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Bringing science to waterfowl management in the California Department of Fish and Wildlife

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In this invited paper we summarize some of the scientific work produced to inform waterfowl management in California and the Pacific Flyway, with an emphasis on those contributions by Department of Fish and Wildlife (Department) waterfowl biologists assigned to Federal Aid in Wildlife Restoration Project W30R and chronicled in *California Fish and Game*. Investigations carried out by other Pittman-Robertson projects also contributed substantially to the Department's science-based programs for waterfowl, particularly regarding waterfowl disease and food habits investigations. Important information needs, addressed by the best scientific methods of the day, included population abundance and trend, breeding and wintering distributions, critical habitat needs, vital rates (survival, recruitment), the establishment of appropriate hunting regulations, and how problems identified could best be addressed to maintain the abundance and distribution of waterfowl for future generations.

Key words: California, Federal Aid in Wildlife Restoration, management, Pittman-Robertson Act, science, waterfowl

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Waterfowl management and wetland conservation in California and North America have benefitted from the efforts of thousands of dedicated, passionate professionals and private individuals. In addition to this human element, the dedication of billions of dollars from public and private funds for waterfowl conservation is a fundamental cause for success.

This combined effort has allowed most waterfowl populations to flourish in the face of ever-expanding anthropogenic changes on the landscape.

Methods

We reviewed literature, either formally published in scientific journals, or available from other sources (primarily progress reports or final reports supported by Federal Aid in Wildlife Restoration Project W30R), including some unpublished material. Through this effort, we summarize some of the scientific work produced to inform waterfowl management in California and the Pacific Flyway. We have especially recognized those contributions by California Department of Fish and Wildlife (Department) waterfowl biologists chronicled in *California Fish and Game*. We acknowledge the many individuals, agencies and organizations in California and across North America that have made, and continue to make, meaningful contributions to the scientific management of the continent's waterfowl. We also identify some of the important management events, and the resulting conservation strategies supported by scientific inquiry, that benefitted waterfowl in California over the past 100 years. In this review we emphasize information on abundance and distribution surveys, wintering habitat evaluations, breeding habitat, nesting studies, and key events in waterfowl management affecting California and the Pacific Flyway**.**

Results and Discussion

The passage of the Migratory Bird Treaty Act in 1918 in response to dramatic declines in the abundance of migratory birds provided a coordinated nation-wide approach under the purview of the U.S. Fish and Wildlife Service (Service). Prior to World War II, the Department's principal role in waterfowl management was protection through enforcement of the regulations governing use of waterfowl (Leach 1997). A few waterfowl management areas were operated to provide food sources for birds and for recreational use, primarily hunting, by humans. The Department began a more robust scientific process to understand and manage waterfowl resources after World War II, bolstered by the passage of the Pittman-Robertson Wildlife Restoration Act and the availability of those funds to establish the Waterfowl Investigations Project (Project). By 1952 the Department had eight full-time biologists assigned to the Project; currently, the Project is staffed by two full-time scientists.

Investigations by other Pittman-Robertson projects made important contributions to the Department's science-based programs for waterfowl conservation. Of particular importance were waterfowl disease and food habits investigations. Food preference was determined by analysis of gizzard contents of thousands of waterfowl and used as a basis for plant selection in moist soil management on public and private wetlands. (George 1963, Clary and George1983). Laboratory and field investigations of diseases affecting waterfowl have been an important function of the Department's Wildlife Investigations Laboratory since the early 1950s. Emphasis was placed on detection, cause and treatment of avian cholera (Hunter and Rosen 1967, Titche 1979) and botulism (Hunter 1969, Hunter 1970, Hunter et al. 1970) and the effects of pesticides (Littrell 1986, Littrell 1988).

