great Basin were presumed to be primarily cinnamon teal (Appendix 3). We used harvest estimates to: weight derivation among cohorts (i.e., adult and juvenile males and females), calculate species-specific estimates of harvest derivation, weight estimates across species, calculate derivation of the entire dabbling duck harvest for each particular harvest jurisdiction, and weight estimates across all harvest jurisdictions to estimate derivation of the entire Pacific Flyway dabbling duck harvest (Munro and Kimball 1982).

Assumptions—Derivation of harvest analysis assumes that population surveys are proportional to population size at the time of banding (Munro and Kimball 1982). This further presumes that: 1) breeding birds and fledged offspring do not move among survey units prior to banding; and 2) age and sex ratios are equal among survey units; however, this latter assumption is less important given that we do not report age- and sex-specific variation in harvest derivation. Additionally, the use of banding and harvest data to evaluate these assumptions requires that: 3) banded samples adequately represent each breeding population; and 4) harvest samples are large enough to provide sufficient recoveries from all important breeding populations (Munro and Kimball 1982). We recognize that each of these assumptions is violated to some extent (Munro and Kimball 1982), and we consider these assumptions in greater detail in the Discussion.

Results

Distribution of Harvest—Mallards were the most widely distributed and harvested dabbling duck in the Pacific Flyway. Aside from Alaska and British Columbia, more than 60% of the mallards harvested from each Pacific Flyway jurisdiction were harvested within the same state where they were banded (Table 1). Mallards from Alaska and British Columbia were harvested primarily in the northern portion of the Pacific Flyway, especially Washington. Substantial portions of mallards banded in Oregon and Nevada were harvested in California, and many Idaho mallards were harvested in Washington (Table 1). Similar patterns occurred for gadwalls and wood ducks (Tables 2 and 3), except that greater proportions of both species were harvested by neighboring states (especially by hunters in California). For cinnamon teal, the only Pacific Flyway production area with >100 recoveries was California, and 99% of the harvest of California-produced birds occurred in California.

Table 1.—Percent distribution of mallard harvests from major Pacific Flyway source areas (columns) among major harvest jurisdictions (rows), 1966-2013. Harvest of local breeding populations is indicated along the main diagonal (values in bold). Trace amounts (< 0.005) were omitted to enhance readability.

	Pacific Flyway Source Areas:							
Harvested in:	**AK**	**BC**	**WA**	**OR**	**CA**	**ID**	**NV**	**UT**
Alaska	**47**							
B. Columbia	11	**26**	2			1		
Washington	27	39	**80**	7		17		
Oregon	12	16	12	**62**	3	8		
California	2	10	5	28	**96**	7	23	2
Idaho	1	10	1	2		**62**	1	5
Nevada							**75**	1
Utah						4	1	**91**

TABLE 2.—Percent distribution of gadwall harvests from Pacific Flyway source areas (columns) among major harvest jurisdictions (rows), 1966-2013. Only source areas with >100 recoveries and harvest areas with > 0.5% proportional harvest are included.

Pacific Flyway Source Areas:					
Harvested in:	**WA**	**OR**	**CA**	**NV**	**UT**
Washington	**69**	3	1		
Oregon	5	**31**	17	1	1
California	26	58	**81**	49	10
Idaho		3			2
Nevada		3	1	**48**	1
Utah		2		2	**86**

TABLE 3.—Percent distribution of wood duck harvests from Pacific Flyway source areas (columns) among major harvest jurisdictions (rows), 1966-2013. Only source areas with >100 banding recoveries and harvest areas with > 0.5% proportional harvest are included.

Pacific Flyway Source Areas					
	WA	**OR**	**CA**	**ID**	**NV**
Washington	**57**	2		13	
Oregon	10	**29**	1	17	
California	32	66	**99**	45	17
Idaho		3		**24**	
Nevada				1	**83**

Northward movement of gadwalls from California to Oregon may represent post-breeding molt migrations (Yarris et al. 1994).

Derivation of Harvest—Pacific Flyway hunters obtained 73% of their total dabbling duck harvest from Alaska and Canada, with 31% of total harvest coming from Alaska and 23% from Alberta (Table 4). Alaska was the most important source area for green-winged teal, pintails, wigeons, and shovelers; British Columbia was the most important source area for wood ducks; and Alberta was the most important source area for mallards. California was the most important source area for gadwalls and cinnamon teal. Oregon and Prairie U.S. were moderately important source areas for gadwalls (Table 4). The Pacific Flyway mallard harvest had especially diverse origins, with only 36% of the harvest coming from areas that have historically defined the western AHM mallard population (14, 6, and 16% from AK, OR, and CA, respectively), with another 14 and 3% coming from jurisdictions (BC, WA) that were recently incorporated into the western mallard population AHM (U.S. Fish and Wildlife Service 2016). Across all dabbling duck species, 44% of the Pacific Flyway harvest was derived from Alaska, Oregon, and California and another 10% from British Columbia and Washington.

Alaska hunters obtained 100% of their mallard and pintail harvest from Alaskan sources, with only trace amounts from Yukon/NWT. Sample sizes for green-winged teal,

Table 4.—Percent derivation of dabbling duck harvests for Pacific Flyway hunters from source areas throughout the Pacific and Central Flyways (columns). Trace amounts (<0.5%) were omitted to enhance readability.

	Pacific Flyway sources:								Mid-continent sources:			
Species[a]	**AK[b]**	**BC**	**WA**	**OR**	**CA**	**ID**	**NV,UT**	**YK,NT**	**AB**	**SK,MB**	**MT,ND,SD**	**Harvest**
AGWT	58	2	1	1	1	1	1	6	24	3	2	462,277
AMWI	41	2						31	19	4	2	349,044
NOPI	47			1	1		2	4	22	15	8	458,892
NOSH	46	1		4	5		1	2	19	2	21	57,047
MALL	14	14	3	6	16	5	9	3	26	1	5	1,019,813
GADW	1	5	3	21	29	2	19		8	2	10	129,127
CITE[c]		17	1	8	46	2	3		10	2	9	54,536
WODU		35	4	9	14	8	18		10		3	37,619
All	31	8	2	4	9	2	5	7	23	4	5	2,568,355

[a] AGWT: American green-winged teal, AMWI: American wigeon, NOPI: northern pintail, NOSH: northern shoveler, MALL: mallard, GADW: gadwall, CITE: cinnamon teal, WODU: wood duck.

[b] AK: Alaska; BC: British Columbia; WA: Washington; OR: Oregon; CA: California; ID: Idaho; NV,UT: Nevada and Utah; YK,NT: Yukon and Northwest Territories; AB: Alberta; SK, MB: Saskatchewan and Manitoba; MT,ND,SD: Montana, North Dakota, and South Dakota (U.S. Prairies).

[c] Harvest from mid-continent sources is predominantly blue-winged teal, harvest from remaining areas is presumed to be primarily cinnamon teal.

wigeons, and shovelers harvested in Alaska were below our minimum threshold of 25 recoveries, but 100% of these species' harvests were also of Alaskan origin. For British Columbia, 71% of pintail harvest came from Alaska, 10% from Northwest Territories, and 19% from Prairie Canada (AB and SK/MB combined); 61% of the British Columbia mallard harvest came from British Columbia, 23% came from Alaska, and 12% came from Prairie Canada. Sample sizes were below threshold level, but most of British Columbia's green-winged teal and wigeon harvest came from Alaska or Yukon/NWT, whereas wood duck harvest was derived entirely from British Columbia.

For Washington and Oregon hunters, Alaska was the most important source area for green-winged teal, wigeons, pintails, and shovelers (Table 5), and accounted for approximately one third of the total dabbler harvest for both states. Alberta accounted for 23−28% of the total dabblers harvested, with mallards, wigeons, and pintails representing the most important species. Contributions from other portions of the Prairie Pothole Region were negligible. Yukon/NWT was an important region for wigeon production and British Columbia was the most important region for wood duck production. Modest proportions of shovelers, mallards, gadwalls, and wood ducks were produced within Washington and Oregon (Table 5).

California exhibited the most diverse derivation of harvest. Alaska and Prairie Canada demonstrated similar overall importance, with each region accounting for 28-29% of the overall dabbler bag of California hunters (Table 6). Alaska was most important for green-winged teal and northern shovelers, whereas Prairie Canada was most important for pintails. Most of California's mallard and gadwall harvest came from within-state production, making California the third most important production region for California hunters (Table

TABLE 5. —Percent derivation of dabbling duck harvests for Washington (top) and Oregon (bottom) from source areas throughout the Pacific and Central Flyways (columns). Trace amounts (<0.5%) were omitted to improve readability. Abbreviations as in Table 4.

	Pacific Flyway sources:						Mid-continent sources:				
Species	AK	BC	WA	OR	CA	ID	YK,NT	AB	SK,MB	MT,ND,SD	Harvest
Washington:											
AGWT	84	5	4			1	4	3			45,668
AMWI	51	3	1				34	10	1		63,567
NOPI	74	1		1			4	14	6	1	31,093
MALL	15	24	9	2		3	4	40	1	2	237,076
GADW		20	36	10	2			12		21	8,802
WODU		60	24	2		10				3	2,505
All	33	16	7	1		2	9	28	1	2	388,711
Oregon:											
AGWT	79	2	1	1		2	3	10		1	45,791
AMWI	34	7		1			28	25	4		57,631
NOPI	63	1		2			5	17	10	2	40,336
NOSH	71			29	1						12,137
MALL	11	16	2	24	4	3	3	33	1	4	148,757
GADW		5	1	54	36			4			11,616
WODU		28	6	39		20				7	8,285
All	32	10	1	16	3	2	7	23	3	3	324,553

6). Approximately 65% of California's combined harvest of cinnamon and blue-winged teal came from areas where cinnamon teal predominate (especially from California), 20% came from the Canadian and U.S. prairies where blue-winged teal predominate, and the remaining 15% came from northern portions of the Pacific Flyway (BC, WA, ID) where both species can co-occur. Northwest Territories was the most important source area for wigeons and British Columbia was the most important source area for wood ducks. Remaining production regions all contributed modestly for at least one species (Table 6).

More than half of Nevada's total dabbler harvest was estimated to have been produced in Nevada; green-winged teal and pintails were exceptions to this pattern, coming primarily from Alaska and Canada (Table 6). Idaho and Utah harvests were more dependent on birds from Prairie Canada (especially Alberta) and less dependent on birds from Alaska and western Canada (BC, NT/YK); however, Alaska still contributed substantially to green-winged teal and pintail harvests in both states (Table 7). A large portion of the mallards and wood ducks harvested in Idaho, and mallards and gadwalls harvested in Utah, were derived from within-state production. Utah was the only Pacific Flyway state where production origins for teal suggested that the harvest was predominantly blue-winged teal rather than cinnamon teal. Yukon/NWT was important for wigeon harvest in both states, and British Columbia was important for wood duck harvest in Idaho (Table 7). Proximity to the U.S. Prairie Pothole Region was somewhat important for pintail, mallard, and gadwall harvest in both states.

Table 6. —Percent derivation of dabbling duck harvests for California and Nevada from source areas throughout the Pacific and Central Flyways (columns). Trace amounts (<0.5%) were omitted to improve readability. Abbreviations as in Table 4.

