# Chapter 5. Waterfowl Ecology and Management

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## Introduction

Suisun Marsh has long been a favored place for waterfowl (ducks, geese, and swans). Before the first duck clubs were established in 1879, market hunters used the Marsh for at least 20 years and continued to hunt it until market hunting was outlawed in 1918 with the passage of the Migratory Bird Treaty Act. Suisun Marsh's proximity to San Francisco allowed market hunters to get their vast harvest to market relatively quickly by boat. During a single hunting season in 1911-1912, an estimated 250,000 ducks were sold in San Francisco markets from all sources, and 350,000 ducks were sold statewide (Garone 2011).

The west side of Suisun Marsh had the first duck clubs, apparently both for the quality of hunting and ease of access. In 1879, the Southern Pacific Company completed a railroad through the west side of the Marsh from Benicia to Suisun City, but it required constant and costly maintenance because it sank repeatedly into the marsh (Arnold 1996; Garone 2011). Most sport duck hunters in those days were wealthy, because it was costly both to travel to the Marsh from San Francisco and to lease hunting rights. Decisions about railroad placement and continued maintenance may have been at least partly due to the influence of wealthy duck hunters (Arnold 1996). Access became easier after the 1913 opening of the railroad along the east side of the Marsh, and the establishment of duck clubs followed (Arnold 1996). From 1880-1930, with the arrival of railroads and construction of levees to restrain tidal water flow, much of Suisun Marsh was converted to agriculture. However, the success of agriculture was relatively short-lived, because increasing soil salinity, at least partially a result of upstream water

diversions to irrigate farms in the Central Valley, made agriculture unprofitable. Ultimately much of the recently reclaimed farmland was converted back into wetland habitats for duck hunting clubs.

Today, Suisun Marsh is one of the largest contiguous brackish marshes in the western United States, and contains 12% of the remaining natural wetlands in California.[1] The continuity and abundance of wetlands in the Marsh is attributable to efforts of duck hunters interested in maintaining high quality waterfowl habitat. Today, 75% is privately owned and managed for waterfowl habitat and hunting opportunities, usually at considerable expense to the landowners (Gill and Buckman 1974). The majority of these privately held wetlands are managed in consultation with the Suisun Resource Conservation District. Presently, 158 privately owned duck hunting clubs exist in Suisun Marsh, and together with the California Department of Fish and Game's Grizzly Island Wildlife Area, provide over 21,000 ha of wetland habitats.[1] These diked wetlands are managed to control the daily tidal influence, reduce salt accumulation in the soil, and promote food production for waterfowl. In particular, the Marsh provides important wetland resources during early winter migration (September-November) when many waterfowl have arrived in California, but when other wetlands are not yet flooded in the Central Valley. Suisun Marsh also provides waterfowl habitats during drought periods, when other Central Valley wetlands are limited.

**Overview: Wintering Waterfowl**

*Population Trends.* California, and in particular the Central Valley, is a major wintering area for waterfowl in North America. Nearly 5 million ducks, geese, and swans winter within California, accounting for 68% of the wintering waterfowl in the Pacific Flyway.[2] Importantly,

[1] http://www.water.ca.gov/suisun/

41% of the North American breeding population of northern pintail (see Table 5-1 for scientific names) winters in California.[2] Suisun Marsh plays an important role relative to its size, supporting more than 60,000 wintering waterfowl each year (Table 5-1).

Wintering waterfowl populations have been surveyed annually in California since 1953 by the California Department of Fish and Game in conjunction with the U.S. Fish and Wildlife Service. We used these mid-winter waterfowl population indices[3] to assess long-term trends (since the 1950s) in California, as a whole, and in Suisun Marsh in particular.[4] Mid-winter waterfowl surveys are subject to substantial survey biases when viewed at small temporal and spatial scales, but they provide the only long-term estimates of overall population trends and species composition over the last 60 years. These results represent population indices rather than actual population size estimates. Prior to this time, waterfowl abundance data are limited. Duck hunting club harvest records are among the better sources of data for waterfowl in the late 1800s and early 1900s, and published records are available from several duck hunting clubs in Suisun Marsh.

The Ibis Gun Club (established 1879) and Tule Belle Shooting Club (established 1886) are among the oldest duck clubs in Suisun Marsh (Arnold 1996; Hall 2011). The Tule Belle Club was characterized as having shallow ponds (more suitable for dabbling ducks) and the Ibis Gun Club had deeper ponds (more suitable for diving ducks; Stoner 1937). Stoner (1934; for

[2] Based on mean mid-winter waterfowl population size indices from 2000-2009.
[3] Mid-winter waterfowl data were collected by the California Department of Fish and Game and U.S. Fish and Wildlife Service, and was kindly provided by Dan Yparraguirre, Shaun Oldenburger, Mike Wolder, and Cheryl Strong. The mid-winter waterfowl index represents an estimated population abundance at the time and location of each survey, and is not extrapolated to estimate true population sizes. Because additional transects were periodically flown over Suisun Bay, Grizzly Bay, and Honker Bay by the U.S. Fish and Wildlife Service, especially in more recent decades, we removed these counts from the Suisun Marsh totals to eliminate possible bias. We also removed the California Department of Fish and Game's count for scaup in 1955, since it was more than 121 times the mean scaup count from 1953-1962 and likely was data collected from Suisun Bay (the original data sheets did not differentiate between Suisun Marsh and Suisun Bay, unlike latter surveys).
[4] The Suisun Marsh survey strata include all wetlands within Suisun Marsh, but exclude Grizzly Bay, Suisun Bay, and Honker Bay where most diving ducks and sea ducks would occur.

Tule Belle Club) and Stoner (1937; for Ibis Gun Club) obtained club hunting archives and published their harvest records. In the late 19th century, there was no regulatory limit in California on the number of ducks that could be harvested, but after 1901 the limit was 50 ducks per day (Arnold 1996).

During 25 hunting seasons from 1882 to 1907, Ibis Gun Club members (3 to 5 people per day) harvested 36,126 ducks, 595 geese (mostly snow geese), and 51 swans, with members averaging 20 birds harvested per person per day (Stoner 1937). During 16 hunting seasons from 1885 to 1901, Tule Belle Club members (4 to 12 people per day) harvested 20,844 ducks, 441 geese (mostly snow geese), and 8 swans, with members averaging a daily bag of 16 birds (Stoner 1934).

Combining the two duck hunting clubs' records shows that the majority of ducks harvested in the late 1800s (*N*=56,970) consisted of pintail (28%), wigeon (25%), green-winged teal (17%; includes some cinnamon teal that were not differentiated), canvasback (15%), shoveler (5%), mallard (5%), scaup and ring-necked ducks (2%, not differentiated), ruddy ducks (1%), bufflehead (1%), and gadwall (<1%; Stoner 1934, 1937). Additionally, hunters harvested 1,036 geese (85% snow geese, 10% white-fronted geese, and 5% Canada geese) and 59 swans, likely tundra swans, at the two clubs (Stoner 1934, 1937). Although this is just a sampling of hunter harvest in those days, these two clubs represent waterfowl abundance at both shallow and deep-water habitats over two decades. Therefore, these data likely characterize the relative species composition of the Marsh, except possibly for ruddy ducks (which hunters likely avoided), and are suggestive of very large population sizes of ducks and snow geese in Suisun Marsh during the late 1800s.

Suisun Marsh continued to be an important wintering area for waterfowl, and state agencies established several public waterfowl areas in the mid-1900s, with the establishment of Joice Island Refuge in 1931 and Grizzly Island Waterfowl Management Area (now called the Grizzly Island Wildlife Area) in 1952. The continued abundance of ducks was demonstrated on opening day of the hunting season in 1952 at the Grizzly Island Wildlife Area when 598 public hunters harvested 5,200 ducks (9 ducks per hunter; Hall 2007). Since then, 12 additional former duck hunting clubs, as well as Joice Island Refuge, have been added to the Grizzly Island Wildlife Area complex, making it the largest single (6,070 ha) managed property in the marsh.

Suisun Marsh currently provides wintering habitat for more than 60,000 waterfowl, nearly 13,000 coots, and countless other shorebirds, seabirds, wading birds, and terrestrial birds (**Table 5-1**). Dabbling ducks are by far the most numerous (55,000), followed by diving ducks (3,000), geese (1,500), sea ducks (600), and swans (350).[5] These numbers are well below the Central Valley Joint Venture (CVJV) Implementation Plan's peak population objective of 300,000 ducks wintering in the Suisun Basin (CVJV 2006), and well below the average of 367,700 waterfowl present in Suisun Marsh during the 1950s.[6]

Population trends for waterfowl in the Marsh have declined for dabbling ducks and geese, remained stable for diving ducks and the very few swans that occur there, and have slightly increased for sea ducks (Figure 5-1). The same trends occur even after accounting for California-wide population trends (Figure 5-2), indicating that proportionately fewer dabbling ducks and geese winter in Suisun Marsh than did historically (Figure 5-3). Much of the decline in dabbling ducks occurred between 1950 and 1970 and is the result of a significant decline in pintail during this time period. Pintail accounted for the majority of dabbling ducks historically

[5] Mean mid-winter waterfowl population size index from 2000-2009.
[6] Mean mid-winter waterfowl population size index from 1953-1962.