At about the same time as the passage of the Pittman-Robertson Wildlife Restoration Act, the Service adopted the concept of waterfowl management by four flyways (Chattin 1964). Flyway boundaries approximated north-south waterfowl migration patterns in the

United States and Mexico, but did not extend into Canada. As a result, the Service began establishing hunting regulations on a flyway basis, rather than on a nationwide basis. After much deliberation, councils of state membership were in place in each of the four flyways by 1952 through a resolution of the International Association of Fish and Wildlife Agencies (Bartonek 1984). The flyway system afforded the states the opportunity for coordination in understanding the status of waterfowl, and through memoranda of understanding between the four flyways and the Service, a unique partnership to develop waterfowl hunting regulations. The Service then established a flyway representative position in each flyway to coordinate and facilitate state participation in flyway studies and management functions (Bartonek 1984).

By the mid-20th century waterfowl again were abundant, visible and valuable to California's economy, although probably still much reduced from the late 1800s. Management actions up to that time were based on limited scientific information. Several key questions arose and many of these continue to be a focus of research and management efforts. These information needs, addressed by the best scientific methods of the day included population abundance and trends, breeding and wintering distributions, critical habitat needs, vital rates (survival, recruitment), the establishment of appropriate hunting regulations, and determining how any problems identified could be addressed to maintain the abundance and distribution of waterfowl into the future.

Abundance and distribution: surveys.—To address abundance and trend, both the Service and the Department (USDI 1988) designed standard protocols and implemented several aerial surveys. The Breeding Ground Survey (BGS) was implemented in 1948 (CDFG 1948) and consisted of complete aerial coverage of the waterfowl habitats in northeastern California (thought to be the primary waterfowl production area), and transects in the Central Valley (Chattin et al. 1949). In 1989 the BGS was redesigned to include randomized transects in areas of California with large blocks of contiguous habitat that supported breeding ducks, and double-sampling was employed to estimate visibility bias (Deuel and Yparraguirre 1989, Zezulak et al. 1991, CDFG 1992). A review of this methodology (Smith 1985) and its continued use (USFWS 2014a) demonstrate the acceptance of these survey protocols. This statistical design provides an estimate of waterfowl in the survey areas and a measure of precision, and this more robust design led to the explicit use of the California survey results in the annual regulation setting process by the Service (USFWS 2008).

The Midwinter Waterfowl Survey (MWS*)* is the oldest of the continental surveys, having been conducted in one fashion or another throughout the conterminous United States since 1936, and in California since 1955. The MWS is a cooperative effort between the Service and the various states. Conducted annually, generally during the first week in January, observers estimate the numbers of all species of waterfowl in major concentration areas. Once the primary means of monitoring population status for setting hunting regulations (Blohm 1989), the MWS now provides indices of relative winter abundance and distribution, and is not used explicitly for management decisions except for black brant (*Branta bernicla)* and tundra swans (*Cygnus columbianus*) (Pacific Flyway Council [PFC] 2001, 2002).

The MWS is not a total census; it is merely an index of waterfowl populations. Yet, variations in survey coverage, weather, observers, and distributional patterns of waterfowl markedly influence these annual indices (Eggeman and Johnson 1989). In 2011, the Pacific Flyway Council, through its Study Committee (PFSC) participated in a nationwide review of the MWS to determine its necessity and usefulness, risks associated with aerial coverage of survey areas, and ways to improve the design, logistics, and safety of the survey. The

PFSC is currently revising this long-running survey to improve statistical design, standardize methods, improve observer training, and create greater availability of qualified observers and appropriate aircraft.

In California particularly, conditions under which the MWS is conducted have changed. Prior to 1992, the survey was routinely completed in 1 to 2 days by surveying important sanctuary areas; after 1992, the practice of flooding rice for straw decomposition led to hundreds of thousands of acres of lightly disturbed habitat (Blank et al. 1993, Bird et al. 2000). This meant the survey took more days, and winter weather conditions not conducive for flying resulted in a longer period to complete the survey. Waterfowl movements among survey areas during this longer period are potentially adding variation in the value of these indices.