	Pacific Flyway sources:							Mid-continent sources:				
Species	AK	BC	WA	OR	CA	ID	NV,UT	YK,NT	AB	SK,MB	MT,ND, SD	Harvest
California:												
AGWT	53	2	1	1	1	1	1	6	28	4	3	278,463
AMWI	28	2	1	1				34	26	5	2	162,385
NOPI	35			1	1		2	5	27	19	9	308,566
NOSH	41			6	9		1	2	21	4	14	142,321
MALL	1	5	1	6	60	1	6	1	14	1	3	275,356
GADW		2	1	25	49		11		7	1	2	67,233
CITE[a]		12		8	53	2	3		10	1	10	41,071
WODU		32	3	11	28	7	2		12		5	22,931
All	28	3	1	4	19	1	3	7	22	7	6	1,298,326
Nevada:												
AGWT	35						5	27	27	5	1	12,088
NOPI	31						13	4	18	26	9	8,718
MALL				1			89	1	5	1	2	21,543
GADW				21	4		75					7,176
WODU						1	99					308
All	14			3	1		53	8	12	6	3	49,833

[a] Harvest from Prairie Canada and U.S. is predominantly blue-winged teal; harvest from remaining areas is presumed to be primarily cinnamon teal.

We evaluated temporal changes in derivation of Pacific Flyway total harvest for mallards, gadwalls, and northern pintails, which had the most extensive recovery data (Appendix 3). Harvest proportions of gadwalls from California and the U.S. Prairies tripled during the second half of our study (Figure 3a), likely due to increased breeding populations. Because total gadwall harvest grew by 44% during this time, apparent declines in derivation from remaining areas in the Pacific Flyway represent lack of similar growth in harvest rather than true declines. For pintails, approximately one third of the total harvest derivation shifted from the Canadian Prairies to Alaska (Figure 3b), while total harvest remained relatively constant. Mallards exhibited an approximate doubling of harvest derivation from California, Nevada, Utah, and the U.S. Prairies (Figure 3c), concurrent with extensive population growth in these same areas. Harvest derivation of mallards from British Columbia declined substantially during the second half of our study, but this was apparently not due to declining populations of mallards in British Columbia (BBS-based population estimates declined by ~10% during this period), but rather due to concurrent decline in mallard harvest from British Columbia (Olson 2014).

TABLE 7.—Percent derivation of dabbling duck harvests for Idaho and Utah from source areas throughout the Pacific and Central Flyways (columns). Trace amounts (<0.5%) were omitted to improve readability. Abbreviations as in Table 4.

	Pacific Flyway sources:						Mid-continent sources:				
Species	**AK**	**BC**	**OR**	**CA**	**ID**	**NV,UT**	**YK,NT**	**AB**	**SK,MB**	**MT,ND,SD**	**Harvest**
Idaho:											
AGWT	63				1		21	6	2	5	14,152
AMWI	23		1				44	25	2	4	18,156
NOPI	50				2	3	8	12	16	10	8,008
MALL	1	10	1		21	1	4	42	4	15	168,907
GADW			29		7	1		43	7	13	7,503
WODU		36	4	1	34			25		1	2,589
All	9	8	2		17	1	8	38	4	13	219,315
Utah:											
AGWT	35	1			2	1	7	46	5	1	41,871
AMWI						4	48	29	12	7	15,905
NOPI	30		1		1	8	5	24	14	17	35,256
MALL	1				5	60	2	17	3	9	73,212
GADW			3	1	6	55		6	2	25	24,332
CITE[a]				7	17	16		33	17	9	7,274
All	13		1		4	31	7	24	7	11	197,850

[a] Harvest from Prairie Canada and U.S. is predominantly blue-winged teal, harvest from remaining areas is presumed to be primarily cinnamon teal.

DISCUSSION

Patterns of Harvest Distribution and Derivation—Over the last 50 years, Alaska produced 31% of the total Pacific Flyway dabbling duck harvest and Alberta produced 23%. Averaged over all species, 44% of the estimated Pacific Flyway dabbling duck harvest was derived from areas that contributed population data for the western mallard population AHM model during 2008−2016 (i.e., Alaska, Oregon, and California) and 10% was derived from areas added to the model in 2017 (British Columbia and Washington; U.S. Fish and Wildlife Service 2016). Of the remainder, 7% came from other production areas within the Pacific Flyway and 39% came from mid-continent sources (especially Alberta).

Over the last 50 years, mallards have comprised approximately 40% of the Pacific Flyway dabbling duck harvest; northern pintails, American green-winged teal, and American wigeons have collectively comprised half of the total dabbler harvest; and gadwalls, shovelers, cinnamon teal, blue-winged teal, and wood ducks have accounted for the remaining 10%. During this period, we found that mid-continent sources accounted for 35% of the total mallard harvest, with remaining states and provinces within the Pacific Flyway accounting for sizeable fractions of the total harvest (see also Munro and Kimball 1982, Giudice 2003). Because such a large component of the harvest was from mid-continent sources, we recom-

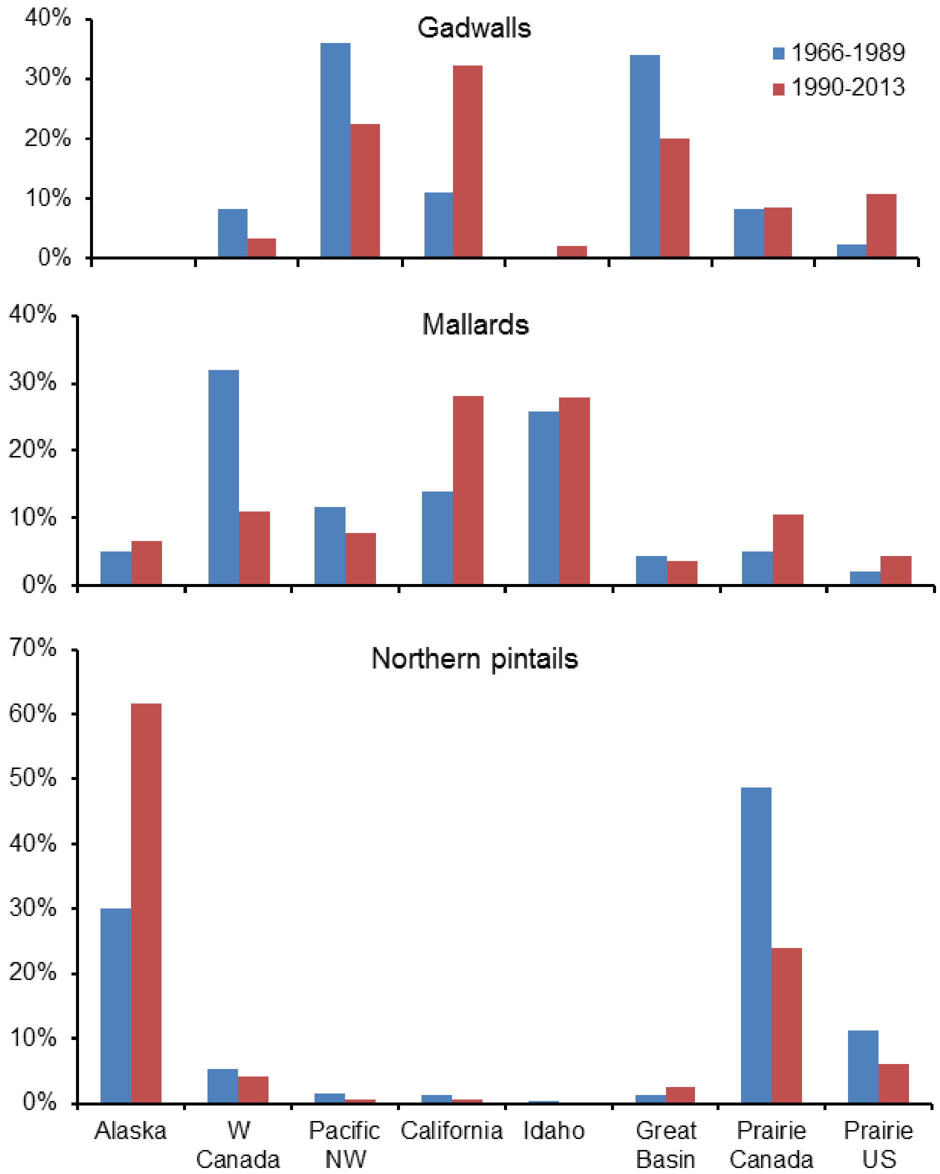

FIGURE 3.—Regional changes in harvest derivation for the Pacific Flyway between 1966-1989 and 1990-2013 (W Canada includes Yukon, Northwest Territories, and British Columbia; Pacific NW includes Washington and Oregon; Great Basin includes Nevada and Utah; Prairie Canada includes Alberta, Saskatchewan, and Manitoba; and Prairie US includes Montana, North Dakota, and South Dakota). Between intervals, average annual gadwall harvest increased by 44% (from 110 to 158 thousand), mallard harvest declined by 13% (1,138 vs. 988 thousand), and northern pintail harvest increased slightly (208 vs. 213 thousand).

mend that analysts attempting to estimate the size of the western mallard population using Lincoln estimators use harvest derivation as a correction factor (Alisauskas et al. 2014); our analysis suggests multiplying the Pacific Flyway total mallard harvest by 0.65 to remove mid-continent contributions. Although within-state production was an important part of the total mallard harvest in nearly all Pacific Flyway jurisdictions, migrant populations provided half or more of the total mallard harvest in Washington, Oregon, and Idaho. For all states except Alaska, greater than 60% of the harvest distribution for mallard populations occurred within the home state, and in California and Utah more than 90% of the total harvest was from the home state. For state waterfowl managers interested in maximizing harvest potential from migrant stocks, while concurrently sustaining breeding populations within their state, we recommend continuation of banding programs to monitor harvest rates of resident breeding mallards.

In addition to mallards, hunters within the Pacific Flyway also obtained large portions of the total gadwall, cinnamon teal, and wood duck harvest from production that occurred within the flyway, and often from within the home state or province. For example, Oregon, California, Nevada, and Utah all obtained half or more of their estimated gadwall harvests from within-state production, especially during the second half of our study period. Although many early studies explored the importance of local duck production in Pacific Flyway states (e.g. Williams and Marshall 1938, Harris 1954, Hunt and Naylor 1955, Steel et al. 1956), this seems to have been temporarily forgotten until the seminal paper by McLandress et al. (1996) examining recent mallard productivity in California rekindled interest in regional nesting studies (e.g., Gazda et al. 2002, Dugger et al. 2016, Ringelman et al. 2016).

Alaska was the most important production area for green-winged teal, wigeons, pintails, and shovelers, accounting for 40-60% of the total harvest for each species. Prairie Canada was the second most important production area for these four species, although Northwest Territories was more important for wigeons and Prairie U.S. was of equal importance for shovelers. Our analysis also identified small within-state contributions to harvest derivation for these species, and we were initially skeptical that these represented bandings of early migrants from northern production areas. However, historical nesting studies consistently identified small nesting populations of these species in lower 48 Pacific Flyway states (Williams and Marshall 1938, Harris 1954, Hunt and Naylor 1955, Steel et al. 1956).

Historically, the Canadian Prairies produced the majority of pintails harvested in the Pacific Flyway, but in recent decades pintail harvest has been derived predominantly from Alaska, presumably in response to long-term declines in pintail breeding productivity in the Canadian Prairies (Mattsson et al. 2012). There were too few banding data for green-winged teal and wigeons to examine whether similar shifts had occurred in their harvest derivations, but pintails are notable for demonstrating substantial population declines in the traditional prairie survey area even as most other species of dabbling ducks were increasing (Mattsson et al. 2012).

Data Limitations and Assumptions—The ability to reliably estimate direct recovery rates is the most limiting factor in any analysis of harvest distribution and derivation, and our analysis was hampered by availability of banding data for green-winged teal, American wigeons, northern shovelers, and cinnamon teal. Relative to their total population size, wigeons and shovelers had the fewest preseason bandings of any species, with each direct recovery recorded in the harvest representing >13,000 birds in the wild (by contrast, each direct mallard recovery represented ~200 birds in the breeding population). For wigeons, estimation of harvest derivation from Alaska, Yukon, and Northwest Territories over all Pacific Flyway states was based on fewer than 200 total band recoveries. In contrast, banding effort was extremely good for all species in Washington, Oregon, California, and Idaho.