(Table 5-2); therefore, after removing pintail from our analysis, the data still indicate a slight decline in other dabbling ducks using Suisun Marsh (Figures 5-1B, 5-3B). This decline in other dabbling ducks, however, has been much less pronounced since 1980. Also of note, the decline in 'dark' geese (Canada geese and white-fronted geese) likely is attributable, in part, to distributional shifts in their wintering areas, rather than population declines or specific avoidance of the Marsh. In fact, small cackling geese and white-fronted geese have experienced population growth in the Pacific Flyway over the past several decades (Collins et al. 2011). Small cackling geese began "short-stopping" in Oregon and Washington instead of continuing their southern winter migration into California. Similarly, the decline in white-fronted geese is partly due to increased flooded rice and wetland habitat within the Sacramento Valley and a correspondingly distributional shift of white-fronted geese out of the Marsh and Delta region in the 1990s (Ackerman et al. 2006).

Many species of dabbling ducks wintering in Suisun Marsh have declined in numbers (Figure 5-4). One exception is gadwall, whose population in the Marshdecreased from the 1950s to 1970s, increased in the 1980s, and has been stable since the 1990s (Figure 5-4F). Concurrently, gadwall populations have rapidly increased both within California (Table 5-1) and continent-wide (U.S. Fish and Wildlife Service 2011). When the state-wide increase in gadwall is accounted for, the proportion of California gadwall wintering in Suisun Marsh has actually declined slightly. Green-winged teal have enjoyed population increases in California (Table 5-1) and continent-wide (U.S. Fish and Wildlife Service 2011), yet have declined in the Marsh relative to their state-wide abundance. Similarly, shoveler have increased dramatically in California (Table 5-1) and continent-wide (U.S. Fish and Wildlife Service 2011), yet their population index in Suisun Marsh has merely remained stable. Therefore, wintering dabbling

ducks by and large have shown significant declines in the Marsh. One contributing factor to the decline of dabbling ducks in the Marshrelative to other parts of the state in recent decades may be the increased wetland area in the Central Valley. For example, wetlands in the Central Valley have increased due to the 1990 implementation of the Central Valley Joint Venture (Fleskes et al. 2005a), increased land area used in rice (*Oryza sativa*) production (Fleskes et al. 2005b), and the widespread practice of flooding, rather than burning, rice straw residues for decomposition due to burning restrictions enacted in 1991 (California Rice Straw Burning Reduction Act of 1991).

Most notable is the decline of pintail (Figure 5-4A), which historically outnumbered all other species of waterfowl wintering in Suisun Marsh (Table 5-2). During the 1950s, an average of 235,800 pintail wintered in the Marsh (Table 5-1), accounting for 54% of all waterfowl (Table 5-2**)**. In contrast, by the 2000s, only 14,000 pintail, or 20% of waterfowl, wintered in Suisun Marsh (Tables 5-1 and 5-2). This dramatic decline reflects, in part, broader declines in pintail at the continental scale (U.S. Fish and Wildlife Service 2011). In fact, pintail represent the only major dabbling duck species in North America, besides American black ducks (*Anas rubripes*), whose population has remained depressed after the 1986 implementation of the North American Waterfowl Management Plan, which was established in response to record-low waterfowl populations continent-wide. Yet, even after accounting for this overall decline, proportionately fewer pintail winter in Suisun Marsh today relative to the state-wide population than historically.

Approximately 13% of California's pintail used the Marsh in the 1950s, but that percentage has steadily declined to only 1% in the 2000s (Table 5-1). Therefore, the dramatic decline in the pintail population index in the Marsh reflects both the decline in the continent-wide population and fewer pintail wintering in the Marsh relative to other parts of the state. This decline of pintail has led many land managers to prioritize management for other waterfowl

species and change wetland management in the Marsh from the shallow open water habitats preferred by pintail to the more vegetated marsh habitats preferred by other dabbling ducks, such as mallards (S. Chappell, personal communication).

In contrast to dabbling ducks and geese, diving duck abundance has remained relatively stable (Figure 5-1C) and sea ducks have increased within the Marsh (Figure 5-1D). The increase in sea ducks is attributable to bufflehead, which have increased in the Marsh proportionately faster than their overall increase within the state. Nonetheless, overall sea duck and diving duck population sizes are much smaller in the Marsh than current populations of dabbling ducks (Table 5-1).

Presently, 90% of waterfowl wintering in Suisun Marsh are dabbling ducks, followed by diving ducks (5%), geese (2%), and sea ducks (1%; Table 5-1). Furthermore, the majority of diving ducks and sea ducks occur at Joice Island, a deep-water wetland unit adjacent to Montezuma Slough and Suisun Slough, and on Mallard Reservoir, located south of Suisun Bay just north of Concord. Therefore, present management in the Marsh remains focused on managing wetlands for dabbling ducks.

It is unlikely that any continued decline of dabbling ducks could be compensated for by increases in diving ducks or sea ducks. Diving ducks and sea ducks require distinctly different habitat requirements than dabbling ducks, preferring deeper water with a diet favoring invertebrates (including bivalves) rather than plants. Interestingly, coots also have declined in abundance within Suisun Marsh (Table 5-1). Coots are a species of rail, but, like dabbling ducks, predominantly use freshwater and brackish wetlands. Whereas California populations of coot have more than tripled in the last 25 years, the wintering population of coot within the

Marsh has not changed over the same time period. The decline of coots along with the decline of dabbling ducks in the Marsh indicates larger landscape changes.

*Waterfowl Habitat Use.* The vast majority of waterfowl that winter in Suisun Marsh are dabbling ducks (Table 5-1), and they primarily use managed wetland habitats provided by duck hunting clubs and state wildlife areas. Casazza et al. (in press), radio-marked female pintails and tracked them each winter from 1990 to 1993. They found that habitats used varied between day, when ducks typically roost and rest, and night, when ducks primarily forage. Pintail selected undisturbed sanctuaries during the day and preferred managed wetland habitats containing a relatively high density of brass buttons (*Cotula coronopifolia*) at night. There also is evidence for limited movements of ducks between Suisun Marsh and the nearby Delta region (Casazza 1995, Miller et al. 2009).

We re-analyzed data obtained with radio-marked pintail specifically to examine habitat selection by ducks in Suisun Marsh. To do so, we compared the spatial patterns of habitat use by ducks to the availability of those habitats at two spatial scales.[7] We estimated habitat use as the proportion of locations of radio-marked pintail found within each habitat type. We found that pintails strongly selected managed wetland habitats at both small and large scales of analysis, with managed wetland habitat use much greater than its availability (Figure 5-5). Pintail avoided tidal marshes, bays and sloughs, and other habitats (Figure 5-5). These findings are consistent with dabbling duck habitat associations for other areas with tidal marsh habitat. For example, along the coast of South Carolina, the occurrence of dabbling ducks in managed coastal

[7] We estimated habitat availability at two spatial scales using the hierarchical ordering process suggested by Johnson (1980) for habitat selection studies. For first order habitat selection, we considered all the area contained in the Suisun Marsh Basin boundary to be potentially available to ducks. For third order habitat selection, we considered all the area contained in the pintail population's home range, as determined by minimum convex polygon using all 7,825 telemetry locations from the 215 radio-marked pintails. We categorized habitats as tidal marsh, managed wetlands, bays and waterways, and other habitat (which included uplands and grazed lands) using the Bay Area EcoAtlas habitat categories (SFEI 1998).

freshwater impoundments was significantly greater than expected by chance, while the occurrence of dabbling ducks in unmanaged tidal wetland habitats was significantly less than expected (Gordon et al. 1998).

*Waterfowl Diets*. Similar to most managed wetland areas within the Central Valley, Suisun Marsh wetlands are managed primarily for waterfowl food production, especially food for dabbling ducks. However, brackish water in the Marsh makes it difficult to manage for plant species which tend to be highly productive and provide abundant energy-rich seeds sought by waterfowl in the Central Valley. Early studies of waterfowl food plants revealed that most ducks in Suisun Marsh fed principally on seeds of several moist-soil plant species. In particular, two studies discovered that ducks used alkali bulrush (salt marsh bulrush; *Bolboschoenus maritimus*) and the alien species brass buttons (*Cotula coronopifolia*) more than other foods present in the Marsh (George et al. 1965; Mall 1969).

On the basis of these studies, biologists developed plans for managing salinity levels that would enable growth of these key waterfowl food plants in wetlands (Miller et al. 1975; Rollins 1973, 1981). The plans were based largely on findings that the duration of soil submergence and soil salinity are the two primary factors that most influence vegetation growth (Mall 1969; Rollins 1973). Because of the seasonally brackish nature of Suisun Marsh, careful management was required to prevent high soil salinities. Rollins (1981) found that circulation of water and multiple leach cycles in spring reduced salinity in plants' root zones and, coupled with specific flooding durations, encouraged plant growth by alkali bulrush, fat hen (*Atriplex prostrata*), and brass buttons. Accordingly, salinity standards for the Marsh were set to ensure desired soil salinity conditions for waterfowl food plants (Suisun Ecological Workgroup 2001).