The most common uses for MWS results include documenting winter waterfowl distribution, providing information to the public, and developing information for winter waterfowl habitat conservation. An important use of this survey was to establish habitat protection and enhancement objectives for the Central Valley Joint Venture (CVJV), established in 1988 as an implementing function of the North American Waterfowl Management Plan (USFWS 1986). Using known energy (i.e., food) needs for ducks and geese, and an index to the wintering population and its distribution, specific habitat objectives were established for nine basins in the Central Valley (CVJV 2006).

The Mid-September Inventory (MSI) was conducted from 1953 to 2002 to better describe the abundance of ducks in the Central Valley where habitat conversions to agriculture led to waterfowl depredation, especially on the maturing rice crop (CDFG 1953). To alleviate crop depredation on private lands, waterfowl hunting seasons were sometimes delayed on public hunt areas to provide food for the newly arriving waterfowl on publicly-owned wetlands. Debates about the number and distribution of ducks led to this survey.

The survey was flown in mid-September on the major waterfowl concentration areas. By mid-September, duck migration into California is well underway and occurs simultaneously with rice crop maturation. Before population surveys were conducted it was common to hear reports of millions of ducks consuming rice crops. In order to meet administrative deadlines the decision of whether to delay the opening of waterfowl season on public hunt areas was needed in advance of the MSI and this survey was terminated.

Bi-weekly Surveys (BWS) were conducted from 1958 to 1979 during the fall and early winter to describe the timing and distribution of waterfowl throughout the Central Valley and Klamath Basin (CDFG 1958, F. M. Kozlik and J. R. LeDonne, California Department of Fish and Game, unpublished data). Aerial estimates in a manner similar to the MWS were made for the major waterfowl concentration areas during six bi-weekly surveys. The BWS also provided information to the public. These surveys were halted because higher priority surveys were needed to estimate declining goose populations from the Yukon-Kuskokwim Delta (YKD) (Pamplin 1986, Fischer and Stehn 2013, USFWS 2014b).

Fall Goose Surveys (FGS) were initiated in 1979 (Smith 1980). Declines in abundance of several YKD nesting goose populations (particularly white-fronted geese, *Anser albifrons* and cackling Canada geese, *Branta canadensis minima*) (Pamplin 1986) led to this survey in California—the primary wintering area for these geese at the time—to better describe fall populations. Indices from these surveys monitor progress towards population objectives developed in the various species plans, as well as fulfilling commitments made under the Yukon-Kuskokwim Delta Goose Management Plan (see section below).

A special December survey was also added for white geese (collectively lesser snow geese [*Chen caerulescens*] and Ross's geese [*C. rossii*]). This survey is supplemented by a trinnial ground survey following a specific protocol (McLandress 1979) to estimate the proportions of white geese that are snow geese and Ross's geese (Kelly et al. 2001, Weaver 2011) because those species cannot be reliably separated during an aerial survey.

Distribution.—Banding has been a long standing method to determine waterfowl migration routes (Crissey 1955). Waterfowl banded in breeding areas and recovered primarily by hunters described associations between breeding and migration and wintering areas. Each year since 1922 waterfowl have been captured and marked by state, Service, and private waterfowl conservation organization biologists with individually numbered leg bands to determine where and when birds are taken by hunters (USDI 1988). The Project has banded more than 350,000 waterfowl in California since 1947 (Table 1, Figure 1). To address the practical aspects of dealing with large numbers of bandings, Project staff developed certain aids to keep bands in numerical sequence and speed banding operations (Miller and Henry 1952) that are still in use today. Despite relatively large samples, it usually took decades for sufficient recoveries to occur to provide information adequate for analysis. Several studies of geese have been conducted in California using auxiliary markers that allow multiple "re-captures" of individual birds. In addition to describing the distribution of waterfowl, analyses of band returns (recoveries) have been the primary method used to assess the impact of hunting mortality on waterfowl populations (Rogers et al. 1979) by estimating vital rates such as harvest rates and survival rates.