The second key data requirement for analysis of harvest derivation is reliable data on population size from each production area. Although most states within the Pacific Flyway have their own dedicated waterfowl surveys (Olson 2014), the extent to which these surveys are comparable is unknown. Breeding Bird Surveys (BBS) are conducted using consistent methodology in all states and provinces of the U.S. and Canada, and although the BBS survey shows a general concordance with results from state and federal surveys, correction factors varied by more than two orders of magnitude among species and survey regions (Figure 2). We used estimates based on BBS routes, with a conservative visibility correction factor of 3.6, to impute population estimates for Idaho, which has no state survey, and for British Columbia, which has estimates for mallards and total ducks beginning in 2006. For Utah and Nevada, estimates from state waterfowl surveys were substantially lower than estimates derived from the BBS, even without visibility correction adjustments, and we therefore elected to use BBS-based estimates of population size for these two states. For Alaska and Yukon Territory, where the WBPHS covers only a small portion of the total area, abundance of widely distributed species like mallards and green-winged teal might be underestimated substantially. We believe there is much work that could be done to improve estimates of waterfowl population sizes throughout North America, including areas that have not traditionally been surveyed using dedicated waterfowl surveys, by combining data from multiple data streams including traditional BPOP surveys, BBS routes, and Lincoln estimators (Alisauskas et al. 2014, Zimmerman et al. 2015).

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Literature Cited

Alisauskas, R. T., T. W. Arnold, J. O. Leafloor, D. L. Otis, and J. S. Sedinger. 2014. Lincoln estimates of mallard (*Anas platyrhynchos*) abundance in North America. Ecology and Evolution: doi 10.1002/ece3.906.

Anderson, D. R., and C. J. Henny. 1972. Population ecology of the mallard I. A review of previous studies and the distribution and migration from breeding areas. U.S. Fish Wildlife Service Resource Publication 105. Washington, D. C.

Arnold, T. W., A. D. Afton, M. J. Anteau, D. N. Koons, and C. A. Nicolai. 2016. Temporal variation in survival and recovery rates of lesser scaup. Journal of Wildlife Management 80:850−861.

BOOMER, G. S., G.S. ZIMMERMAN, N. L ZIMPFER, P.R. GARRETTSON, M.D. KONEFF, T.A. SANDERS, K.D. MAGRUDER, AND J.A. ROYLE. 2013. Band reporting probabilities for mallards recovered in the United States and Canada. Journal of Wildlife Management 77:1059–1066.

CARNEY, S. M. 1992. Species, age and sex identification of ducks using wing plumage. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Washington, D.C.

DUGGER, B. D., J. M. COLLUCY, K. M. DUGGER, T. T. FOX, D. KRAGE, AND M. J. PETRIE. 2016. Population dynamics of mallards breeding in eastern Washington. Journal of Wildlife Management 80:500−509.

GARRETTSON, P. R., R. V. RAFTOVICH, J. E. HINES, AND G. S. ZIMMERMAN. 2014. Band reporting probabilities of mallards, American black ducks, and wood ducks in eastern North America. Journal of Wildlife Management 78:50−57.

GAZDA, R. J., R. R. MEIDINGER, I. J. BALL, AND J. W. CONNELLY. 2002. Relationships between Russian olive and duck nest success in southeastern Idaho. Wildlife Society Bulletin 30: 337−344.

GEIS A. D., R. I. SMITH, AND J. P. ROGERS. 1971. Black duck distributions, harvest characteristics, and survival. U.S. Fish and Wildlife Service Special Science Report—Wildlife 139, Washington, D.C.

GENDRON, M. H., AND A.C. SMITH. 2015. National Harvest Survey website. [Internet]. Bird Populations Monitoring, National Wildlife Research Centre, Canadian Wildlife Service, Ottawa, Ontario; [cited 20 August 2015]. Available from: http://www.ec.gc.ca/reom-mbs/enp-nhs/dis_e.cfm.

GIUDICE, J. H. 2003. Survival and recovery of mallards and gadwalls banded in eastern Washington, 1981-1998. Journal of Field Ornithology 74:1−11.

HARRIS, S. W. 1954. An ecological study of the waterfowl of the Potholes Area, Grant County, Washington. American Midland Naturalist 52:403−432.

HENNY, C. J., AND K. P. BURNHAM. 1976. A reward band study of mallards to estimate reporting rates. Journal of Wildlife Management 40:1−14.

HORVITZ, D. G., AND D. J. THOMPSON. 1952. A generalization of sampling without replacement from a finite universe. Journal of the American Statistical Association 47:663−685.

HUNT, E. G., AND A. E. NAYLOR. 1955. Nesting studies of ducks and coots in Honey Lake Valley. California Fish and Game 41:295−314.

KÉRY M, AND M. SCHAUB. 2012. Bayesian Population Analysis Using WinBUGS, A Hierarchical Perspective. First Edition, Academic Press, Elsevier, Massachusetts, USA.

KLIMSTRA, J. D., AND P. I. PADDING. 2012. Harvest distribution and derivation of Atlantic Flyway Canada geese. Journal of Fish and Wildlife Management 3:43−55.

MATTSSON, B. J., M. C. RUNGE, J. H. DEVRIES, G. S. BOOMER, J. M EADIE, D. A. HAUKOS, J. P. FLESKES, D. N KOONS, W. E. THOGMARTIN, AND R. G. CLARK. 2012. A modeling framework for integrated harvest and habitat management of North American waterfowl: Case-study of northern pintail metapopulation dynamics. Ecological Modelling 225:146−158.

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.

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

Olson, S. M. 2014. Pacific Flyway Data Book. U.S. Fish and Wildlife Service, Vancouver, WA.

Osnas, E. E., M. C. Runge, B. J. Mattsson, J. Austin, G. S. Boomer, R. G. Clark, P. Devers, J. M. Eadie, E. V. Lonsdorf, and B. G. Tavernia. 2014. Managing harvest and habitat as integrated components. Wildfowl Special Issue 4: 305–328.

Raftovich, R. V., and K. A. Wilkins. 2013. Migratory bird hunting activity and harvest during the 2011-12 and 2012-13 hunting seasons. U.S. Fish and Wildlife Service, Laurel, Maryland.

Ringelman, K. M., J. M. Eadie, J. T. Ackerman, A. Sih, D. L. Loughman, G. S. Yarris, S. L. Oldenburger, and M. R. Mclandress. 2017. Spatiotemporal patterns of duck nest density and predation risk: a multi-scale analysis of 18 years and more than 10,000 nests. Oikos 126:332–338.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, Results and Analysis 1966 - 2010. Version 12.07.2011. USGS Patuxent Wildlife Research Center, Laurel, Maryland.

Steel, P. E., P. D. Dalke, and Bizeau, E. G. 1956. Duck production at Gray's Lake, Idaho, 1949-1951. Journal of Wildlife Management 20:279–285.

Szymanski, M. L., and J. A. Dubovsky. 2013. Distribution and derivation of the Blue-winged Teal (Anas discors) harvest, 1970-2003. U.S. Department of Interior, Fish and Wildlife Service, Biological and Technical Publication FWS/BTP-R6017-2013, Washington, D.C.

U.S Fish and Wildlife Service. 1999. Adaptive Harvest Management: 1999 Hunting Season. U.S. Department of Interior, Washington, D.C.

U.S. Fish and Wildlife Service. 2015. Waterfowl population status, 2015. U.S. Department of the Interior, Washington, D.C.

U.S. Fish and Wildlife Service. 2016. Adaptive Harvest Management: 2017 Hunting Season. U.S. Department of Interior, Washington, D.C.

Williams, C. S., and W. H. Marshall. 1938. Duck nesting studies, Bear River Migratory Bird Refuge, Utah, 1937. Journal of Wildlife Management 2:29–48.

Yarris, G. S., M. R. Mclandress, and A. E. H. Perkins. 1994. Molt migration of postbreeding female mallards from Suisun Marsh, California. Condor 96:36–45.

Zimmerman, G. S., J. R. Sauer, K. Fleming, W. A. Link, and P. R. Garrettson. 2015. Combining waterfowl and Breeding Bird Survey data to estimate wood duck breeding population size in the Atlantic Flyway. Journal of Wildlife Management 79:1051–1061.

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APPENDIX 1.—Average annual breeding population estimates (thousands) for Pacific and Central Flyway source areas, 1990-2013, derived from state or federal waterfowl surveys (BPOP) or Breeding Bird Survey routes (BBS).

Region	Survey	AGWT	AMWI	NOPI	NOSH	BWTE	MALL	GADW	CITE	WODU
Pacific Flyway										
Alaska	BPOP	670	774	959	505	1	544	3	NA	NA
	BBS	57	157	42	26	1	66	1	1	0
Yukon	BPOP	15	73	29	15	0	15	0	NA	NA
	BBS	3	6	1	2	1	7	1	0	0
Brit. Columbia	BBS	6	10	1	2	6	97	4	3	3
Washington	BPOP	4	5	1	7	NA	57	14	6	2
	BBS	0	1	0	2	1	21	3	2	1
Oregon	BPOP	6	6	6	23	NA	92	51	36	5
	BBS	1	1	1	1	0	27	12	4	1
California	BPOP	4	5	11	33	NA	375	84	41	8
	BBS	0	1	6	12	0	154	60	19	7
Idaho	BBS	2	2	1	1	0	26	6	4	1
Nevada	BPOP	0	0	1	1	NA	3	7	6	0
	BBS	2	1	5	2	0	34	11	11	1
Utah	BPOP	0	0	1	4	NA	9	8	7	0
	BBS	3	4	5	2	0	26	18	11	0
Central Flyway										
NWT	BPOP	384	501	137	89	26	384	13	NA	NA
	BBS	38	64	17	13	8	39	6	0	0
Alberta	BPOP	682	399	326	654	754	1469	437	NA	NA
	BBS	26	41	54	93	125	470	87	5	0
Saskatch-ewan	BPOP	463	353	645	1055	1727	2281	887	NA	NA
	BBS	36	57	101	157	226	733	138	1	1
Manitoba	BPOP	160	109	57	149	389	736	113	NA	NA
	BBS	11	6	21	25	71	381	20	0	6
Montana	BPOP	28	78	108	117	131	311	171	NA	NA
	BBS	3	13	9	9	11	73	22	3	1
Wyoming	BBS	3	1	3	1	3	34	6	2	0
Colorado	BBS	3	1	1	1	2	41	8	3	0
North Dakota	BPOP	58	70	353	516	1458	1173	711	NA	NA
	BBS	5	8	40	42	111	272	91	0	3
South Dakota	BPOP	50	49	237	299	1346	824	439	NA	NA
	BBS	1	3	11	8	44	106	29	0	2

Appendix 2.—Region and species specific visibility correction factors, calculated as BPOP:BBS for regions with two concurrent surveys.

Region	AGWT	AMWI	NOPI	NOSH	BWTE	MALL	GADW	CITE	WODU	Region
Alaska	11.8	4.9	22.7	19.4	1.1	8.3	2.2			10.0
Yukon	4.3	11.8	20.4	8.6		2.1				6.7
Washington	13.3	6.5	11.0	3.9		2.7	4.9	2.9	1.6	5.9
Oregon	11.4	8.4	6.0	19.1		3.4	4.4	8.7	3.2	8.1
California	12.7	7.8	1.9	2.8		2.4	1.4	2.1	1.1	4.0
Nevada	0.1	0.7	0.1	0.3		0.1	0.6	0.5	0.1	0.3
Utah	0.1		0.2	1.6		0.4	0.4	0.6		0.4
NWT	10.0	7.8	7.9	6.9	3.1	9.8	2.0			6.8
Alberta	26.2	9.7	6.0	7.0	6.0	3.1	5.0			9.0
Saskatchewan	12.9	6.2	6.4	6.7	7.6	3.1	6.4			7.0
Manitoba	14.3	18.5	2.7	6.0	5.5	1.9	5.8			7.8
Montana	11.2	6.2	12.5	13.1	12.0	4.3	7.7			9.6
North Dakota	12.0	9.3	8.8	12.4	13.2	4.3	7.8			9.7
South Dakota	55.8	15.3	22.2	37.4	30.4	7.8	15.0			26.3
Spp. Avg.	14.0	8.1	9.2	10.4	8.8	3.8	4.6	3.0	1.2	7.8

APPENDIX 3.—Preseason bandings (B) and direct recoveries (R) of dabbling ducks from Pacific Flyway production areas, 1966-2013, all ages and sexes combined.