More recent studies (Burns 2003, Burns et al. 2003) found that ducks consumed over 30 species of plant seeds, with seeds of only 10 species accounting for >90% of the diet. The most important food plants for ducks included alkali bulrush, watergrass (*Echinochloa crus-galli*) and western sea purslane (*Sesuvium verrucosum*), although their importance varied among duck species (percent aggregate dry mass: 37% sea purslane, 24% alkali bulrush, 21% watergrass, 6% fat hen, 4% swamp timothy (*Crypsis schoenoides*), 3% pickleweed (*Salicornia pacifica*), 2% brass buttons, and 1% each for smartweeds (*Persicaria* spp.), rabbit's foot grass (*Polypogon monspeliensis*), and dock (*Rumex crispus, R. occidentalis*). Ducks also consumed over 20 invertebrate taxa, but they composed a very small proportion of the total diet (<5%). Overall, these diet studies confirmed the importance of moist soil seed plants for dabbling ducks in Suisun Marsh.

**Overview: Breeding Waterfowl**

Waterfowl are highly migratory, and most waterfowl that winter within the United States originate from breeding grounds in Alaska and Canada. California is unique among wintering areas for North American waterfowl, in that a large percentage of mallard, gadwall, and cinnamon teal are produced locally on breeding grounds within the state. In fact, over 60% of mallards harvested in California originate in California, with the remaining birds originating from Oregon, Washington, British Columbia, Alberta, Alaska, and the Yukon Territories of Canada (Munro and Kimball 1982, Ackerman et al. 2010).

The breeding population index of dabbling ducks in California has averaged 562,000 ducks, of which 364,000 are mallard, since the annual breeding population survey[8] was

[8] Breeding population survey data is collected by the California Department of Fish and Game, and was kindly provided by Dan Yparraguirre and Shaun Oldenburger.

established in 1992 (Figure 5-6). In addition to mallard (62%), these ducks include gadwall (15%), cinnamon teal (8%), shoveler (6%), wood duck (1%), and pintail (1%). On average, 5% of California's surveyed mallard and 7% of gadwall breed in Suisun Marsh. The larger areas in the Sacramento Valley (36%), northeastern California (25%), and San Joaquin grasslands (16%) support the majority of mallard (other areas are East Valley: 6%, San Joaquin desert: 4%, Napa marshes: 4%, San Francisco Bay and Sacramento-San Joaquin Delta: 2%, and West Valley: 2%).[9]

The *proportions* of mallard and gadwall breeding in Suisun Marsh relative to their state-wide breeding populations have declined significantly since 1992 (Figure 5-6). Nevertheless, breeding *densities* of ducks in Suisun Marsh are still among the highest in the state. The Marsh is considered a hot-spot for high nesting densities and is even considered high relative to more traditional nesting areas in North America, such as the Prairie Pothole Region in the central United States and Canada. In addition to occurring in high nesting densities, ducks in Suisun Marsh also tend to initiate nesting attempts earlier in the breeding season than elsewhere in North America, thus yielding more opportunities for hens to produce a successful clutch during the summer (McLandress et al. 1996; Krapu et al. 2002).

One of the world's longest-running studies on nesting ecology of ducks has been conducted annually in Suisun Marsh since 1985 at the Grizzly Island Wildlife Area (Ackerman et al. 2009). The majority of breeding ducks are mallard (75%), gadwall (17%), pintail (5%), cinnamon teal (2%), and shoveler (1%). However, in recent years the proportion of nesting mallard has been much lower (60%), while the proportion of gadwall (33%) has increased. This upland habitat used for nesting by ducks also is used for nesting by northern harriers, short-eared owls, American bitterns, ring-necked pheasants, and numerous songbirds. The study

[9] Mean breeding population size index from 1992 to 2011.

documented a dramatic increase in dabbling duck nesting density, up to 16 nests per ha, followed by a precipitous decline (Ackerman et al. 2009). The decline in duck productivity may be associated with upland vegetation quality. In the 1980s and early 1990s, the California Department of Fish and Game actively managed vegetation in several of the fields by planting various mixes of tall wheat grass (*Elymus ponticus*), vetch (*Vicia* spp.), alfalfa (*Medicago sativa*), perennial rye grass (*Festuca* spp.), and wheat (*Elymus* spp.) that that produced high quality, dense nesting cover for ducks. Ducks seemed to respond positively to this active upland vegetation management, and nesting densities increased until they peaked in 1997. During February1998, a series of strong El Niño storms flooded the Marsh (including Grizzly Island Wildlife Area) as a result of levee breaches and overtopping. Brackish water subsequently intruded and much of the vegetation used as nesting cover was flooded, and in the following years the habitat deteriorated. Concurrently, nesting densities declined after 1997.

Nest survival is highly variable in Suisun Marsh (McLandress et al. 1996; Ackerman 2002a, b; Ackerman et al. 2003, 2004), as it is in most duck nesting areas, but has shown a general decline since 1985 (Ackerman et al. 2009). Still, in most years, nest survival has been above the estimated 15% to 20% nest success required to maintain a stable mallard population (Cowardin et al. 1985) and is among the highest reported for ducks in North America (McLandress et al. 1996). The reason for the decline of nest density and nest survival most likely involves interactions among predators, alternate prey resources, and habitat quality. Since 2008, vegetation at Grizzly Island Wildlife Area has been undergoing large-scale restoration of upland plant communities, and water delivery infrastructure has been improved in an attempt to improve waterfowl breeding opportunities (Ackerman et al. 2009). Although it may take several

years to assess breeding duck response to these changes, a rapid increase in nest densities and improved nest survival has been documented.

After breeding, waterfowl lose and regrow their flight feathers (molt) over about three weeks in late summer, during which time they are flightless. This is a critical time period, because ducks are more susceptible to predation, physiological stress, and disease. Most mallard that breed in the Marsh do not molt there , but instead migrate northward to the Sacramento Valley and Klamath Basin (Yarris et al. 1994). Large wetlands are traditionally flooded during summer and are dominated by tall emergent vegetation, such as bulrush (*Schoenoplectus* spp.) and cattail (*Typha* spp.), which can provide important cover, protection, and a reliable food source during this vulnerable time. The molt migration from Suisun Marsh suggests that predictably available molting habitats within the Marsh are limited. This further suggests that efforts to improve and expand molting habitat could be successful management actions to sustain waterfowl populations (Fleskes et al. 2010).

The widespread contribution of local reproduction of ducks in Suisun Marsh is illustrated by band recoveries from hunter-killed ducks. Dabbling ducks, primarily mallards, have been banded during summer (May-September) and more than 9,000 of these ducks have been recovered throughout North America since 1932 (Figure 5.7).[10]. Banding data illustrate the extensive connectedness of Suisun Marsh ducks to the Pacific Flyway and throughout the continent's dabbling duck populations.

[10] Ducks were banded within the Suisun Marsh by California Waterfowl and California Department of Fish and Game, and band recoveries were thereafter managed by the U.S. Geological Survey's Bird Banding Lab.

**Data Gaps**

There are numerous data gaps for for wintering and breeding waterfowl in Suisun Marsh, and we highlight five major areas of needed research below.

1. *If a portion of Suisun Marsh is restored to tidal marsh, will there be enough food to maintain the present size of waterfowl populations?* The Central Valley Joint Venture estimates that converting 2,025 ha (5,000 acres) of managed wetlands to tidal marsh in Suisun Marsh could reduce food resources below those necessary to support the wintering population of dabbling ducks by mid-January (CVJV 2006). However, because detailed information about food values of brackish seasonal and tidal wetlands in the Marsh is lacking, this estimated model projection should be refined when more precise estimates of seed production, abundance of vegetation and invertebrate food resources, available energy of seed and other foods, and resource availability (e.g., water depth) to waterfowl become available.

2. *Will ducks use tidal marsh habitats to the same extent as they use managed wetlands?* When the Marsh was relatively less altered in the late 1800s, wintering waterfowl abundance was substantially greater than present populations. However, under the highly altered landscape of today, most dabbling ducks do not use tidal marsh habitats (Figure 5.5). Whether or not ducks would use tidal areas within Suisun Marsh if their extent increased markedly is questionable, because overall salinity levels have already increased due to water diversions, and waterfowl food production within tidal marshes is considerably lower than in diked, brackish wetlands.

3. *Will Suisun Marsh continue to provide habitat for some of the highest nest densities and reproductive success of breeding ducks in California?* Suisun Marsh provides some of the highest nesting densities of ducks in California and contributes a relatively large proportion of ducks to the state relative to its size. How the future habitat mosaic will affect duck nest

densities and reproductive success if waterfowl habitat configurations in the Marsh are altered is unknown.

4. *Would an increase in tidal marsh and overall salinity levels in wetlands reduce duck reproductive success?* Considerable evidence indicates that duckling growth and survival can be affected by water salinity levels because salt glands of ducklings are poorly developed at hatching. For example, ducklings subjected to water salinity as low as 4 milli Siemens per cm (mS/cm) have impaired growth rates, whereas 20 mS/cm is lethal to mallard ducklings (Mitcham and Wobeser 1988a,b). Survival rates of ducklings and shorebird chicks are not known for Suisun Marsh, but these data will be critical to evaluate future habitat restoration plans.