Table 1.—Summary of waterfowl banded by California Department of Fish and Game personnel, 1947–2013.

Species	Number banded
Northern Pintail	161,879
Mallard	80,399
Canada geese	46,657
American Wigeon	20,645
All others	56,389
Total	365,969

Figure 1.—Nearly 50,000 Canada geese have been banded in California since 1947.

An early effort to describe lesser snow goose wintering distribution in California, and in their northward spring migration, was conducted from 1954 to1955 (Kozlik et al. 1959). Three chemicals were used to temporarily dye a sample of geese (Figure 2) in an effort to determine how some individual geese used various habitats of the Central Valley, and what areas were visited in spring migration. These birds were sighted in spring and summer in eastern Oregon and Montana; Alberta and Yukon Territory, Canada; and in western Alaska. Rienecker (1965) expanded on the fall and spring distribution of lesser snow geese by analyzing recoveries of standard leg bands and documented two distinct migration routes between the breeding grounds and California.

Figure 2.—Lesser snow geese color-marked with various dyes in an effort to determine local movements and migration routes (Kozlik et al. 1959).

The wintering distribution of Canada geese (*B. c. moffitti*) that nest and molt in northeastern California was also described by marking samples with uniquely numbered neck collars that were observed throughout the wintering period (Rienecker 1985a). With this technique, more information was used to describe wintering distribution than would be available through normal recoveries through bands encountered and reported by hunters. Additional studies using auxiliary markers deployed by Project personnel to describe distribution and other aspects of population ecology of geese included studies of cackling geese (Raveling and Zezulak 1992) and Aleutian Canada geese (*B. c. leucopariea)* (Woolington et al. 1979, Sanders and Trost 2013). Other neck collar marking projects with tule greater white-fronted geese (tule geese; *Anser albifrons elgasi*) by Project staff were used to describe population ecology on breeding areas in Alaska (Ely et al. 2006, Ely et al. 2007). Marking of tule geese with neck collars incorporating VHF radio transmitters and surgically implanted satellite transmitters (Figure 3) provided new insights to migration routes and stop-over areas across North America (Figure 4). Information from the VHF radio transmitters, combined with cooperative ground surveys, is currently used to estimate the population size (Yparraguirre and Weaver 2008) of the smallest population of any subspecies of geese in the world (Baldassarre 2014).

Analyses of standard leg band recoveries that described distribution included studies of redhead (*Aythya americana*) (Rienecker 1968); American wigeon (*Anas americana*) (Rienecker 1976); canvasback (*Aythya valisineria*) (Rienecker 1985b); northern pintail (*Anas acuta*) (Rienecker 1987a, Raquel 1988); Canada geese (*B. c. moffitti*) (Rienecker 1987b) and mallards (*Anas platyrhynchos*) (Rienecker 1990).