		Banding Areas:										
Species		AK	BC	WA	OR	CA	ID	NV,UT	NT,YK	AB,SK,MB	MT,ND,SD	Total
MALL	B	15,067	28,798	46,058	123,171	194,875	60,944	19,451	54,161	1,127,297	257,065	1,926,887
	R	838	1,796	4,516	11,548	18,698	4,593	2,256	599	12,036	1,187	58,067
NOPI	B	58,263	901	698	3,843	3,513	1,107	13,050	57,401	221,188	27,637	387,601
	R	1,902	17	22	154	119	40	342	709	2,962	199	6,466
AGWT	B	21,875	875	579	1,637	130	361	821	15,287	48,451	5,592	95,608
	R	811	28	34	90	11	12	19	80	266	38	1,389
AMWI	B	356	105	57	375	90	52	15	722	5,173	1,754	8,699
	R	73	24	8	78	12	5	2	109	308	49	668
GADW	B	26	296	546	24,958	12,073	241	2,753	8	18,560	9,686	69,147
	R	2	28	39	3,167	1,377	7	255	0	29	12	4,916
NOSH	B	889	41	69	3,098	349	39	423	122	1,951	3,957	10,938
	R	62	2	6	233	23	0	20	2	19	27	394
CITE	B	0	122	98	1,229	5,998	502	2,317	0	1,210	148	11,624
	R	0	0	1	10	229	9	31	0	2	0	282
BWTE	B	40	856	109	219	29	286	54	856	667,763	180,426	850,638
	R	0	8	0	6	0	1	0	0	60	8	83
WODU	B	0	815	2,424	6,540	10,431	5,457	265	0	1,904	11,734	39,570
	R	0	56	194	442	560	412	20	0	5	18	1,707
Total	B	95,516	32,809	50,638	165,070	227,488	68,989	39,149	128,557	2,093,497	497,999	3,400,712
	R	3,688	1,959	4,820	15,728	21,029	5,079	2,945	1,499	15,687	1,538	73,972

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Book Review

And then there were none: the demise of desert bighorn sheep in the Pusch Ridge Wilderness

Paul R. Krausman. 2017. University of New Mexico Press, Albuquerque, USA. 229 pages (hard cover). $65.00. ISBN 978-0-8263-5785-4

"... wilderness areas shall be devoted to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use."

— 88th Congress (Second Session), 1964
The Wilderness Act

"We can wring our hands and do nothing about the destructive policies that harm the wild big-game populations of the world, or we can figure out how to modify or work around benighted government policies ..."

— Ronald S. Gabriel, 2013
A Sheep Hunter's Diary

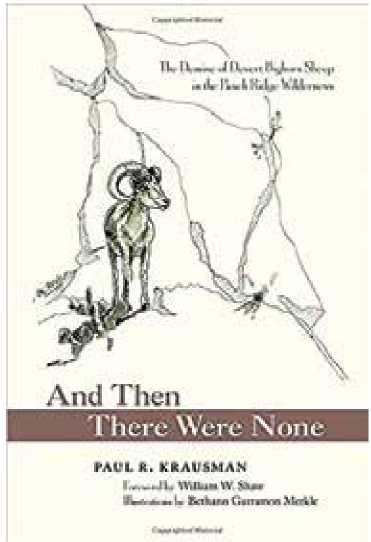
"Society's role in wildlife management and conservation is critical. It needs to be taken seriously; without such support, all other efforts by humans on wildlife's behalf will be of marginal value."

— Paul R. Krausman, 2017
And Then There Were None...

"This is no time for refusing to look facts in the face."

— Agatha Christie, 1939
And Then There Were None

Paul Krausman and his students have spent more than 40 years studying the population of desert bighorn sheep (*Ovis canadensis*) inhabiting the Santa Catalina Mountains, and specifically the Pusch Ridge Wilderness, in southern Arizona, USA. Paul is an authority on southwestern wildlife in general and on the ecology of desert bighorn sheep in particular. In this book, Krausman has compiled much of the history of the Catalina Mountains and the Pusch Ridge Wilderness—an area of ~230 km^2 established in 1978—located adjacent to and just north of the metropolis of Tucson. In the introduction, Paul details the early habitation by the Hohokam Indians, who disappeared from the area more than 500 years ago; early exploration of the area by expeditions led by Padre Kino; establishment of a game preserve in 1934; and a brief history of what is known about the numbers of bighorn sheep occupying the Santa Catalina Mountains.



Chapter 1 is dedicated to describing the Santa Catalina Mountains study area, and how land developers and others used the proximity of the Pusch Ridge wilderness as a marketing tool. Also included is a history of the Catalina State Park, and its transition to ownership by the U.S. Forest Service.

Chapter 2 consists mostly of a description of the life history characteristics and taxonomy of desert bighorn sheep, and is based largely on a review paper published earlier by Krausman and Bowyer (2003). A detailed description of the study area is included, but the basic material in this chapter is somewhat dated. Although useful to those not familiar with the biology of bighorn sheep, it would have been more complete if a greater amount of more current literature was referenced. Much of the material included in this chapter is based on results of research conducted by Krausman's students at the University of Arizona.

Krausman provides the details of what is known about the population of bighorn sheep inhabiting the Santa Catalina Mountains in Chapter 3. Therein he details the historical literature on the subject, observations reported by individuals as documentation that bighorn sheep persisted in the area, and population estimates based on records of USFS personnel from 1925 to 1954 and those based on ground and aerial surveys by Arizona Game and Fish Department personnel from 1955 to 1997, the year when the last official survey was conducted. There may have been a "sheep or two" remaining in the area and unconfirmed sightings continued until 2010, but the population was, by 1997, no longer viable.

"Human Intervention and Management" is the title of chapter 4, and in it Paul discusses the potential for "Urbanization, recreation, fire suppression, hunting, water shortages, predation, other ungulates, and disease…" as potential contributors to the demise of bighorn sheep in the Pusch Ridge Wilderness. Each of these factors are plausible explanations of the extirpation of those unique ungulates from an area in which they formerly occurred, and my friend and colleague dwells at length on urbanization, unbridled recreation (i.e., disturbance), and habitat fragmentation as primary factors in the extirpation of bighorn sheep from that federally protected area. He concludes that fire suppression was instrumental in eliminating bighorn habitat and, hence, played an important role in the demise of those native ruminants. Additionally, Paul provides a detailed description of bighorn sheep harvested from the Catalina Mountains, and states that, "It is possible… that along with urbanization and fire suppression, the hunting of bighorn sheep contributed to their demise… because of their small population size." Although unlikely and speculative, that possibility cannot be completely ignored. He goes on to dismiss an absence of water as an explanation, and concludes that abundance of forage was a problem because, "…it hinders visibility, more than because it is of low quality or in limited quantity." In summary, he concludes that there is no evidence that predation, limited water, disease, or the presence of other ungulates were factors contributing to the extirpation of bighorn sheep from the Pusch Ridge Wilderness. Instead, encroachment of Tucson and surrounding urban areas have not had positive influences on the population of bighorn sheep despite "protection" afforded by designation as wilderness. In the penultimate sentence of chapter 4, he concludes that there are "numerous, cumulative influences" that challenged the viability of bighorn sheep on Pusch Ridge.

In Chapter 5, Krausman describes in some detail the ongoing effort — now several years into implementation — to restore bighorn sheep to the Santa Catalina Mountains and the Pusch Ridge Wilderness, and the importance of public support for that and similar efforts. He provides a somewhat detailed review of translocation successes and failures, credits many non-governmental organizations for their advocacy and financial support of bighorn sheep conservation, and concludes that current efforts are now more efficient and effective than in the past. He then continues with a list of "Keys to Successful Translocations." Based on my experience overseeing dozens of capture or translocation projects over a period of >30 years, that section is a must read for all managers addressing the restoration of bighorn sheep to historically occupied range. Paul also goes on to emphasize that, "Wilderness areas and national parks are places where anthropogenic influences are minimal, but the wildlife in those places still has to be managed."

Krausman's research on bighorn sheep in the southwestern United States is nearly legendary in scope. This is especially true with respect to the contributions that he and his many students have made on behalf of understanding the decline and eventual extirpation of bighorn sheep from the Pusch Ridge Wilderness. From that perspective, this is a work that every wilderness advocate and political operative, as well as politicians themselves, must read. Indeed, the road to Hell is filled with good intentions and, in this case, bighorn sheep were the losers despite good intentions. Protecting an island of bighorn sheep habitat that advocates thought would ensure natural processes occur in perpetuity clearly was not an adequate strategy in the absence of active management on behalf of that iconic species.

Krausman concludes the book with several appendices, one of which is comprised of Section 1 and Section 2(a), (b), and (c) of the Wilderness Act; it is noteworthy that Section (c) emphasizes that wilderness areas must be of sufficient size as to make practicable its preservation and use in an unimpaired condition, and that such areas "may also contain *ecological* [emphasis added], geological, or other features of scientific, educational, scenic, or historical value" (US Congress 1964). Clearly, designation of the Pusch Ridge Wilderness was a futile effort to preserve the ecological integrity of that area, in large part because most such areas have been established with little, if any, ecological forethought and its implications for wildlife conservation (Bleich 2014, 2016).

Two additional appendices are included. Appendix 2 addresses the agreement between the University of Arizona and a corporate land developer that resulted in funding for the research conducted by Krausman and his students. The third includes a summary of important components of an adaptive mountain lion management plan that was a precursor to the ongoing efforts to reestablish bighorn sheep in the Pusch Ridge Wilderness. That plan was a critically important component of the restoration effort and was supported by stakeholders despite the many differing opinions regarding the management and conservation of Puma concolor.

This book is not the best-edited piece that Paul has produced in his career, but part of that shortcoming might lie with the copy editors. There are numerous misspellings and minor editorial inconsistencies, particularly early in the book (e.g., areas are referred to as refugium, not refugia; gallapova, not gallipavo, for the specific epithet of the wild turkey; infraorbital formen instead of infraorbital foramen; the use of a singular reference [that] to refer to a plural term [anatomy and physiology]; wildlife mammals instead of wild mammals; the occasional misspelling of names (Akeson instead of Akenson); and mistaken dates of publication [Jones 1959 instead of Jones 1949], etc. My intent is not to diminish the value of Krausman's contribution but, rather, to encourage refinement if there is a second edition. Additionally, the book likely would be more useful to individuals not familiar with the ecology of bighorn sheep if the literature had been updated a bit and was more current.

Despite these minor flaws, Paul Krausman has produced a volume providing a history of what is known about the demise of bighorn sheep in a federally protected wilderness area, an extirpation that occurred despite the good intentions of that designation. Moreover, he provides the reader with suggestions regarding the importance of intervening on behalf of wildlife conservation to maintain the ecological integrity of such areas. I can only hope that the well-planned and widely supported efforts to restore bighorn sheep in the Santa Catalina Mountains will be successful. If that is the case it will be, at least in part, a result of the efforts of Krausman and his students over the past four decades.

—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.

Literature Cited

Bleich, V. C. 2014. Thoughts on the Wilderness Act. Wildlife Professional 8(4):7.

Bleich, V. C. 2016. Wildlife conservation and wilderness: wishful thinking? Natural Areas Journal 36:202–206.