5. *What are the societal impacts of having fewer waterfowl in Suisun Marsh?* The fact that Suisun Marsh is the largest contiguous brackish marsh in the western United States owes much to the conservationist legacy of duck hunting. Suisun Marsh wetlands have been preserved through the duck hunting heritage at considerable expense, with 75% of wetlands in Suisun Marsh under private ownership (Gill and Buckman 1974). The societal impacts of returning portions of Suisun Marsh to tidal marsh are important, although some conversion is inevitable with sea level rise and the increasing pressure on the Delta's levee system (Chapter 3). We urge a collaborative approach to Suisun Marsh restoration and maintaining the strong stewardship duck hunters have provided to the Marsh since the turn of the 20$^{th}$ century.

**The Future**

*Carrying Capacity for Waterfowl.* Ultimately, the goal of understanding waterfowl population trends and diets is not only to improve habitat management programs, but also to determine the capacity of Suisun Marsh to support current (or desired) populations of waterfowl.

To establish wintering habitat objectives, the Central Valley Joint Venture (CVJV; one of the original six priority joint ventures formed under the North American Waterfowl Management Plan) uses a bioenergetic model that calculates the energy requirements of a waterfowl population. The model is useful for assessing current habitat conditions for wintering waterfowl, and it also can be used to predict how changes in policy, land use, or habitat programs might impact waterfowl (CVJV 2006).

The CVJV waterfowl population goal is a population size comparable to those of the mid-1970s under the directive of the North American Waterfowl Management Plan. Suisun Marsh supported up to 300,000 waterfowl (mainly dabbling ducks) at peak abundance by late December in the 1970s, with numbers tapering to 50,000 by mid-February. Estimating the energy supply (food abundance and caloric value) for waterfowl in Suisun Marsh is much more difficult, because systematic studies have not been conducted. However, several studies have suggested that plants in brackish or tidal saline habitats have lower seed abundance, produce seeds of lower metabolizable energy, and result in waterfowl in poorer body condition (Mall 1969; Atwater et al. 1979; Tietje and Teer 1988, 1996; Ballard et al. 2004). Therefore, the CVJV developed planning models for Suisun Marsh under several scenarios. One model assumed that moist soil seed production in Suisun Marsh was equivalent to seed production in freshwater marshes (566 lbs/acre). An alternative model used an estimate of seed production that was half that of freshwater marshes (283 lbs/acre). Under both scenarios, the CVJV then incorporated potential effects of the conversion of 2,025 ha of managed wetlands into tidal marsh (CVJV 2006).

The bioenergetic model outcomes under these different scenarios are profoundly different. Under the assumption that brackish wetlands in Suisun Marsh have similar food

production as freshwater wetlands, food supply is more than adequate to meet the foraging needs of desired waterfowl populations; this remains true even if, for example, 2,025 ha are restored to tidal marsh. However, if food production in tidal marsh is half that of managed freshwater wetlands, then the food supply could be exhausted by early spring. Furthermore, the impact of converting 2,025 ha of managed wetlands to tidal marsh under this scenario could be large, with food demand exceeding available supply by mid-January. Thus, the impact of tidal marsh restoration on waterfowl from a bioenergetics perspective may either be of little or great consequence, depending largely on baseline levels of seed production and quality in both managed and tidal marshes. Such results suggest that alternative management scenarios need to be considered, such as concentrating efforts (e.g., levee maintenance) in areas most defensible from sea level rise, land subsidence, and other factors (see Chapter 9).

*The Past and Future of Waterfowl.* If we look far enough into the future, sea level rise and levee failures will likely flood some portion of the currently diked wetland landscapes in Suisun Marsh (Knowles 2010; Stralberg et al. 2011). In the near term (e.g., this century), reinforcing levees, raising levee crown heights, using large water pumps, and managing soil salinity levels with intensive leaching strategies may be able to overcome such flooding events and salinity intrusion, and many diked wetlands may be able to be retained.

If the immediate future for Suisun Marsh includes restoring a portion of the marsh to a tidal system to prepare for future conditions, it is important to understand how this will impact the carrying capacity of Suisun Marsh and the waterfowl populations that depend on these resources. Yet, this necessary information is incomplete and uncertain. We know that in the past nearly 370,000 waterfowl wintered in Suisun Marsh, and we know that the plant community composition was undoubtedly different. Atwater et al. (1979, p. 369), for example, described the

tidal-marsh plants of Carquinez Strait and Suisun Bay as "an intricate, mutable transition between the salt marshes of San Francisco Bay and the freshwater marshes of the Delta." Plant species that prevailed in the transitional tidal zone of Suisun Marsh that may have provided food value to waterfowl, included pickleweed, various bulrushes, brass buttons, rabbit's foot grass, and lamb's quarters (*Chenopodium album*; Atwater et al. 1979). Invertebrates and bivalves are important to diving ducks and sea ducks, but dabbling ducks rely on invertebrates primarily during late winter and early spring when they require protein for migration and breeding. Therefore, with the exception of alkali bulrush and potentially sago pondweed (*Stuckenia pectinatus*; Moffitt 1938), it is unclear what food plants might have produced sufficient seeds for the large numbers of waterfowl in Suisun Marsh prior to the 1850s.

Moreover, it is unclear how the existing food base would change as a result of tidal marsh restoration efforts. For example, higher salinity levels during drought periods in Suisun Marsh substantially reduced the growth and seed production of alkali bulrush (Mall 1969; Atwater et al. 1979). Studies in Gulf Coast marshes have shown that foods consumed in relatively saline habitats by pintails contained less protein and fat than foods consumed in inland freshwater wetlands and flooded rice fields, and that ducks in saline environments had lower body condition (Ballard et al. 2004). Presently, body condition of pintail and mallard are slightly better in Suisun Marsh than in the Delta, suggesting that saline conditions are not currently affecting adult duck body condition within the marsh (Miller et al. 2009).

The fact that waterfowl populations were much larger historically in Suisun Marsh and that the more saline conditions likely favored plant species with lower seed yields, is not necessarily at odds. For example, food resources may have been limited when considered on a *per unit area* basis, but this low productivity may have been more than compensated for by the

historically extensive wetlands that occurred in the Suisun Marsh, Delta, and Central Valley. The expansiveness of California's wetland areas is long past, with 91% of wetlands in California lost to agriculture and urban development (Dennis and Marcus 1984; Dahl 1990). To support the remaining waterfowl populations, we may not be able to simply turn back the clock with a desired habitat end-state mimicking the tidal marshes before the Gold Rush. California has been so highly modified that active, and perhaps even intense, wetland management will be required to maintain the diversity and abundance of waterfowl and other wildlife.

A similar conundrum exists just down river in San Francisco Bay, where former salt evaporation ponds provide habitat for most of the migrating, wintering, and breeding shorebirds, seabirds, and waterfowl using the Bay. The restoration of these salt ponds to tidal marsh is being balanced with a mosaic of intensively managed wetlands for waterbird habitat (http://www.southbayrestoration.org/). In both San Francisco Bay and Suisun Marsh, the question is the same: *How do we provide for the historical diversity and abundance of animals that existed in the past within a tidal marsh system that has been drastically reduced in size?* The answer is simply that we cannot. Thus, having a marsh mosaic that includes managed wetlands with their higher productivity, and tidal marsh with their more natural state, may be the only way to both restore tidal marsh habitat and maintain the diversity and abundance of animals that once used these habitats. The intellectual and logistical challenges that face us in Suisun Marsh are to find an array of solutions that balance the needs of waterfowl with the myriad of other ecological services provided by the marsh.

**Summary**

Five million waterfowl, representing 68% of waterfowl in the Pacific Flyway, winter within California. Suisun Marsh hosts over 60,000 of these waterfowl, and plays an important role relative to its size (470 $km^2$ or 116,000 acres). Current waterfowl abundance is below the population objective for 300,000 ducks wintering in Suisun Basin, and well below the nearly 370,000 waterfowl that wintered there during the 1950s. Long-term population trends for dabbling ducks and geese are declining in the marsh, but diving ducks and swans are stable, and sea ducks are slightly increasing. These same trends occur after accounting for California-wide population trends, indicating that proportionately fewer dabbling ducks and geese are choosing to winter in Suisun Marsh than historically. Most notable is the decline of pintail. During the 1950s, more than 235,000 pintail accounted for 54% of all waterfowl using the marsh, but, by the 2000s, their numbers had declined to only 14,000 pintail, or 20% of all waterfowl. The decline of pintail led many land managers to change wetland management from shallow open water habitats preferred by pintail to more vegetated habitats. The increase in sea ducks in Suisun Marsh is attributable to bufflehead, which have increased in the marsh disproportionately faster than their increase within the state. Dabbling ducks presently -- as they did historically -- account for 90% of wintering waterfowl in Suisun Marsh, followed by diving ducks (5%), geese (2%), sea ducks (1%), and swans (1%). Dabbling ducks strongly select managed wetland habitats and avoid tidal marshes, bays, and sloughs, feeding mainly on seeds of alkali bulrush, watergrass, and sea purslane.

Suisun Marsh also supports among the highest densities of breeding ducks in California. Approximately 5% of California's 364,000 surveyed mallards and 7% of California's 90,000 gadwall breed in the relatively small area of the Marsh. Ducks banded in the Marsh are

recovered throughout the Pacific Flyway and North America, illustrating its connectedness to the continent's waterfowl populations.