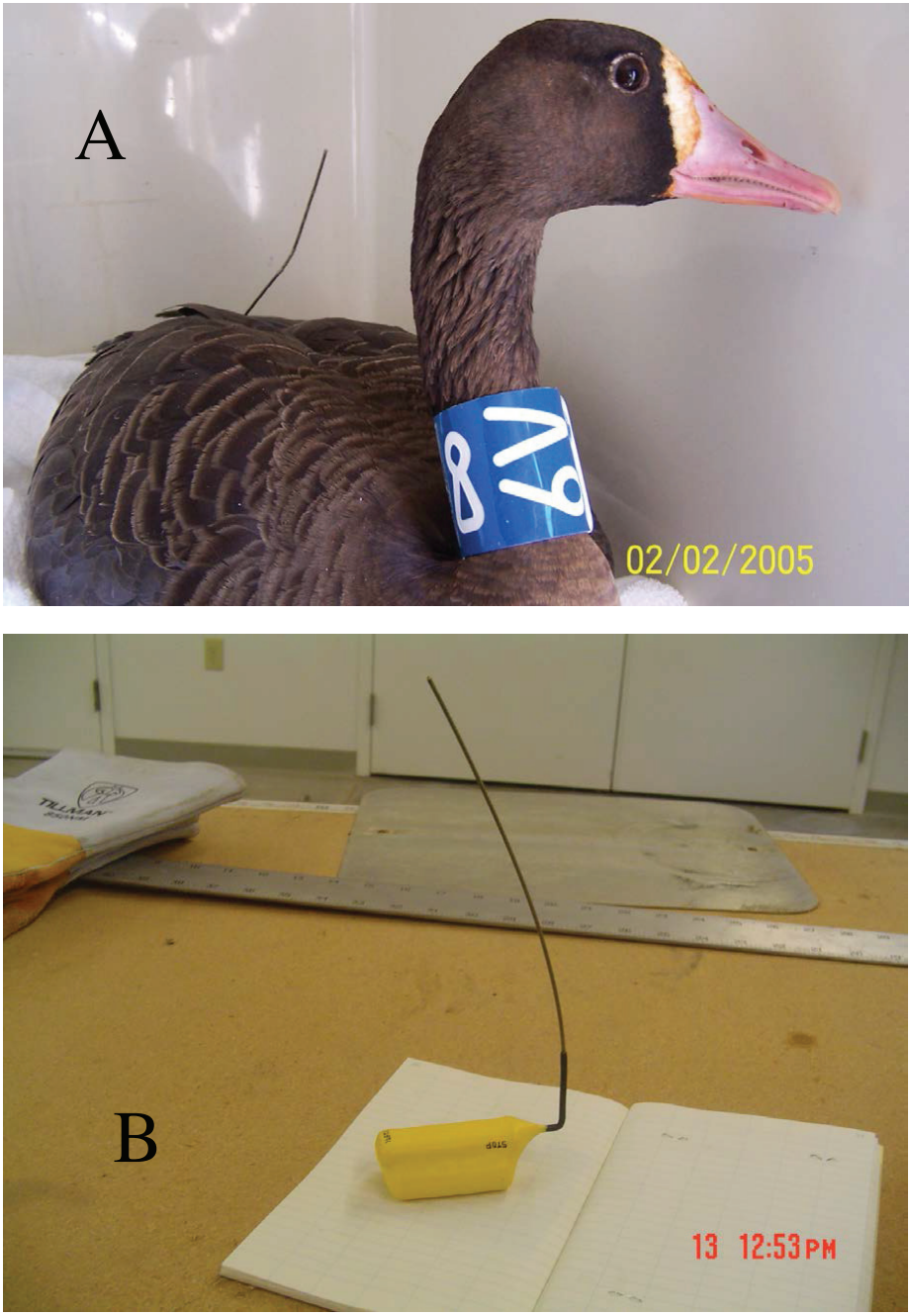

Figure 3.—(A) An adult tule white-fronted goose recovering from anesthesia following surgical implantation of an internal satellite transmitter. (B) These transmitters were placed in geese captured near Maxwell, California, during 2005 and 2006, and have been indispensable in determining migratory patterns of this subspecies.