Krausman, P. R., and R. T. Bowyer. 2003. Mountain sheep (Ovis canadensis and O. dalli). Pages 1095-1118 in G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. Second edition. Johns Hopkins University Press, Baltimore, Maryland, USA.

US Congress. 1964. Wilderness Act. Public law 88–577, 88th Congress of the United States, second session. Washington, D.C.

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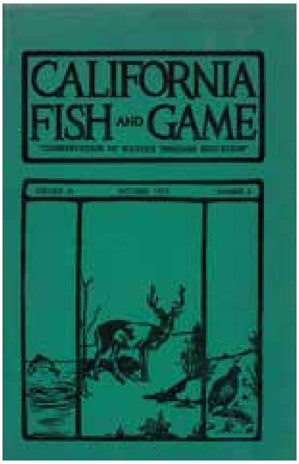
Nesting studies of ducks and coots in Honey Lake Valley



E.G. Hunt and A.E. Naylor

Introduction

During the spring of 1951 and 1953 studies were made to determine the status of nesting ducks and coots in Honey Lake Valley, Lassen County, California.

The main objectives of the studies were to obtain information on nesting populations, nesting density, preferred nesting habitat, nesting success, and the production derived from successful nesting. The 1951 study was the first survey made on nesting ducks and coots in the valley. The 1953 study determined what changes had occurred in nesting activities and also supplied data additional to those obtained in 1951.

Sample areas were established and utilized during each study, and nest histories were completed on all nests found in these areas.

The results obtained in both years were similar in most cases. The most apparent difference was a shift in the bulk of nesting from dry upland areas in 1951 to marshy areas in 1953. The average nesting success for both years was approximately 50 percent for ducks and 96 percent for coots.

Brood data showed a slight reduction in the brood size of ducks and an extensive reduction in the brood size of coots during the first week of life.

Acknowledgements

The authors wish to thank several individuals for their help. John R. LeDonne assisted with the collection of data in 1951 and Robert Kirkpatrick and Charles Victor Oglesby assisted in 1953. Thanks are extended to the following members of the Department of Fish and Game: M. E. Foster, Refuge Manager of Honey Lake Waterfowl Management area; Cliffa E. Corson, who prepared the map and graph; and A. W. Miller, who assisted with the preparation of the manuscript.

Locale of the Studies

The study areas were located in Honey Lake Valley in southeastern Lassen County (Figure 1). Most of the preferred waterfowl nesting habitat in this valley was in an area along the lower reaches of the Susan River, from the mouth of Willow Creek to the river's entrance into Honey Lake. During the west cycles, when Honey Lake is filled to capacity or near capacity, suitable nesting habitat is available from the mouth of the Susan River west along the lakeshore for approximately five miles. A further description of waterfowl

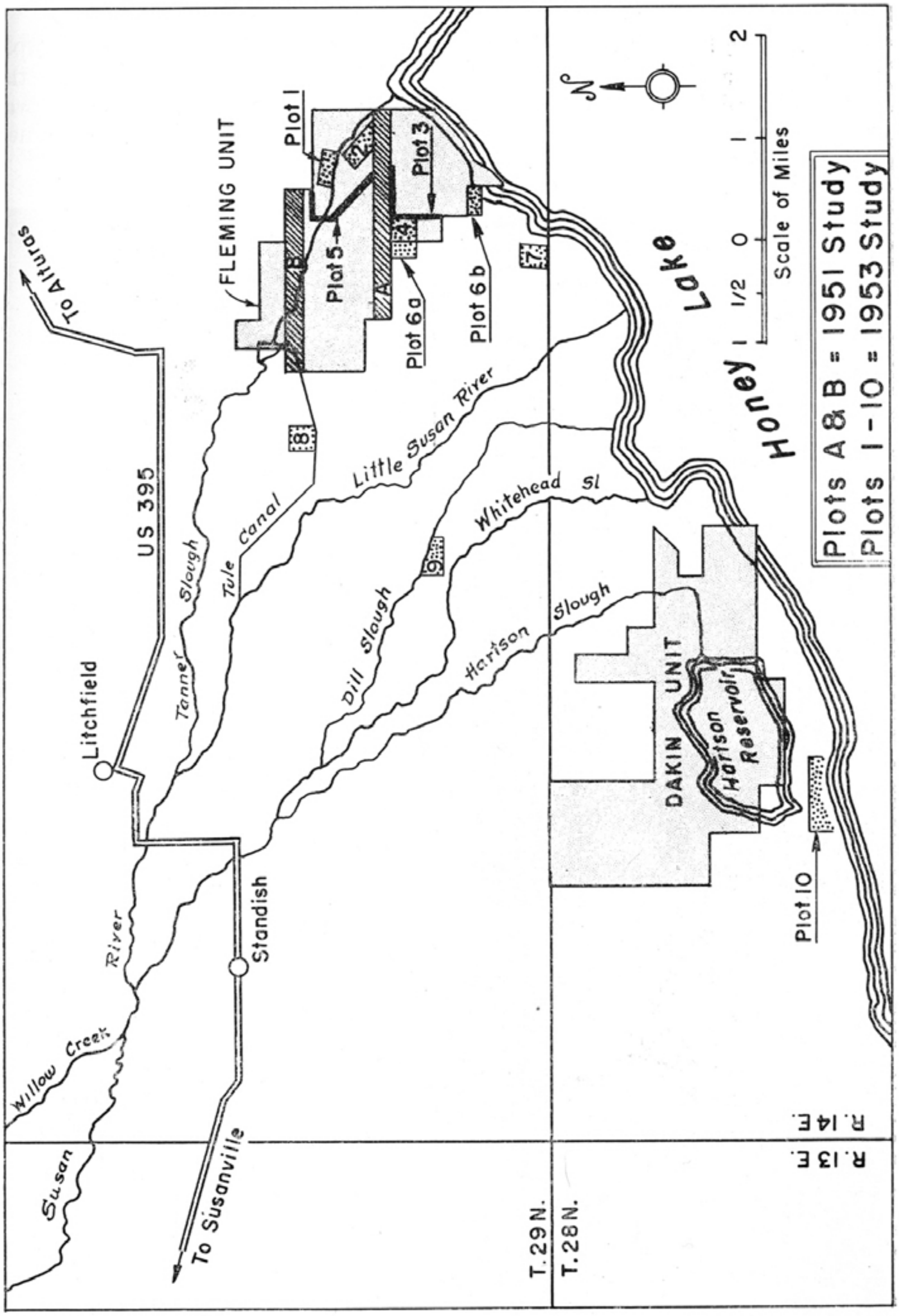


FIGURE 1.—Map of study areas in Honey Lake Valley.

nesting area in the valley has been published previously (Naylor, 1953; Naylor and Hunt, 1954).

Approximately 80 percent of the nesting population of ducks and coots in the Honey Lake Valley was found along the Susan River and its diversions from Litchfield to Honey Lake. It was in this area that the studies were located.

The 1951 study was conducted by Naylor on the Fleming unit of the state-owned Honey Lake Waterfowl Management area. The second study was conducted by Hunt in 1953 on the Fleming unit and on privately owned land.

History

The water level of Honey Lake throughout the years has been characterized by fluctuation, determined mainly by west and dry climate cycles. The lake has contained water several years after filling, but at times reverts to a dry alkaline lakebed. When full the lake covers approximately 100 square miles and has an average depth of 18 inches.

The main source of water for Honey Lake is the Susan River drainage. The water in this drainage is either stored for domestic use and irrigation or allowed to flow into the lake. The amount of water that eventually enters the lake is determined by the amount of spring runoff and the demand on the water supply. Only during the years of extremely large spring runoff does an appreciable amount of water enter Honey Lake. Some water enters the lake from Long Valley Creek and several other small streams, but the volume is small and is not considered an important source for Honey Lake.

Honey Lake filled during 1937 and then gradually receded until it became dry in the late 1940s. Above-normal winter rains and snowfall combined to fill the lake partially during the winter of 1950-51. Water was abundant in the vicinity of the lake until spring (May, 1951), at which time the water level of the lake receded rapidly until fall, when little or no water remained. The abundant spring water supply enabled dormant emergent vegetation to attain some growth before the water level dropped in the fall. However, with the continuation of heavy winter precipitation during the winters of 1951-52 and 1952-53, the emergent vegetation became abundant. In 1953 growth was considered to have reached a maximum. Vegetative growth along the lakeshore, excluding the large area at the mouth of the Susan River, was not appreciably increased during 1952 and 1953, when water was abundant. In general, dryer conditions prevailed during the nesting season of 1951 than was the case in 1953. In 1953 the vegetation had become rank and ideal for nesting in the area at the mouth of the Susan River.

Land use practices in Honey Lake Valley have remained relatively stable during the last few years. The chief agricultural activities are concerned with pasturing livestock and raising cereal crops.

Methods

Because of the large size of the study area, plots were used to sample the nesting activities. The methods used in locating and marking the nests different slightly in the two studies. None of the differences was of great significance, and methods utilized in both studies obtained satisfactory results.

Each plot was visited at least every 10 days. A rope was dragged several times on plots to flush the nesting birds when the nature of the vegetation made this practice possible. As each nest was found it was assigned a number and marked by placing a willow marker several feet from the nest to facilitate location on return visits. The marker was aligned with the nest and a fixed object, a mountain peak easily seen from any spot on all study plots. The distance between the marker and nest varied from three feet in very dense cover to 15 feet in sparse cover. The markers were placed away from the nest to reduce the chance of predators being attracted to the nest. The top of each willow marker was cut on an angle, and the number assigned to the nest was written on the cut surface. In the 1953 study a white specimen tag was tied to the top of each willow marker that was placed in dense cover and to some markers that were placed in sparse cover. The flashing of this white tag facilitated the finding of nests in all types and colors of vegetation. It was found that little or no increase in the amount of predation occurred in areas where the white tags were used.

At each visit to a nest all necessary information was recorded on a nest card. A nest card was assigned to each nest, and all data gathered during subsequent visits to the nest were recorded on the same card (Figure 2).

Table 1 gives the species composition of the nests found during both studies.

An attempt was made to find as many of the nests as possible, but on the densely vegetated plots all could not be found. In 1951 it was estimated that the percentage of nests found in relation to the actual number on each plot ranged from approximately 60 percent in the densely covered plots to 100 percent in some of the sparsely vegetated plots. In 1953 an estimated 75 percent of the nests in the densely covered plots were found and 100 percent of those in some of the sparsely vegetated plots.

The scientific names of all birds, mammals, and plants referred to in this study are given in Appendix A.

Selection of study plots

Because most of the nesting in Honey Lake Valley in 1951 was confined to the Fleming Unit of the Honey Lake Waterfowl Management Area, the 1951 study was made on this unit. In 1953 nesting activity was more widespread, and the study was conducted on both the Fleming Unit and private land. Data on the number of breeding pairs of ducks and coots are given in Table 2.

Two strip plots were used in 1951. These plots included all covered types present on the area. The combined area of the two strip plots was approximately 300 acres, or 15 percent of the total area of the Fleming unit.

In 1953 11 study plots were established to sample nesting on approximately 20,000 acres. They contained 328 acres, or approximately 1.6 percent of the total acreage in the study area.

Description of the 1951 study

Practically all the open water and marsh area in northeastern Honey Lake Valley existed on the Fleming Unit of the Honey Lake Waterfowl Management Area. Water was

FIGURE 2.—Field recording of nest history data on a unisort analysis card.

TABLE 1.—Species composition of nests found.