With more than 90% of California's wetlands lost, Suisun Marsh represents one of the last remaining contiguous wetland habitats in the state. Waterfowl have long been present in the Marsh at considerably larger abundance. Maintaining the present, if not historic, diversity and abundance of waterfowl in the Marsh likely will depend on active wetland management for higher yielding seed plants, which increase the carrying capacity of the few remaining wetlands.

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**Figure Legends**

**Figure 5.1.** Mid-winter population size indices for waterfowl taxa groups in Suisun Marsh during 1953 to 2009. Waterfowl are categorized as A) dabbling ducks, B) dabbling ducks not including pintail, C) diving ducks, D) sea ducks, E) dark geese, and F) white geese. See Table 1 for species within each taxa group. Solid line illustrates the population trend and was estimated with a LOESS function. Mid-winter waterfowl data were collected by the California Department of Fish and Game and U.S. Fish and Wildlife Service. Suisun Marsh was not surveyed as part of the mid-winter waterfowl survey in 2010 and 2011.

**Figure 5.2.** Mid-winter population size indices for waterfowl taxa groups state-wide in California during 1953 to 2011. Waterfowl are categorized as A) dabbling ducks, B) dabbling ducks not including pintail, C) diving ducks, D) sea ducks, E) dark geese, and F) white geese. See Table 1 for species within each taxa group. Solid line illustrates the population trend and was estimated with a LOESS function (Neter et al. 1996). Mid-winter waterfowl data were collected by the California Department of Fish and Game and U.S. Fish and Wildlife Service.

**Figure 5.3.** The proportion of waterfowl in each taxa group wintering in Suisun Marsh relative to the entire state of California during 1953 to 2009. Waterfowl are categorized as A) dabbling ducks, B) dabbling ducks not including pintail, C) diving ducks, D) sea ducks, E) dark geese, and F) white geese. See Table 1 for species within each taxa group. Solid line illustrates the population trend and was estimated with a LOESS function. Mid-winter waterfowl data were

collected by the California Department of Fish and Game and U.S. Fish and Wildlife Service. Suisun Marsh was not surveyed as part of the mid-winter waterfowl survey in 2010 and 2011.

**Figure 5.4.** Mid-winter population size indices for dabbling ducks by species in Suisun Marsh during 1953 to 2009. Dabbling ducks are A) northern pintail, B) mallard, C) American wigeon, D) northern shoveler, E) American green-winged teal, and F) gadwall. Solid line illustrates the population trend and was estimated with a LOESS function. Mid-winter waterfowl data were collected by the California Department of Fish and Game and U.S. Fish and Wildlife Service. Suisun Marsh was not surveyed as part of the mid-winter waterfowl survey in 2010 and 2011.

**Figure 5.5.** A) Locations (*N*=7,825) of 215 radio-marked female northern pintail in Suisun Marsh habitats from August to February during winters 1990-1993. B) Habitat use by radio-marked pintails in relation to habitat availability in Suisun Marsh to show habitat selection. Used habitats are represented by the percent of radio-marked pintail locations (*N*=7,825) found within each habitat type. Habitat availability was estimated two ways: those habitats available within the (1) Suisun Marsh Basin boundary as pictured in Figure 1A, and (2) minimum convex polygon (MCP) depicting the home range of the entire population of 215 radio-marked pintails. Habitats were categorized as tidal marsh, managed wetlands, bays and waterways, and other habitat (which included uplands and grazed lands).

**Figure 5.6.** Breeding population index for dabbling ducks in California (left axis) and Suisun Marsh (right axis) from 1992 to 2011. The filled black polygon represents the population size estimate for dabbling ducks in California, and the filled grey polygon represents the population

size estimate for mallards in California (left axis). The thin white line represents the population size estimate for mallard in Suisun Marsh, and the thin black line represents the population size estimate for gadwall in Suisun Marsh (right axis). Species included in the dabbling duck category were mallard, gadwall, pintail, cinnamon teal, and shoveler. Breeding population surveys were conducted by the California Department of Fish and Game.

**Figure5.7.** Location and abundance of ducks captured and banded in Suisun Marsh during the late summer (May-September), and recovered (*N*=9,368) since 1932 in North America. The main map shows recovered mallards (orange) in the western U.S., and the inset map shows recovered mallard (orange; *N*=8,367), northern pintail (green; *N*=670), gadwall (blue; *N*=246), and cinnamon teal (yellow; *N*=85) in North America. Ducks were banded within the Suisun Marsh by the California Department of Fish and Game and California Waterfowl Association, and band recoveries were thereafter managed by the U.S. Geological Survey's Bird Banding Lab.

**Table 1.** Main waterfowl species present in Suisun Marsh, their primary habitat, timing of use of Suisun Marsh, past and current population size index for Suisun Marsh and California, and long-term (1953-2011) and short-term (1990-2011) population trends for each species in Suisun Marsh, California, and proportional trend in Suisun Marsh relative to the state-wide population size index. Waterfowl population indices based on annual mid-winter waterfowl surveys conducted aerially by plane. Surveys were not conducted in Suisun Marsh in 2010 or 2011 due to inclement weather. Data from U.S. Fish and Wildlife Service and Califonria Department of Fish and Game.