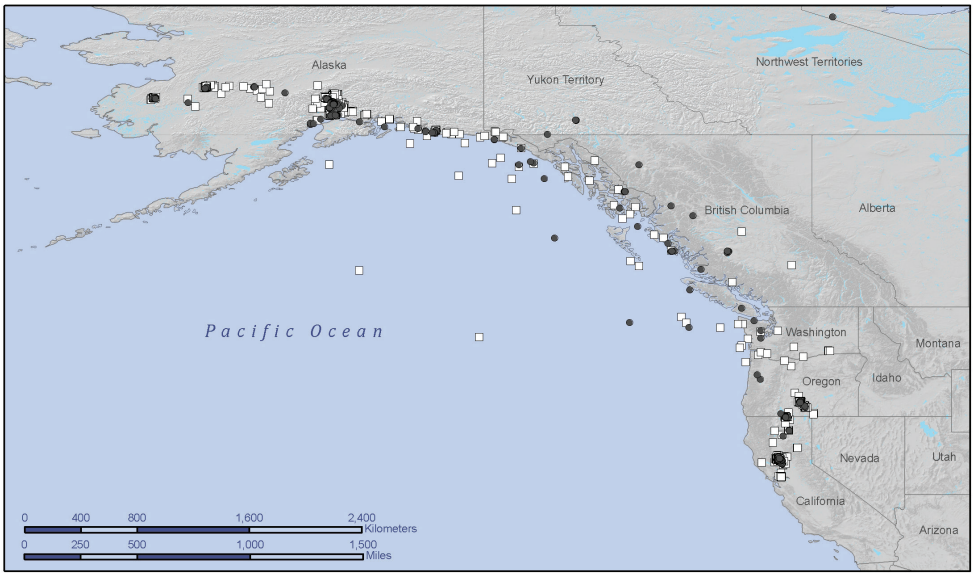

Figure 4.—Locations of satellite-based telemetry detections of tule white-fronted geese during 2005 (white squares) and 2006 (dark circles). Locations depicted are only the highest location quality for all birds marked. All (n=23) but one of the geese were adults when marked. Geese were captured and marked near Maxwell in the Sacramento Valley, California in a cooperative project with the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service.

Wintering habitat evaluations.—While the Central Valley of California was well known as a critically important wintering area for waterfowl in North America (Day 1949), Project personnel and others applied scientific methods to improving the habitat conditions for wintering waterfowl (Clary and George 1983). Three habitat management guides (Miller and Arend 1960, George 1963, Ermacoff 1968) were produced by Project personnel to aid in the management of wetland habitats.

The progression in habitat management was often guided by food habits studies for the particular species involved. Early studies utilized the gizzards from hunter-harvested birds (Anderson 1959). As a result, much of the early management work focused on providing grains and hard seeds which were prevalent in the food analyses (CDFG 1965a, CDFG 1965b, CDFG 1965c, CDFG 1966). Subsequent analyses identified a bias in food habits analysis from gizzard contents (Dillon 1958, Swanson and Bartonek 1970). When the contents of the esophagus and proventriculus were included, the results indicated an important intake of invertebrates (Connelly and Chesemore 1980, Miller 1987). The digestive process early in the digestive system was making the detection and identification of invertebrates virtually impossible once that food item reached the stomach. This revelation led to a much more robust management for vegetation and water that favored invertebrate food sources, in addition to that reflected by Miller and Arend (1960), George (1963), and Ermacoff (1968).

The majority of the seasonal wetland habitat in California is privately owned and is managed for waterfowl habitat and hunting (CVJV 2006). To determine the extent, management regime and trends of this habitat, surveys of duck clubs were conducted by

Project and other Department staff (CDFG 1975). As technology improved in the early 2000s, the use of satellite imagery and Geographic Information Systems (GIS) (Kempka et al. 1992) replaced the field surveys, interviews with land owners, and aerial photography (CDFG 1975) used previously to identify and monitor trends in wetland habitat managed as duck clubs.

Breeding habitat and nesting studies.—Although the large wintering waterfowl populations and their needs were a priority for research, the Project at the outset recognized that it would be critical to include studies to describe the nesting habits, habitats, and basic population parameters of common nesting waterfowl. Miller and Collins (1953) conducted a nesting study of Canada geese (*B. c. moffitti*) on the Tule Lake and Lower Klamath national wildlife refuges and determined that nest success was high and predation was not a factor in the successful production of these geese. Subsequent studies of Canada geese on the Honey Lake Wildlife Area and surrounding lands (primarily the Susan River) by Naylor (1953) and by Naylor and Hunt (1954) documented similar nest success but also documented high desertion rates (Naylor and Hunt 1954). Artificial nest structures for wood ducks (*Aix sponsa*) (Naylor 1960) and Canada geese (Rienecker 1971) were designed and tested as a way to further increase the recruitment of these species by providing "habitat" that reduced predation.