Species	Total nests		Percentage of total	
	1951	1953	1951	1953
Mallard	63	143	31.2	39.8
Pintail	45	53	22.3	14.8
Cinnamon teal	22	125	10.9	34.8
Gadwall	18	13	8.9	3.6
Shoveller	17	7	8.4	2.0
Baldpate	--	1	0.0	0.3
Ruddy duck	--	6	0.0	1.7
Redhead	3	11	1.5	3.0
Unclassified	2	--	1.0	0.0
Unclassified, destroyed when found	15	--	7.4	0.0
Unclassified, hatched when found	17	--	8.4	0.0
Total ducks	202	359	100.0	100.0
Coot	20	143	9.0	28.0

TABLE 2.—Breeding pairs of ducks and coots in Honey Lake Valley 1951-1953.

Species	1951†	1952	1953
Mallard	734	1,214	1,010
Pintail	364	201	220
Cinnamon teal	266	262	283
Gadwall	668	714	294
Shoveller	173	110	68
Redhead	323	129	212
Scaup	5	1	8
Ruddy duck	40	28	10
Other	6	18	3
Total ducks	2,579	2,677	2,108
Coot	126	398	620

impounded in artificial ponds during the nesting season and early summer. As a result of the availability of this water and marsh area, most of the waterfowl nesting in the valley was believed to have been confined to the Waterfowl Management Area.

The information gathered during the 1951 study was compiled from nests found on the two strip plots located on the Fleming Unit which were representative of the cover types found on the unit. Plot A contained the following cover types: pasture grasses, volunteer barley, cultivated wheat, five-hooked bassia, ryegrass, Baltic rush, hardstem bulrush and others. Plot B contained five-hooked bassia, ryegrass, Baltic rush, hardstem bulrush, sagebrush, greasewood, and other cover types.

Description of the 1953 study plots

Eleven study plots were established in nine different cover types representing the general cover types used most extensively by nesting waterfowl in the Honey Lake Valley in 1953. Seven plots of 40 acres each, two plots of 20 acres each, and two plots one mile long by 30 feet wide were used. The two one-mile plots were along a ditchbank and a levee and were both approximately four acres in area. In order to sample 40 acres of cover growing on ditchbanks and levies it would have taken 10 miles of ditchbank and levee, a factor not feasible in that study. The two 20-acre plots were of Baltic rush cover type. The seven 40-acre plots were established to include samples of the following major cover types: hardstem bulrush, river bulrush, sagebrush and greasewood, five-hooked bassia, rye grass, salt grass, cereal crops, and other cover types.

Nest Sites and Cover Types

In compiling data on both studies, two broad headings were used in describing the locations of waterfowl nests. These headings or classifications were nest sites and cover types. The nest site classification described the physical characteristics of the terrain where the nest was located; e.g., in a marsh, on an island, or on a dike. The most abundant species of vegetation in the immediate vicinity of the nest was used to designate the cover type found at each site. As an example of cover type and nest site relationship, most of the duck nests found in 1953 were constructed in marsh nest sites and the dominant cover type around the nests was Baltic rush.

A description of the different nest sites used during the studies follows:

Dike or Ditchbank.—Elevated margins of any slough, creek, river, irrigation ditch, or dam embankment were classified as dike nest sites.

Marsh.—Areas such as lakeshores, artificial ponds, and all semiwet land were recorded as marsh-type sites.

Island.—Any sizable piece of land completely surrounded by water was considered to be an island nest site.

Agricultural Land.—All land used for agricultural purposes was listed as agricultural nest sites. During both studies most of the agricultural land was either in irrigated pasture or in cereal crops.

Uncultivated Land.—Dry upland-type areas not under cultivation were classified as uncultivated land nest sites.

A difference was shown in the location of nest sites by ducks in 1951 and 1953. In 1951 nests were located primarily in dry upland areas. Dikes and uncultivated fields were the most common nest sites used by ducks that year. Results of the 1953 study showed an over-all change of location to the marsh type site. The change was attributed to the increased proportion of marsh nest sites available to the nesting waterfowl. The marsh nest sites contained 14.7 percent of all duck nests found in 1951 and 67.4 percent of all duck nests found in 1953. All coot nests found in 1951 and 98.6 percent of the coot nests found during the 1953 study were located in marsh nest sites. Location of nest sites by species is shown in Table 3.

TABLE 3.—Nest sites (percentage in each site).

Species	Dike	Island	Marsh	Uncultivated	Agricultural	Total
Mallard						
1951	39.7	1.6	23.8	19.0	15.9	100.0
1953	18.9	0.0	62.9	15.4	2.8	100.0
Pintail						
1951	26.7	4.4	4.4	22.2	42.3	100.0
1953	22.6	0.0	37.7	34.0	5.7	100.0
Cinnamon teal						
1951	59.0	9.2	9.2	18.1	4.5	100.0
1953	1.6	0.0	89.6	8.0	0.8	100.0
Gadwall						
1951	44.4	0.0	0.0	27.8	27.8	100.0
1953	7.7	0.0	23.1	69.2	0.0	100.0
Shoveller						
1951	29.4	0.0	17.7	23.5	29.4	100.0
1953	0.0	0.0	0.0	85.7	14.3	100.0
Baldpate						
1951	0.0	0.0	0.0	0.0	0.0	0.0
1953	0.0	0.0	0.0	100.0	0.0	100.0
Ruddy duck						
1951	0.0	0.0	0.0	0.0	0.0	0.0
1953	0.0	0.0	100.0	0.0	0.0	100.0
Redhead						
1951	0.0	0.0	100.0	0.0	0.0	100.0
1953	0.0	0.0	100.0	0.0	0.0	100.0
Unclassified						
1951	50.0	0.0	0.0	0.0	50.0	100.0
Average for ducks						
1951	37.7	2.9	14.7	20.6	24.1	100.0
1953	11.7	0.0	67.4	18.4	2.5	100.0
Coot						
1951	0.0	0.0	100.0	0.0	0.0	100.0
1953	0.7	0.0	98.6	0.7	0.0	100.0

The change in nest sites between 1951 and 1953 was accompanied by the change in cover types. The cover utilized most often by nesting ducks in 1951 was rye grass, five-hooked bassia and salt grass. These three plant species provided cover for 60.6 percent of all duck nests found that year. In 1953, 59.7 percent of all duck nests found were in Baltic rush. Emergent plants were the preferred cover types utilized by coots during both studies. During 1951, 95 percent of the coot nests found were in hardstem bulrush. Baltic rush, river bulrush, and hardstem bulrush provided cover for 98.6 percent of the coot nests found in 1953. The utilization of the different cover types during both studies is presented in Table 4.

TABLE 4.—Cover types utilized (percentage in each type).

Cover type	Mallard	Pintail	Cinnamon teal	Gadwall	Shoveller	Baldpate	Ruddy duck	Redhead	Unclassified	Average ducks	Coots
Baltic rush											
1951	7.8	6.6	9.0	5.6	29.4	0.0	0.0	66.7	0.0	10.6	0.0
1953	35.7	51.0	96.0	69.2	57.1	0.0	16.6	18.2	0.0	59.7	42.0
Hardstem bulrush											
1951	22.2	8.9	0.0	0.0	0.0	0.0	0.0	33.3	0.0	11.2	95.0
1953	31.4	7.5	0.8	0.0	0.0	0.0	83.4	72.7	0.0	17.6	23.8
River bulrush											
1951	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1953	1.4	1.9	0.0	0.0	0.0	0.0	0.0	9.1	0.0	1.1	32.8
Sagebrush-rye grass											
1951	7.8	4.4	4.5	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0
1953	8.4	13.2	0.8	23.1	14.3	100.0	0.0	0.0	0.0	6.9	0.0
Bassia											
1951	25.5	17.8	4.5	22.2	5.9	0.0	0.0	0.0	50.0	18.2	0.0
1953	7.7	11.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0
Rye grass											
1951	23.8	33.3	55.0	38.8	23.5	0.0	0.0	0.0	0.0	31.2	0.0
1953	7.7	5.7	0.0	7.7	0.0	0.0	0.0	0.0	0.0	4.2	0.0
Salt grass											
1951	3.3	13.4	18.0	5.6	29.4	0.0	0.0	0.0	50.0	11.2	0.0
1953	2.8	0.0	1.6	0.0	28.6	0.0	0.0	0.0	0.0	2.2	0.0
Cereal crops											
1951	4.8	15.6	0.0	11.2	11.8	0.0	0.0	0.0	0.0	8.2	0.0
1953	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Other											
1951	4.8	0.0	9.0	16.6	0.0	0.0	0.0	0.0	0.0	4.7	5.0
1953	4.2	9.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	3.3	1.4
Total											
1951	100.0	100.0	100.0	100.0	100.0	0.0	0.0	100.0	100.0	100.0	100.0
1953	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	100.0	100.0

In order to get the overall trend of the preferred nesting sites and cover types, information from these two classifications was combined in Table 5.

TABLE 5.—Nest site—cover type relationships.

Nest Site—Cover Type Relationships

	Nest site *		Cover type	
Species	1951	1953	1951	1953
Mallard	General	General	Bassia Rye grass Hardstem bulrush	Baltic rush Hardstem bulrush
Pintail	General	General	Rye grass Bassia	Baltic rush
Cinnamon teal	General	Marsh	Rye grass	Baltic rush
Gadwall	Dike	Unculti-vated	Rye grass Bassia	Baltic rush
Shoveller	Dike	Unculti-vated	Salt grass Baltic rush	Baltic rush Grasses
Baldpate	--	Unculti-vated	--	Sagebrush-grease-wood
Ruddy duck	--	Marsh	--	Hardstem bulrush
Redhead	Marsh	Marsh	Baltic rush Hardstem bulrush	Hardstem bulrush
Average duck	Dike	Marsh	Rye grass Hardstem bulrush Bassia	Baltic rush Hardstem bulrush
Coot	Marsh	Marsh	Hardstem bulrush	Baltic rush River bulrush Hardstem bulrush

* Where the term "general" is used, there was no definite preference for a nest site, and nesting occurred in the nest sites with about the same frequency.

NESTING PERIODS

The springs of 1951 and 1953 were considered favorable for nesting waterfowl in Honey Lake Valley. Although a change in location of nest sites and cover types was found in the two studies, the nesting periods and hatching dates were quite similar. The first nest found in 1951 was on 19 April; in 1953 the first nest was found on 22 April. The last nest history in 1951 was completed on 25 July and in 1953 on 17 July. Nesting continued in the valley after these dates during both years, but it is believed that the number of nests hatched after 25 July was nominal and had little or no effect on the peak of hatch.

Nesting periods similar to those shown above were recorded at the Tule Lake and Lower Klamath National Wildlife Refuges in Siskiyou County (Miller and Collins, 1954).

Information concerning peak of hatch for both ducks and coots is illustrated (Figure 3).