| | | | | | | | | | Winter Waterfowl Population Trends [1] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Use of Suisun Marsh | | Mid-Winter Waterfowl Index (mean: 1953-1962) | | Mid-Winter Waterfowl Index (mean: 2000-2009) | | 1953-2011 | | | 1990-2011 | | |
| **Species (Family/Sub-family/Tribe)** | **Latin** | **Main Habitat** | **October-March** | **April-September** | **Suisun Marsh** | **California** | **Suisun Marsh** | **California** | **Suisun Marsh** | **California** | **Proportion in Suisun Marsh vs. California** | **Suisun Marsh** | **California** | **Proportion in Suisun Marsh vs. California** |
| Dabbling Ducks (Anatidae/Anatinae/Anatini) | | | | | | | | | | | | | | |
| Northern Shoveler | *Anas clypeata* | Freshwater Wetlands | **X** | **X** | 21,262 | 171,576 | 17,196 | 532,612 | ≈ | + | ≈ | ≈ | + | ≈ |
| Northern Pintail | *Anas acuta* | Freshwater Wetlands | **X** | **X** | 235,845 | 1,770,961 | 14,061 | 1,210,806 | − | − | − | − | + | − |
| American Wigeon [2] | *Anas americana* | Freshwater Wetlands | **X** | | 31,962 | 710,976 | 7,472 | 523,962 | − | − | ≈ | ≈ | ≈ | ≈ |
| American Green-winged Teal | *Anas crecca* | Freshwater Wetlands | **X** | | 11,679 | 163,597 | 7,296 | 405,451 | ≈ | + | − | − | + | − |
| Mallard | *Anas platyrhynchos* | Freshwater Wetlands | **X** | **X** | 22,530 | 541,384 | 6,402 | 341,705 | − | − | ≈ | − | ≈ | ≈ |
| Gadwall | *Anas strepera* | Freshwater Wetlands | **X** | **X** | 2,014 | 20,168 | 2,034 | 166,881 | ≈ | + | − | ≈ | + | ≈ |
| Cinnamon Teal | *Anas cyanoptera* | Freshwater Wetlands | **X** | **X** | 105 | 1,454 | 55 | 6,888 | ≈ | + | ≈ | ≈ | ≈ | ≈ |
| Perching Ducks (Anatidae/Anatinae/Cairinini) | | | | | | | | | | | | | | |
| Wood Duck | *Aix sponsa* | Riparian, Freshwater Wetlands | **X** | **X** | 0 | 1,550 | 0 | 1,686 | *na* | ≈ | *na* | *na* | ≈ | *na* |
| Stiff-tailed Ducks (Anatidae/Anatinae/Oxyurini) | | | | | | | | | | | | | | |
| Ruddy Ruck | *Oxyura jamaicensis* | Freshwater Wetlands | **X** | **X** | 2,269 | 37,108 | 1,439 | 85,834 | ≈ | + | ≈ | + | + | + |
| Diving Ducks (Anatidae/Anatinae/Aythyini) | | | | | | | | | | | | | | |
| Scaup [2] | *Aythya affinis & Aythya marila* | Open Bay, Wetlands | **X** | | 495 | 81,316 | 1,025 | 111,307 | ≈ | + | ≈ | ≈ | ≈ | + |
| Canvasback | *Aythya valisineria* | Open Bay, Wetlands | **X** | | 3,768 | 55,557 | 657 | 50,987 | ≈ | ≈ | ≈ | ≈ | + | ≈ |
| Ring-necked Duck | *Aythya collaris* | Freshwater Wetlands | **X** | | 44 | 648 | 105 | 57,970 | ≈ | + | ≈ | ≈ | + | ≈ |
| Redhead | *Aythya americana* | Open Bay, Wetlands | **X** | **X** | 116 | 589 | 17 | 1,629 | ≈ | + | ≈ | ≈ | ≈ | ≈ |
| Sea Ducks (Anatidae/Anatinae/Mergini) | | | | | | | | | | | | | | |
| Bufflehead | *Bucephala albeola* | Open Bay, Wetlands, Lakes | **X** | | 17 | 2,512 | 552 | 25,750 | + | + | + | ≈ | ≈ | + |
| Common Goldeneye [2] | *Bucephala clangula* | Open Bay, Lakes | **X** | | 20 | 2,522 | 84 | 2,998 | ≈ | ≈ | + | ≈ | ≈ | ≈ |
| Common Merganser [2] | *Mergus merganser* | Rivers, Lakes | **X** | | 0 | 335 | 1 | 5,875 | ≈ | + | ≈ | ≈ | ≈ | ≈ |
| Surf Scoter [2] | *Melanitta perspicillata* | Open Bay, Coastal Ocean | **X** | | 0 | 13,308 | 0 | 30,604 | ≈ | + | ≈ | ≈ | - | ≈ |
| Geese (Anatidae/Anserinae/Anserini) | | | | | | | | | | | | | | |
| Canada Goose [2] | *Branta canadensis* | Agricultural Fields, Freshwater Wetlands | **X** | **X** | 1,394 | 36,085 | 1,302 | 29,972 | ≈ | ≈ | + | ≈ | ≈ | ≈ |
| Cackling Geese [2] | *Branta hutchinsii* | Agricultural Fields, Freshwater Wetlands | **X** | | 8,976 | 125,564 | 0 | 28,609 | − | − | ≈ | *na* | ≈ | *na* |
| Greater White-fronted Goose | *Anser albifrons* | Agricultural Fields, Freshwater Wetlands | **X** | | 16,883 | 142,704 | 189 | 307,581 | − | + | − | ≈ | + | ≈ |
| Snow & Ross' Goose [2] | *Chen caerulescens & Chen rossii* | Agricultural Fields, Freshwater Wetlands | **X** | | 8,117 | 354,278 | 0 | 564,311 | − | + | − | ≈ | + | ≈ |
| Swans (Anatidae/Anserinae/Cygnini) | | | | | | | | | | | | | | |
| Tundra Swan | *Cygnus columbianus* | Freshwater Wetlands | **X** | | 281 | 15,940 | 360 | 73,765 | + | + | ≈ | ≈ | + | ≈ |
| Rails (Rallidae) | | | | | | | | | | | | | | |
| American Coot | *Fulica americana* | Freshwater Wetlands | **X** | | 57,375 | 445,528 | 12,810 | 438,216 | − | ≈ | − | ≈ | + | ≈ |
| Taxa Groups | | | | | | | | | | | | | | |
| Dabbling Ducks [3] | *Anas & Aix* | Freshwater Wetlands | **X** | **X** | 325,397 | 3,381,666 | 54,515 | 3,189,992 | − | − | − | − | + | ≈ |
| Dabbling Ducks (no pintail) [3,4] | *Anas & Aix* | Freshwater Wetlands | **X** | **X** | 89,552 | 1,610,705 | 40,454 | 1,979,186 | − | ≈ | ≈ | ≈ | + | ≈ |
| Diving Ducks [5] | *Aytha & Oxyura* | Open Bay, Wetlands | **X** | | 6,643 | 167,085 | 3,243 | 307,728 | ≈ | + | ≈ | ≈ | + | ≈ |
| Sea Ducks | *Melanitta, Bucephala, & Mergus* | Open Bay, Coastal Ocean, Lakes | **X** | | 38 | 18,677 | 637 | 65,228 | + | + | + | ≈ | − | + |
| Dark Geese [6] | *Branta & Anser* | Agricultural Fields, Freshwater Wetlands | **X** | **X** | 27,252 | 307,852 | 1,490 | 371,169 | − | ≈ | − | ≈ | + | ≈ |
| White Geese [6] | *Chen* | Agricultural Fields, Freshwater Wetlands | **X** | | 8,117 | 354,278 | 0 | 564,321 | − | + | − | ≈ | + | ≈ |
| Swans | *Cygnus* | Freshwater Wetlands | **X** | | 281 | 15,940 | 364 | 73,771 | ≈ | + | ≈ | ≈ | + | ≈ |
| Total Waterfowl | *Anseriformes* | All of the Above | **X** | **X** | 367,728 | 4,245,498 | 60,249 | 4,572,209 | *na* | *na* | *na* | *na* | *na* | *na* |

[1] Waterfowl trends were analyzed using linear regression with alpha = 0.05. A "+" means that the population is significantly increasing and a "−" means the population is significantly declining.

[2] Some species are not differentiated during mid-winter waterfowl surveys, and we have listed the dominant species only. However, canada goose includes lesser, Taverner, dusky, and western canada goose; cackling goose includes aleutian and small cackling goose; American wigeon may include some Eurasian wigeon; scaup includes both lesser scaup and greater scaup; surf scoter may include some black scoter and white-winged scoter; common goldeneye may include some Barrow's goldeneye; and common merganser may include some hooded merganser and red-breasted merganser.

[3] Wood ducks were included in dabbling duck taxa group.

[4] All dabbling ducks except northern pintails.

[5] Ruddy ducks were included in diving duck taxa group.

[6] The dark geese taxa group includes all Canada geese races *(Branta spp.* ) and white-fronted goose. The white geese taxa group includes snow goose and Ross' goose.

**Table 2.** Percent species composition of waterfowl in Suisun Marsh (left panel) and California (right panel) based on (A) mid-winter waterfowl surveys and (B) hunter harvested birds. Mid-winter waterfowl surveys were started in 1953, but were not conducted in Suisun Marsh in 2010 or 2011. Hunter harvest surveys were started in 1961. Mid-winter waterfowl survey data from U.S. Fish and Wildlife Service and Califonria Department of Fish and Game, and hunter harvest data from U.S. Fish and Wildlife Service's parts survey.

**A) Mid-Winter Waterfowl Population Index**

| | Suisun Marsh | | | | | | | California | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species[1] | 1953-1959 | 1960-1969 | 1970-1979 | 1980-1989 | 1990-1999 | 2000-2009 | 2010-2011 | 1953-1959 | 1960-1969 | 1970-1979 | 1980-1989 | 1990-1999 | 2000-2009 | 2010-2011 |
| Northern Pintail | 54.3% | 56.6% | 48.8% | 43.7% | 22.4% | 19.6% | *na* | 41.5% | 39.1% | 52.2% | 35.7% | 25.5% | 26.5% | 27.6% |
| American Wigeon | 9.7% | 7.8% | 3.9% | 5.5% | 10.8% | 12.6% | *na* | 14.8% | 15.8% | 10.6% | 11.4% | 10.9% | 11.5% | 7.9% |
| Mallard | 7.1% | 4.9% | 7.0% | 10.5% | 13.1% | 13.0% | *na* | 13.2% | 8.5% | 8.6% | 11.5% | 11.2% | 7.5% | 4.5% |
| Northern Shoveler | 5.4% | 11.7% | 13.9% | 21.4% | 26.3% | 27.8% | *na* | 3.9% | 5.1% | 10.1% | 8.9% | 9.8% | 11.5% | 13.3% |
| Greater White-Fronted Goose | 4.2% | 4.2% | 8.6% | 1.9% | 0.4% | 0.3% | *na* | 2.9% | 3.2% | 1.5% | 1.9% | 4.2% | 6.6% | 7.5% |
| American Green-winged Teal | 2.6% | 5.9% | 1.8% | 7.8% | 15.6% | 12.7% | *na* | 3.5% | 5.7% | 3.4% | 6.5% | 9.5% | 8.7% | 10.5% |
| Snow & Ross' Goose | 1.5% | 2.0% | 0.4% | 0.0% | 0.0% | 0.0% | *na* | 7.1% | 10.9% | 6.7% | 11.4% | 12.8% | 12.1% | 14.2% |
| Cackling Goose | 1.3% | 3.3% | 4.6% | 0.0% | 0.0% | 0.0% | *na* | 2.7% | 2.9% | 1.1% | 0.7% | 0.9% | 0.6% | 1.0% |
| Gadwall | 0.8% | 1.1% | 0.2% | 0.6% | 2.7% | 3.3% | *na* | 0.4% | 1.1% | 0.3% | 1.3% | 2.7% | 3.7% | 3.7% |
| Ruddy Duck | 0.7% | 0.4% | 1.1% | 2.4% | 1.6% | 2.6% | *na* | 0.8% | 1.9% | 1.3% | 2.4% | 2.2% | 1.9% | 2.4% |
| Canvasback | 0.6% | 1.2% | 7.7% | 1.4% | 2.3% | 0.8% | *na* | 1.5% | 1.1% | 1.0% | 1.0% | 0.9% | 1.1% | 1.5% |
| Canada Goose | 0.3% | 0.4% | 1.0% | 1.4% | 1.6% | 2.4% | *na* | 1.0% | 0.5% | 0.8% | 1.0% | 0.9% | 0.6% | 0.3% |
| Scaup | 0.2% | 0.0% | 0.8% | 2.3% | 1.1% | 2.6% | *na* | 1.8% | 2.0% | 0.9% | 2.4% | 2.8% | 2.5% | 2.0% |
| Redhead | 0.1% | 0.0% | 0.0% | 0.0% | 0.3% | 0.0% | *na* | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% |
| Cinnamon Teal | 0.0% | 0.1% | 0.1% | 0.0% | 0.0% | 0.1% | *na* | 0.0% | 0.1% | 0.0% | 0.1% | 0.2% | 0.2% | 0.1% |
| Tundra Swan | 0.0% | 0.1% | 0.0% | 0.0% | 0.5% | 0.5% | *na* | 0.3% | 0.7% | 0.8% | 1.4% | 1.7% | 1.6% | 1.3% |
| Ring-necked Duck | 0.0% | 0.0% | 0.0% | 0.2% | 0.1% | 0.2% | *na* | 0.0% | 0.0% | 0.0% | 0.2% | 0.7% | 1.2% | 1.1% |
| Common Goldeneye | 0.0% | 0.0% | 0.0% | 0.0% | 0.5% | 0.2% | *na* | 0.0% | 0.1% | 0.0% | 0.0% | 0.1% | 0.1% | 0.0% |
| Bufflehead | 0.0% | 0.0% | 0.0% | 0.3% | 0.2% | 1.2% | *na* | 0.1% | 0.1% | 0.1% | 0.5% | 0.6% | 0.6% | 0.3% |
| Black Brant | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | *na* | 0.1% | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.3% |
| Eider | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | *na* | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | *na* |
| Common Merganser | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | *na* | 0.0% | 0.0% | 0.1% | 0.1% | 0.1% | 0.1% | 0.0% |
| Surf Scoter | 0.0% | 0.0% | 0.1% | 0.2% | 0.1% | 0.0% | *na* | 0.3% | 0.5% | 0.4% | 1.1% | 1.5% | 0.7% | 0.2% |
| Wood Duck | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | *na* | 0.0% | 0.1% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% |