Studies of other nesting waterfowl occurred at the same time that documented high nest success for ducks (Miller and Collins 1954, Hunt and Naylor 1955, Rienecker and Anderson 1960, Hunt and Anderson 1966). These nest-success estimates were generally higher than those from more well-known duck nesting areas in Prairie Canada and the north-central United States (Klett et al. 1988, Beauchamp et al. 1996). Similar studies were expanded to other parts of California (Anderson 1956, 1957, 1960). Naylor (1960) added to the work of early ornithologists (Grinnell 1915, Dixon 1924) documenting the abundance and distribution of nesting wood ducks in California. Later, research by McLandress et al. (1996) indicated production of mallards in California was an important contribution to wintering mallard populations. The results of these studies confirmed that California was providing important nesting and production habitats for certain species of waterfowl (Kozlik 1975).

Public use and its management.—An early contribution of the Project documented the expansion of hunting opportunities for "un-attached" hunters (Kozlik 1955). As with habitat management, producing information for the public about waterfowl in California was a high priority (Kozlik et al. 1985).

The hunting program for waterfowl on state-managed lands has been closely monitored since its inception (Kozlik 1955), and substantial changes in the size and species composition of the harvest on public hunting areas has occurred over the ensuing decades (Gilmer et al. 1989, Fleskes et al. 1994). At a state and flyway-wide level, the ability to differentiate species from wing and tail feathers submitted by hunters (Carney 1992) was an important contribution. However, as changes in the environment occur over time, some methods were shown to need adjustment (Oldenburger et al. 2011).

Perhaps the greatest scientific contributions arise from the synergistic effect of the population monitoring (i.e. surveys and banding) accomplished in California by the Project and, more importantly, throughout North America by Service and other biologists, to inform harvest management (Geis et al. 1969) and investigate the role of harvest in population dynamics (Oldenburger et al. 2008, Sedinger and Herzog 2012). Advances in analytical processes led to a more advanced understanding of the role of harvest in duck

population dynamics (Martin and Carney 1977) and, further, to the development of an adaptive management approach to setting duck harvest regulations (Williams and Johnson 1995, Nichols et al. 2007). Some questioned whether this more robust approach resulted in real improvements to the understanding of the fundamental processes (Humburg et al. 2000) but, by 2008, population surveys in California (along with Alaska and Oregon) were formally adopted by the Service when duck hunting regulations for the Pacific Flyway are developed (USFWS 2008).

A continuing issue of importance in California has been the establishment of hunting regulations for northern pintail. The effect of harvest on pintail has been disputed (Raveling and Heitmeyer 1989), and this work was informed by work conducted by Project biologists (Rienecker 1987c). The Project maintains an active banding program for northern pintail.

Key events.—Funding for wildlife conservation has never met the needs. In 1971, Governor Ronald Reagan signed legislation creating the first state duck stamp in the nation, modeled after the Federal Migratory Bird Hunting and Conservation Stamp introduced by the Service in 1934. These stamps are required of adult hunters for hunting waterfowl.

Since its creation, sales of the California stamp have been primarily to hunters and have provided more than $24 million for the conservation and management of habitats for waterfowl in California. In addition to providing a financial commitment for improving waterfowl and wetland conditions in the state, the enabling legislation specified a portion of the funds derived from the sale of the stamp go to Canada. This unusual specification is an indication of how strong sentiments were for improving waterfowl nesting conditions on prairies in Canada. Another example of support for prairie projects is the number of projects named in honor of their California sponsors. Indeed, three projects in Alberta, the Will Reid Project, the Lake San Francisco Project with funds from the San Pablo Rod and Gun Club; and the Walt Disney Project indicate that support (F.A. Reid, Ducks Unlimited, personal communication). This importance of the prairies of Canada as nesting sites for several species of ducks (particularly pintails), which are a principal component of the wintering ducks in California, was firmly established by the banding program (Hestbeck 1993a, 1993b) conducted by the Project personnel and other contributors.