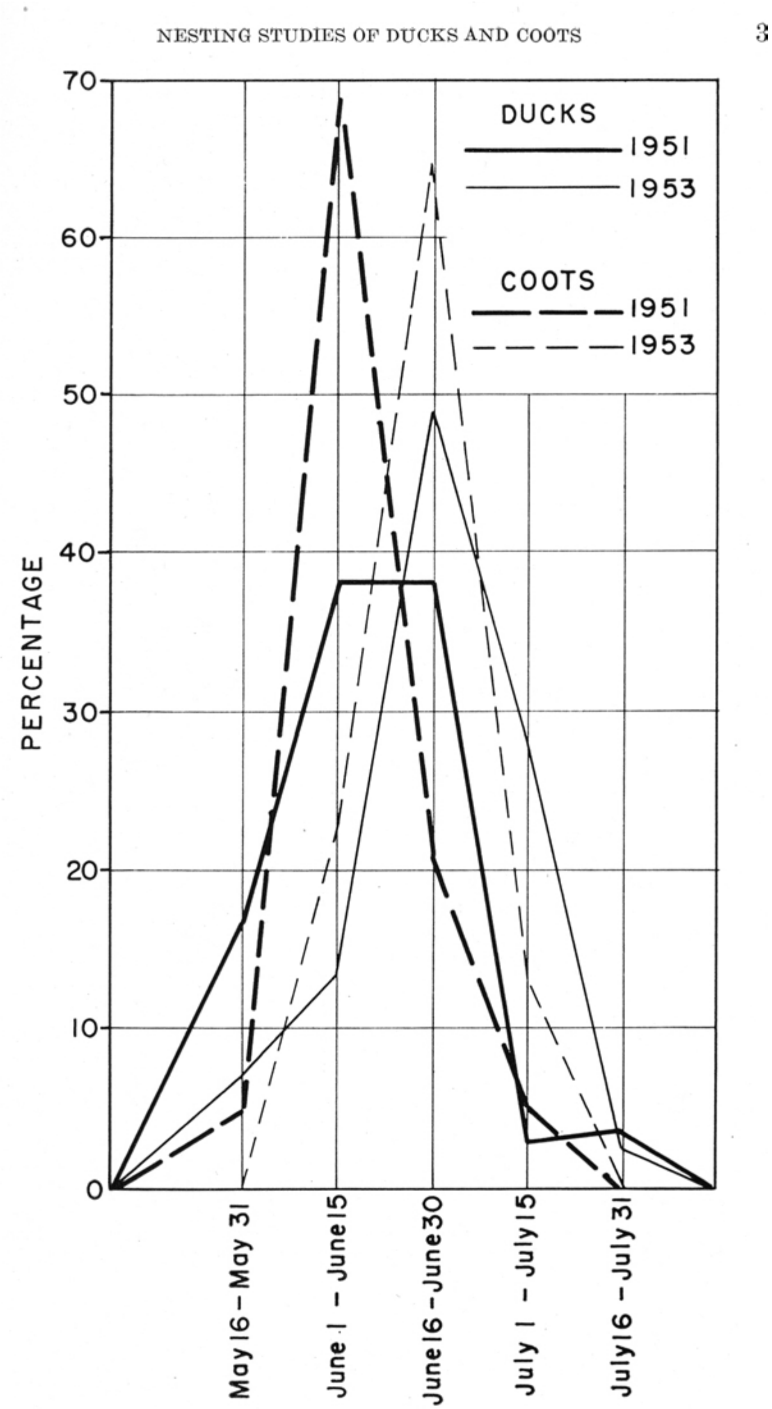


FIGURE 3.—Hatching periods and peak of hatch for duck and coot nests in Honey Lake Valley.

Fate of Nests

The categories used in classifying fates of nests were the same as those used in several other nesting studies in Caifornia. The fate of nest classification used was as follows: (1) hatched nests, (2) deserted nests, (3) flooded nests, (4) destroyed nests and (5) fate unknown nests. A definition of these categories has been published by Miller and Collins (1953). Table 6 shows the fate of all nets found during the studies.

Table 6.—Fate of nests.*

Species	Number of nests	Percentage nests hatched	Percentage nests destroyed	Percentage nests deserted	Percentage nests flooded	Total
Mallard						
1951	63	60.4	28.5	7.9	3.2	100.0
1953	143	47.6	36.4	14.0	2.0	100.0
Pintail						
1951	45	33.3	57.8	4.5	4.4	100.0
1953	53	45.3	45.3	9.4	0.0	100.0
Cinnamon teal						
1951	22	54.6	13.6	31.8	0.0	100.0
1953	125	56.0	28.8	13.6	1.6	100.0
Gadwall						
1951	18	66.7	22.1	5.6	5.6	100.0
1953	13	38.5	46.1	15.4	0.0	100.0
Shoveller						
1951	17	58.8	41.2	0.0	0.0	100.0
1953	7	28.6	42.8	28.6	0.0	100.0
Ruddy duck						
1951	--	0.0	0.0	0.0	0.0	0.0
1953	6	66.7	0.0	33.3	0.0	100.0
Redhead						
1951	3	33.3	66.7	0.0	0.0	100.0
1953	11	54.5	9.1	36.4	0.0	100.0
Total ducks						
1951	168	52.5	35.0	9.5	3.0	100.0
1953	359	50.1	34.3	14.2	1.4	100.
Coot						
1951	20	95.0	5.0	0.0	0.0	100.0
1953	143	97.2	2.1	0.7	0.0	100.0

* 34 nests not shown from the 1951 study were: 2 unclassified, 15 destroyed when found, 17 hatched when found. One nest not shown from the 1953 study was a baldpate nest that was destroyed.

Successful Nests

The average nesting success for the duck nests found on study plots during both years was similar. In 1951, 52.5 percent of the duck nests hatched, while in 1953 success rate dropped slightly, with a hatch of 50.1 percent.

The overall hatching success of dabbling ducks was lower in 1953 than in 1951. The pintail was the only dabbling duck that showed any appreciable gain in nesting success in 1953. The rate of success found in cinnamon teal nesting was relatively constant during both studies. In 1951 gadwall, mallard, and shoveler were the most successful nesters of the dabbling ducks, with success rates of 66.7, 60.4, and 58.8 percent, respectively. In 1953 the three species of dabbling ducks that were the most successful nesters were the cinnamon teal, mallard, and pintail. The success rates for these species were 56.0, 47.6, and 45.3 percent, respectively. The success rates of the nests of diving ducks found during the studies were 33.3 percent for redheads in 1951 and 54.5 percent in 1953. The hatching success of ruddy duck nests was 66.7 percent in 1953. No ruddy duck nests were found in 1951.

All recent duck and coot nesting surveys in northeastern California have indicated that the coot is the most successful nester with respect to hatching success and hatchability of eggs. The success rate for coots at Honey Lake was 95.0 percent in 1951 and 97.2 percent in 1953. The success rate for coots at the Tule Lake and Lower Klamath National Wildlife refuges was 94.6 percent in 1952 (Miller and Collins, 1954).

Unsuccessful Nests

Destruction.—Predation on nets of both ducks and coots was the greatest single cause of nesting failures during both studies. The amount of destruction attributed to predation was relatively constant during both studies. Of all the duck nests that were found, 35.0 percent were destroyed in 1951, while 34.3 percent were destroyed in 1953. The amount of predation on coot nests was light, with 5.0 percent of the nests destroyed in 1951 and 2.1 percent destroyed in 1953.

The cause of nest destruction was difficult to determine in many cases. The lack of sufficient evidence to establish definitely the cause of predation was responsible for the large number of nests attributed to destruction by unknown causes (Table 7). If there was any doubt as to the identity of the predator a nest was listed as destroyed by unknown causes. Mammalian predators known to occur in the area were the striped skunk, coyote, house cat, badger, bobcat, and weasel; the avian species which prey on nets were the California and ring-billed gulls, the black-billed magpie, the crow, and the raven. An instance of nest destruction by unnatural causes occurred during 1951, when five nests were destroyed by land-leveling operations.

Preseason trapping of predators by a State trapper on the Honey Lake Waterfowl Management Area resulted in the capture of 23 striped skunks, 4 coyotes, 9 house cats, and 2 bobcats in 1951 and 31 striped skunks, 1 coyote, and 5 house cats in 1953.

Desertion.—The amount of desertion found in duck nests was 9.5 percent in 1951 and 14.2 percent in 1953. This higher rate of desertion was the greatest difference found in comparing the results of the fate of nests in the two studies.

TABLE 7.—Percentage of destroyed duck nests found in each nest site.

	Dike	Island	Marsh	Uncultivated land	Agricultural land	Total
Destroyed by mammal						
1951	64.0	0.0	33.3	85.7	38.9	55.4
1953	25.7	0.0	40.0	45.3	16.7	36.6
Destroyed by bird						
1951	12.0	0.0	50.0	0.0	5.5	12.5
1953	20.0	0.0	27.5	11.9	16.7	19.5
Destroyed by unknown causes						
1951	24.0	0.0	16.7	14.3	27.8	23.2
1953	54.3	0.0	32.5	42.8	66.6	43.9
Destroyed by unnatural causes						
1951	0.0	0.0	0.0	0.0	27.8	8.9
1953	0.0	0.0	0.0	0.0	0.0	0.0
Total						
1951	100.0	0.0	100.0	100.0	100.0	100.0
1953	100.0	0.0	100.0	100.0	100.0	100.0

One coot nest was destroyed in 1951 and three coot nests were destroyed in 1953 in marsh nest sites and are not shown in the table.

Competition for preferred nest sites among the ducks probably accounted for some desertion. However, data concerning desertion due to competition for preferred nest sites were inconsistent, and no definite statement can be made on this subject.

Parasitism occurred in 2.7 percent of the total duck nests found in 1951 and in 6.2 percent of the total duck nests found in 1953. Any nest containing eggs laid by two species of ducks or a duck and pheasant was considered parasitized (Figure 4). There were no instances of a duck nest being parasitized by another species of duck during the 1951 study. In 1953, 13 (42 percent) of the duck nests parasitized contained eggs laid by anther species of duck. Parasitism of duck nests by pheasants occurred in all five of the parasitized nest found in 1951 and in 18 (58 percent) of the duck nests parasitized in 1953. Some desertion resulting directly from parasitism in duck nests probably occurred, but data gathered during both studies showed that parasitism was not an important cause of desertion. No instance of parasitism was found in coot nests during either study.

Only one coot nest was recorded as deserted during the 1953 study, and none was deserted during the 1951 study. It was believed that overcrowding in preferred nest sites and parasitism that may exist in duck nests were not factors that affected coot nesting. The pugnacity with which the coot defends a nesting territory might be a reason for such a low desertion rate.

Flooding.—The flooding of nests was of minor significance in the success of duck and coot nesting. Five duck nests were found flooded during each of the studies. No instance of a coot nest being flooded was recorded. Stable or receding water levels during the nest season accounted for the low incidence of flooded nests.

FIGURE 4.—Mallard duck nest parasitized by a pheasant. The six pheasant eggs show darker and smaller than the five duck eggs.

Fate of Eggs and Clutch Size of Successful Nests

The information collected from successful nests was used to determine the average clutch and fate of eggs. The average clutch size of both ducks and coots was found to be slighty lower in 1953 than in 1951 (Table 8).

Table 8.—Clutch size and average hatch per clutch.

Species	Successful nests	Total eggs	Average clutch	Average hatch per clutch
Mallard				
1951	38	339	8.9	8.3
1953	64	529	8.3	6.9
Pintail				
1951	15	111	7.4	6.8
1953	25	176	7.0	5.9
Cinnamon teal				
1951	12	125	10.4	9.7
1953	64	583	9.1	7.8
Gadwall				
1951	12	126	10.5	9.6
1953	5	50	10.0	7.4
Shoveller				
1951	10	109	10.9	10.1
1953	2	20	10.0	10.0
Ruddy duck				
1951	0	0	0.0	0.0
1953	3	15	5.0	5.0
Redhead				
1951	1	14	14.0	4.0
1953	5	42	8.4	5.4
All ducks				
1951	88	824	9.4	8.1
1953	168	1,415	8.4	7.1
Coot				
1951	19	154	8.1	7.9
1953	123	913	7.4	7.4

All available data concerning the fate of eggs were recorded in the following categories: (1) number of eggs hatched, (2) number of eggs destroyed, (3) number of eggs infertile, (4) number of eggs containing dead embryos, (5) number of eggs missing, and (6) number of dead in nest. The fate of eggs in successful nests is shown in Table 9. The number of dead young in nests were included in the percentage of eggs hatched.

The successful duck nests produced 824 eggs in the 1951 study and 1,415 eggs in the 1953 study, of which 755 hatched in 1951 and 1,187 hatched in 1953. The hatching success of the duck eggs in 1951 was 91.7 percent; in 1953 it was 83.9 percent. The hatching success of coot eggs was 97.5 percent in 1951 and 99.3 percent in 1953. Only four coot eggs out of 154 in 1951 and seven out of 913 in 1953 did not hatch.