**B) Hunter Harvest**

| | Suisun Marsh | | | | | | | California | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species[1] | 1953-1960 | 1961-1969 | 1970-1979 | 1980-1989 | 1990-1999 | 2000-2009 | 2010-2011 | 1953-1960 | 1961-1969 | 1970-1979 | 1980-1989 | 1990-1999 | 2000-2009 | 2010-2011 |
| Northern Pintail | *na* | 46.6% | 50.7% | 28.3% | 13.1% | 8.6% | 9.3% | *na* | 31.6% | 35.9% | 22.5% | 11.9% | 9.1% | 14.2% |
| American Wigeon | *na* | 13.4% | 12.2% | 13.0% | 16.0% | 14.4% | 13.5% | *na* | 12.8% | 11.1% | 10.5% | 12.2% | 13.7% | 13.2% |
| Northern Shoveler | *na* | 11.4% | 10.6% | 11.4% | 14.6% | 12.9% | 19.9% | *na* | 9.1% | 8.4% | 9.5% | 11.0% | 12.2% | 12.9% |
| Mallard | *na* | 10.6% | 8.3% | 22.0% | 23.7% | 25.4% | 27.7% | *na* | 18.0% | 15.5% | 23.1% | 26.1% | 23.5% | 19.4% |
| American Green-winged Teal | *na* | 9.6% | 11.1% | 14.1% | 19.0% | 19.7% | 17.6% | *na* | 15.9% | 17.7% | 19.3% | 23.9% | 24.4% | 23.0% |
| Gadwall | *na* | 1.4% | 1.1% | 3.5% | 5.2% | 6.6% | 3.7% | *na* | 2.7% | 2.4% | 4.7% | 7.0% | 7.8% | 7.3% |
| Greater White-Fronted Goose | *na* | 1.1% | 0.6% | 0.4% | 0.2% | 0.9% | 1.4% | *na* | 3.2% | 2.2% | 1.2% | 1.5% | 3.6% | 4.0% |
| Canada Goose | *na* | 1.1% | 0.8% | 0.3% | 0.5% | 2.1% | 0.7% | *na* | 4.2% | 3.8% | 3.5% | 2.4% | 3.3% | 4.0% |
| Ruddy Duck | *na* | 1.0% | 0.8% | 0.6% | 0.1% | 0.4% | 1.0% | *na* | 1.2% | 1.1% | 0.7% | 0.4% | 0.2% | 0.7% |
| Cinnamon Teal | *na* | 0.9% | 0.8% | 1.4% | 1.5% | 2.0% | 1.0% | *na* | 3.2% | 2.9% | 3.3% | 3.0% | 3.4% | 2.8% |
| Scaup | *na* | 0.8% | 0.5% | 1.2% | 2.1% | 2.1% | 0.6% | *na* | 1.9% | 1.4% | 1.6% | 1.2% | 1.4% | 0.8% |
| Canvasback | *na* | 0.7% | 1.2% | 1.8% | 1.1% | 0.7% | 0.0% | *na* | 0.7% | 1.2% | 1.1% | 1.1% | 0.8% | 1.0% |
| Ring-Necked Duck | *na* | 0.4% | 0.3% | 0.5% | 0.4% | 0.3% | 0.6% | *na* | 0.7% | 0.7% | 1.4% | 1.8% | 1.7% | 2.2% |
| Bufflehead | *na* | 0.3% | 0.1% | 0.4% | 0.8% | 0.9% | 0.8% | *na* | 0.9% | 0.4% | 0.7% | 0.8% | 0.8% | 0.5% |
| Common Goldeneye | *na* | 0.2% | 0.1% | 0.4% | 0.8% | 1.4% | 1.0% | *na* | 0.4% | 0.2% | 0.3% | 0.3% | 0.4% | 0.3% |
| Snow & Ross' Goose | *na* | 0.2% | 0.2% | 0.3% | 0.0% | 0.3% | 0.0% | *na* | 3.9% | 4.3% | 4.0% | 4.1% | 4.0% | 4.1% |
| Redhead | *na* | 0.2% | 0.1% | 0.2% | 0.4% | 0.2% | 0.0% | *na* | 0.4% | 0.5% | 0.7% | 0.7% | 0.6% | 0.4% |
| Wood Duck | *na* | 0.1% | 0.1% | 0.2% | 0.4% | 0.4% | 0.8% | *na* | 1.1% | 1.2% | 1.9% | 2.3% | 2.4% | 2.0% |
| Black Brant | *na* | 0.0% | 0.0% | 0.0% | 0.0% | 0.3% | 0.0% | *na* | 0.5% | 0.2% | 0.0% | 0.3% | 0.1% | 0.0% |
| Common Merganser | *na* | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | *na* | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% |
| Surf Scoter | *na* | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | *na* | 0.1% | 0.1% | 0.1% | 0.0% | 0.0% | 0.3% |

[1] Some species are not differentiated during mid-winter waterfowl surveys, and we have listed the dominant species only. However, canada goose includes lesser, Taverner, dusky, and western canada goose; cackling goose includes aleutian and small cackling goose; American wigeon may include some Eurasian wigeon; scaup includes both lesser scaup and greater scaup; surf scoter may include some black scoter and white-winged scoter; common goldeneye may include some Barrow's goldeneye; common merganser may include some hooded merganser and red-breasted merganser; and eider includes *Somateria spp.*