The development and implementation of the YKD Goose Management Plan in 1984 is an example of an unprecedented emergency action to alleviate a serious problem affecting two goose species (Bartonek 1986). The numbers of cackling geese and white-fronted geese that nested in the YKD of Alaska and wintered primarily in California experienced a precipitous decline in cackling geese during the 1970s and early 1980s (Pamplin 1986). The underlying reason for the decline appeared to be overharvest (Raveling et al. 1992), but whether the harvest was on the nesting or wintering grounds, or both, was a matter of dispute. Remedial action through normal Service-Native channels could not be effected in a timely manner. Thus, the Department, its sister agency in Alaska, the Service, and a committee representing the Native villages in the YKD reached an agreement that special hunting of these species on the YKD in summer should be eliminated and hunting in California in winter severely reduced. As a result, Natives shifted their spring subsistence take to other species on the YKD. The California Fish and Game Commission, through emergency action, immediately closed the season on cackling geese and subsequently reduced the season and bag limit on white-fronted geese. Both species responded to the actions taken, and populations returned to normal and above normal within several years. The result is an example of cooperative discussions and action taken in good faith by all

parties, yielding a successful conclusion. The use of previously developed science-based findings about harvest was instrumental in reaching mutual accord in this matter.

The North American Waterfowl Management Plan (NAWMP) and its related Act, the North American Wetlands Conservation Act (NAWCA) of 1986 and 1989, respectively, provided an unprecedented venue for restoring and conserving waterfowl habitat throughout North America. NAWMP was implemented in 1986 in the United States and Canada (USFWS 1986) and expanded to include Mexico in 1994. NAWMP has been updated four times since 1986 (USFWS 2014c). The first NAWMP set objectives to achieve waterfowl populations numbers prevalent in the 1970s. Improvements to and expansion of wetland habitats are the core elements employed in this plan. Program-oriented joint ventures are the main venues for implementing those habitat projects, which are funded through grants awarded through NAWCA. Non-federal matching funds are required in grant proposals. Usually, these partnerships are formed at the local level to cooperatively implement projects that achieve specific joint venture goals. The program has been operational for more than 25 years and through the partnerships is expected to continue well into the future. From 1990 to the present, approximately 5,000 partners in 2,421 projects have raised nearly $1.3 billion in NAWCA grants. They have contributed another $2.7 billion in matching funds to affect >11 million ha of habitat (USFWS 2014d).

Five joint ventures are operational in California: two are completely within the state and three include territory outside the state as well. In California through 2013, NAWCA-sponsored projects have improved about 310,000 ha at a cost of $460 million (USFWS 2014e). The Department, primarily through a role representing the Pacific Flyway Council, has served more than twenty years on various functions of NAWMP and NAWCA. During this time, the Department has encouraged the use of science in both programs, wherever feasible. Currently, the Action Plan for the 2012 update of NAWMP encourages the use of science wherever appropriate, including the process of adaptive management.

Acknowledgments

The great diversity and abundance of waterfowl is a valuable and treasured part of California's natural heritage. Using scientific methods to provide for the conservation and wise use of waterfowl has been the focus of many individuals in California and elsewhere, which are too numerous to list here. For this invited review, we have focused on the contributions, primarily from the Pittman-Robertson Waterfowl Investigations Project published in *California Fish and Game* and elsewhere, but this approach does not provide sufficient credit to those individuals that have been a part of the Waterfowl Project since its establishment in 1947. In addition to the authors, W. Anderson, P. H. Arend, J. Chattin, B. D. Collins, B. E. Deuel, H. A. George, D. Hinz, F. M. Kozlik, J. R. LeDonne, H. McKinnie, A. W. Miller, A. E. Naylor, S. L. Oldenburger, W. C. Rienecker, D. A. Skalos, and J. D. Waithman have all been assigned to Project W30R.

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