The total number of eggs attributed to parasitism in successfully hatched duck nests was 26 in 1953 and two in 1951. Of the 26 eggs found in 1953, 16 were duck eggs and 10 were pheasant eggs; both of the eggs found in 1951 were pheasant eggs. The small number of eggs resulting from parasitism made little difference in the total number of eggs in the successfully hatched nests and was not computed in the fate of eggs or average clutch.

TABLE 9.—Fate of eggs expressed in percentages.

Species	Hatched	Dead embryo	Infertile	Destroyed	Missing	Total
Mallard						
1951	93.5	5.0	0.0	0.0	1.5	100.0
1953	83.5	12.8	0.2	1.3	2.2	100.0
Pintail						
1951	91.9	7.2	0.9	0.0	0.0	100.0
1953	84.2	10.7	1.1	0.6	3.4	100.0
Cinnamon teal						
1951	92.8	0.8	0.8	0.0	5.6	100.0
1953	85.5	11.2	0.0	1.0	2.3	100.0
Gadwall						
1951	91.2	3.2	1.6	0.0	4.0	100.0
1953	74.0	16.0	0.0	4.0	6.0	100.0
Shoveller						
1951	92.7	4.6	0.9	0.0	1.8	100.0
1953	100.0	0.0	0.0	0.0	0.0	100.0
Ruddy duck						
1951	0.0	0.0	0.0	0.0	0.0	0.0
1953	100.0	0.0	0.0	0.0	0.0	100.0
Redhead						
1951	28.6	71.4	0.0	0.0	0.0	100.0
1953	61.9	26.2	11.9	0.0	0.0	100.0
Average of all ducks						
1951	91.7	5.4	0.6	0.0	2.3	100.0
1953	83.9	12.0	0.6	1.0	2.5	100.0
Coot						
1951	97.5	0.0	0.6	0.0	1.9	100.0
1953	99.3	0.3	0.0	0.4	0.0	100.0

Infertile eggs and eggs containing dead embryos that were found in successfully hatched nests were classified by the method described by Kossack (1950). An egg was considered infertile if the yolk was suspended in the albumen and no indication of development was present. Any egg that contained a dead embryo in any stage of development or contained yellow custard-like material was classified as a dead embryo.

In all, 45 eggs containing dead embryos and five infertile eggs were found in successfully hatched duck nests in 1951, and 172 eggs containing dead embryos and eight infertile eggs were found in 1953. In all the successfully hatched coot nests only three eggs containing dead embryos and no infertile eggs were found in 1953, and no dead embryos and one infertile egg were found in 1951.

A total of 50 eggs was either destroyed or missing from the successfully hatched duck nests in 1953, while in 1951 there were 19 eggs missing from successful duck nests, but no eggs were destroyed. Successful coot nests contained four destroyed eggs and had no eggs missing in 1953; there were no destroyed eggs and four eggs were missing in 1951.

Brood Data

The number of duck brood counts taken during the two studies was 132 and 1951 and 151 in 1953. Most of the duck broods counted were either one or two weeks old. Only 30.1 percent of the duck broods counted during 1951 and 44.3 percent of the duck broods counted during 1953 were over two weeks old. Losses in broods during the first week of life averaged 0.1 bird in 1951 and 0.7 bird in 1953.

No coot broods were counted during 1951, and only 24 coot broods were counted during 1953. Since a pair of coots will often split the brood between them, brood count may not accurately reflect the actual brood size. Therefore, observers tallied only those broods that could be considered complete. An average loss of 3.0 coots per brood during the first week of life occurred in the few coot broods taken. This loss was undoubtedly due to the general helplessness of young coots during their first few days of life (Gullion, 1954).

Discussion

The amount of water in Honey Lake has a definite bearing on the number of waterfowl utilizing the valley throughout the year. The lake in wet years provides an adequate resting place for the spring migrants and attracts breeding pairs that remain to nest in the area. Fall migrating waterfowl feed and rest in the vicinity of the lake and, together with the waterfowl produced in the valley, provide hunting during the waterfowl season.

In 1951 most of the duck nesting occurred in dry, upland-type habitat that was adjacent to artificial ponds. These nesting areas provided a combination of good nesting cover and sufficient water for rearing broods. The preferred nesting cover under 1951 conditions was rye grass, five-hooked bassia, and salt grass. These plant species grew in clumps and provided cover that was relatively low and dense. In 1953 there was not only an abundant growth of upland plant species, instant growth of emergent plant species, including rye grass, five-hooked bassia, and salt grass, but also an abundant growth of emergent plant species, such as Baltic rush. The Baltic rush offered the same concealment factors as the rye grass, five-hooked bassia, and salt grass and was usually growing in or near water. Approximately the same percentage of duck nests was found in the Baltic rush in 1953 as was found in rye grass, five-hooked bassia, and salt grass in 1951. Apparently the conditions that prevailed at the nest location, such as concealment and proximity to water, were more important to the nesting ducks than the selection of a certain plant species in which to build a nest. The coot nesting during both studies was confined to areas that grew emergent plant species.

From observations made of coots it appears that both parents participate in incubation of the egg. A further observation is that the coot often commences incubation at some interval after the first egg is laid and before the final egg of the clutch is laid. This would enable the coot to hatch several of the young and allow one parent to take the young from the nest and the other parent to continue incubating until all eggs in the clutch were hatched. These observations followed the coot nesting behavior described by Gullion (1954) and others. As an example of the frequency of this behavior, 83 of the 139 coot nests hatched during the 1953 study were hatched in this manner. The early start in incubation would also give the coot eggs more protection than that received by duck eggs.

The most frequent cause of nest failure was predation. Approximately one-third of all nests found during both studies were destroyed by predators. The species of ducks that nested in the dry upland locations sustained the majority of the nest destruction in each study. Many of the ducks nesting in the upland areas preferred ditch banks and dikes for a nest location. Mammalian predators, principally the striped skunk, seemed to hunt these areas extensively in search of food. Nest destruction in the marsh area was very limited, apparently because of protection afforded by standing water. Undoubtedly the absence of such aquatic predators as the mink was also a factor in the low incidence of predation in the marsh area. The rate of nest destruction by avian predators was low in marshy areas and moderate in the upland areas during both studies. Since coots habitually built their nests overwater they were protected from most mammalian predators, and thus were the most successful nesters studied. Another factor which may have contributed to the high rate of nesting success of coots was the participation of both parents in guarding the nest.

An insufficient number of broods was counted to determine accurately brood regression during either study. The utilization of dense escape cover by the duck and coot broods made brood counting difficult. The one-and two-week-old broods were the only age classes that were counted frequently. Information taken from the brood cards regarding week-old duck broods indicated that there was a slight reduction in brood size during the first week of life. The coot broods that were counted showed a loss of approximately 40 percent of the number of hatched young during the first week of life.

Summary

1. Studies on nesting ducks and coots were conducted during the spring of 1951 and 1953 in Honey Lake Valley, Lassen County, California.
2. Two sample strips with a total area of 300 acres were studied during 1951; 11 study plots with a total area of 328 acres were studied during 1953.
3. Nest histories were completed on 202 duck nests and 20 coot nests during 1951. In 1953 nest histories were completed on 359 duck nests and 143 coot nests.
4. The peak of hatch for coot nests was between 1 June and 15 June during 1951; for duck nests, between 1 June and 30 June. The peak of hatch for both ducks and coots during 1953 was between 16 June and 30 June.

5. The nesting success for all nets found in 1951 was 52.5 percent for ducks and 95.0 percent for coots; in 1953 the nesting success for all nests found was 50.1 percent for ducks and 97.2 percent for coots.
6. Predation was the most important cause of unsuccessful nesting of ducks and coots during both studies.
7. The hatching success of eggs in the successful nests in 1951 was 91.7 percent for ducks and 97.5 percent for coots; in 1953, the hatching success was 83.9 percent for ducks and 99.3 percent for coots.
8. In 1951, 132 duck broods were counted, while in 1953, 151 duck broods were tallied. The brood count data showed that on the average less than one duck per brood was lost during the first week of life. The 24 coot broods counted in 1953 revealed an average reduction of 3 coots per brood during the first week of life.

References

Gullion, Gordon W. 1954. The reproductive cycle of American coots in California. Auk, vol. 71, no. 4, p. 366-412.

Kossack, Charles W. 1950. Breeding habits of Canada geese under refuge conditions. Amer. Midl. Nat., vol. 43, no. 3, p. 627-649.

Miller, A. W., and B. D. Collins. 1953. A nesting study of Canada geese on Tule Lake and Lower Klamath National Wildlife Refuges, Siskiyou County, California. Calif. Fish and Game, vol. 39, no. 3, p. 385-396.

_______1954. A nesting study of ducks and coots on Tule Lake and Lower Klamath National Wildlife Refuges. Calif. Fish and Game, vol. 40, no. 1, p. 17-37.

Naylor, Albert E. 1953. Production of the Canada goose on Honey Lake Refuge, Lassen County, California. Calif. Fish and Game, vol. 39, no. 1, p. 83-94.

Naylor, A.E., and E.G. Hunt. 1954. A nesting study and population survey of Canada geese on the Susan River, Lassen County, California. Calif. Fish and Game, vol. 40, no. 1, p. 5-16.

Appendix 1.—Scientific Names of Animals and Plants Listed in the Text

Birds

- Mallard—*Anas platyrhynchos*
- Pintail—*Anas acuta tzitzihoa*
- Cinnamon Teal—*Anas cyanoptera*
- Gadwall—*Anas strepera*
- Shoveller—*Spatula clypeata*
- Baldpate—*Mareca americana*
- Ruddy Duck—*Oxyura jamaicensis rubida*
- Redhead—*Athya americana*
- Coot—*Fulica americana*
- California Gull—*Larus californicus*
- Ring-billed Gull—*Larus delawarensis*
- Black-billed Magpie—*Pica pica hudsonia*
- Western Crow—*Corvus brachyrhynchos hesperis*
- Raven—*Corvus corax*

Mammals

- Great Basin Striped Skunk—*Mephitis mephitis major*
- Mountain Coyote—*Canis latrans lestes*
- Pallid Bobcat—*Lynx rufus pallescens*
- California Badger—*Taxidea taxus neglecta*
- Weasel—*Mustela* sp.
- Housecat—*Felis domesticus*

Plants

- Grasses—*Gramineae*
- Cultivated Barley—*Hordeum vulgare*
- Cultivated Wheat—*Triticum aestivum*
- Black Greasewood—*Sarcobatus vermiculatus*
- Sagebrush—*Artemisia tridentata*
- Five-hooked Bassia—*Bassia hyssopifolia*
- Rye Grass—*Elymus* sp.
- Baltic Rush—*Juncus balticus*
- Hardstem Bulrush—*Scirpus acutus*
- River Bulrush—*Scirpus fluviatilis*
- Alkali Bulrush—*Scirpus paludosus*
- Salt grass—*Distichlis spicata*
- Alfalfa—*Medicago sativa*

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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.

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Literature Cited

Bleich, V. C., N. J. Kogut, and D. Hamilton. 2011. Information for contributors to California Fish and Game. California Fish and Game 97:47-57.

CSE (Council of Science Editors). 2006. Scientific style and format: the CSE manual for authors, editors, and publishers. 7th edition. The Rockefeller University Press, New York, USA.

About the Covers

Front.—The Northern pintail, *Anas acuta*, is by far the most abundant wintering waterfowl species in California, usually making up about 50% of the total in midwinter. Common to abundant August to March, fewer in July and April, in Central Valley, Salton Sea area, along Colorado River, and in shallow coastal bays and lagoons. Photo by Gerald and Buff Corsi © California Academy of Sciences

Rear.—The Amargosa Canyon upstream from the confluence with Willow Creek. This important riparian area is undergoing habitat restoration by the Amargosa Conservancy. Photo courtesy of Nancy Good, newlightfotodesign.com.

Photo courtesy of Nancy Good, newlightfotodesign.com.

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