Figure 1. Suisun Guilds

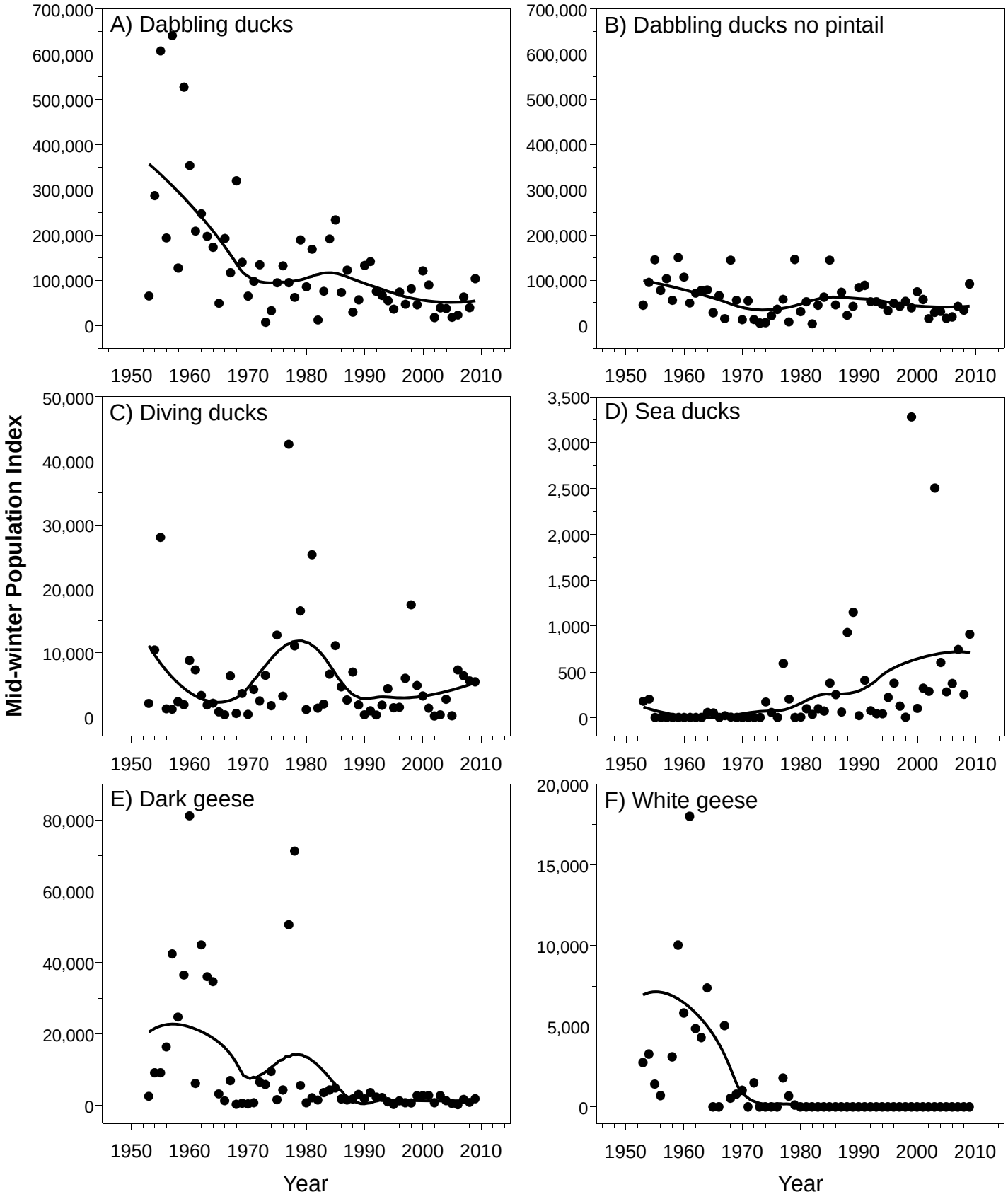


Figure 2. CA Guilds

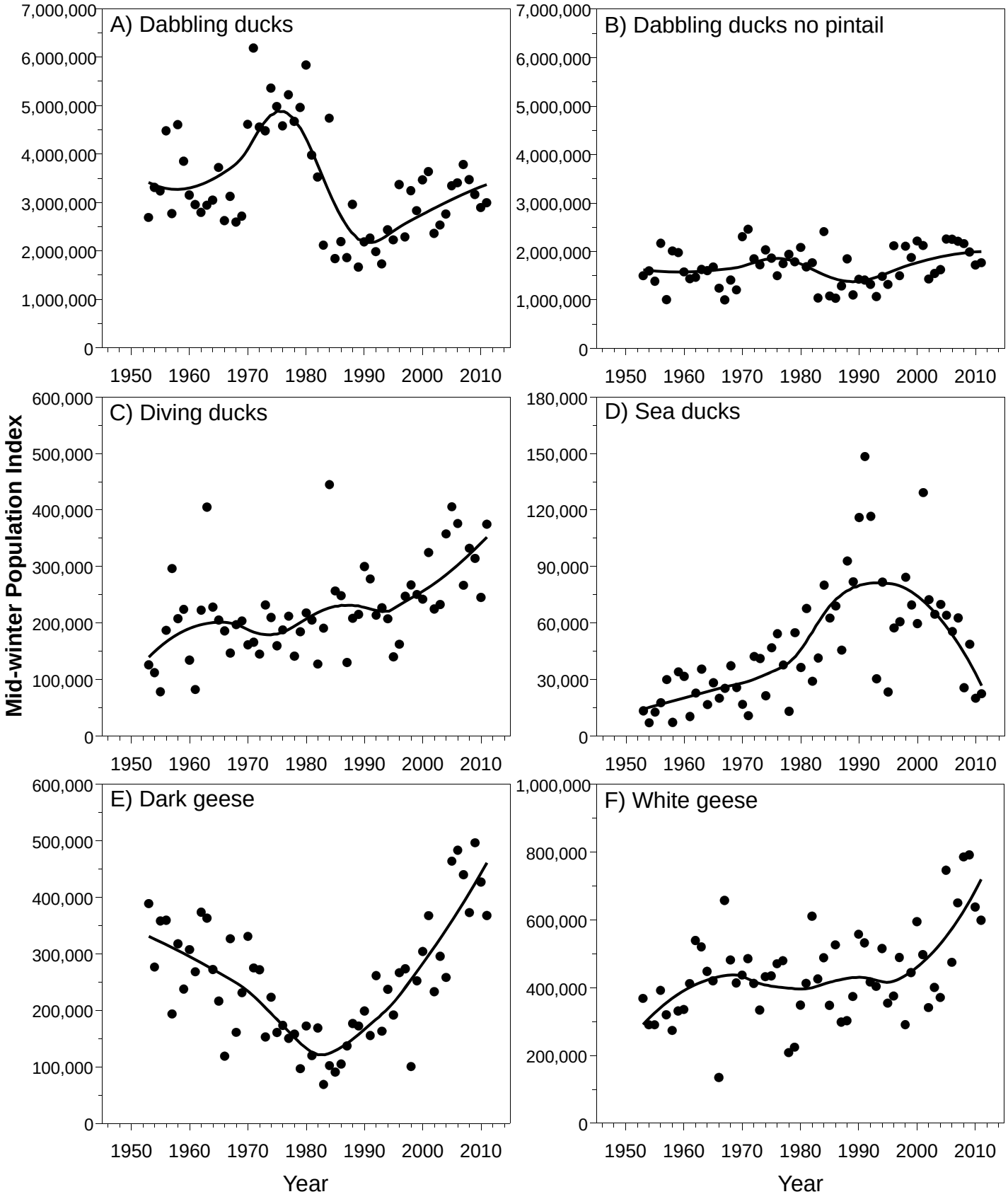


Figure 3. Proportion Suisun vs CA

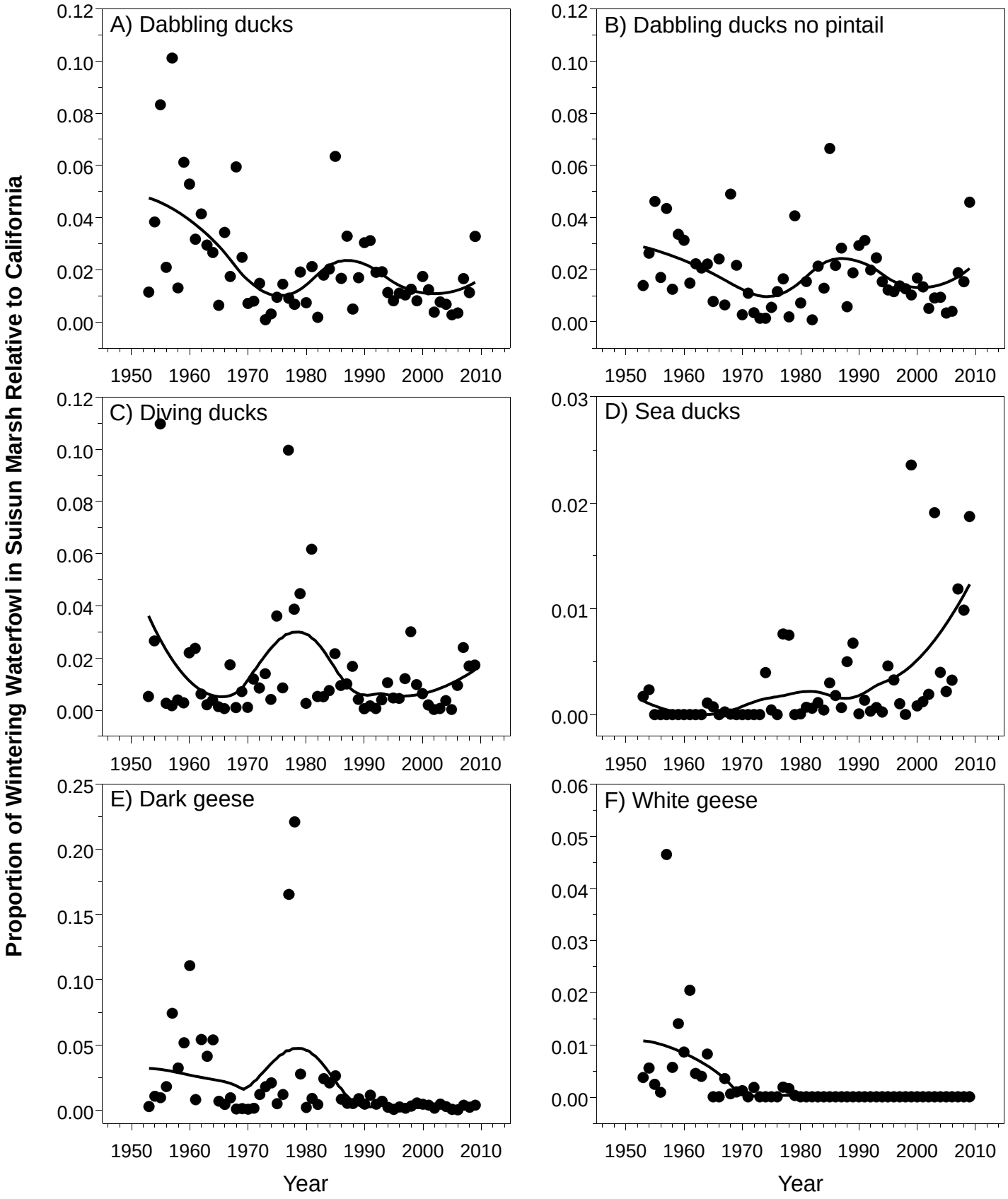
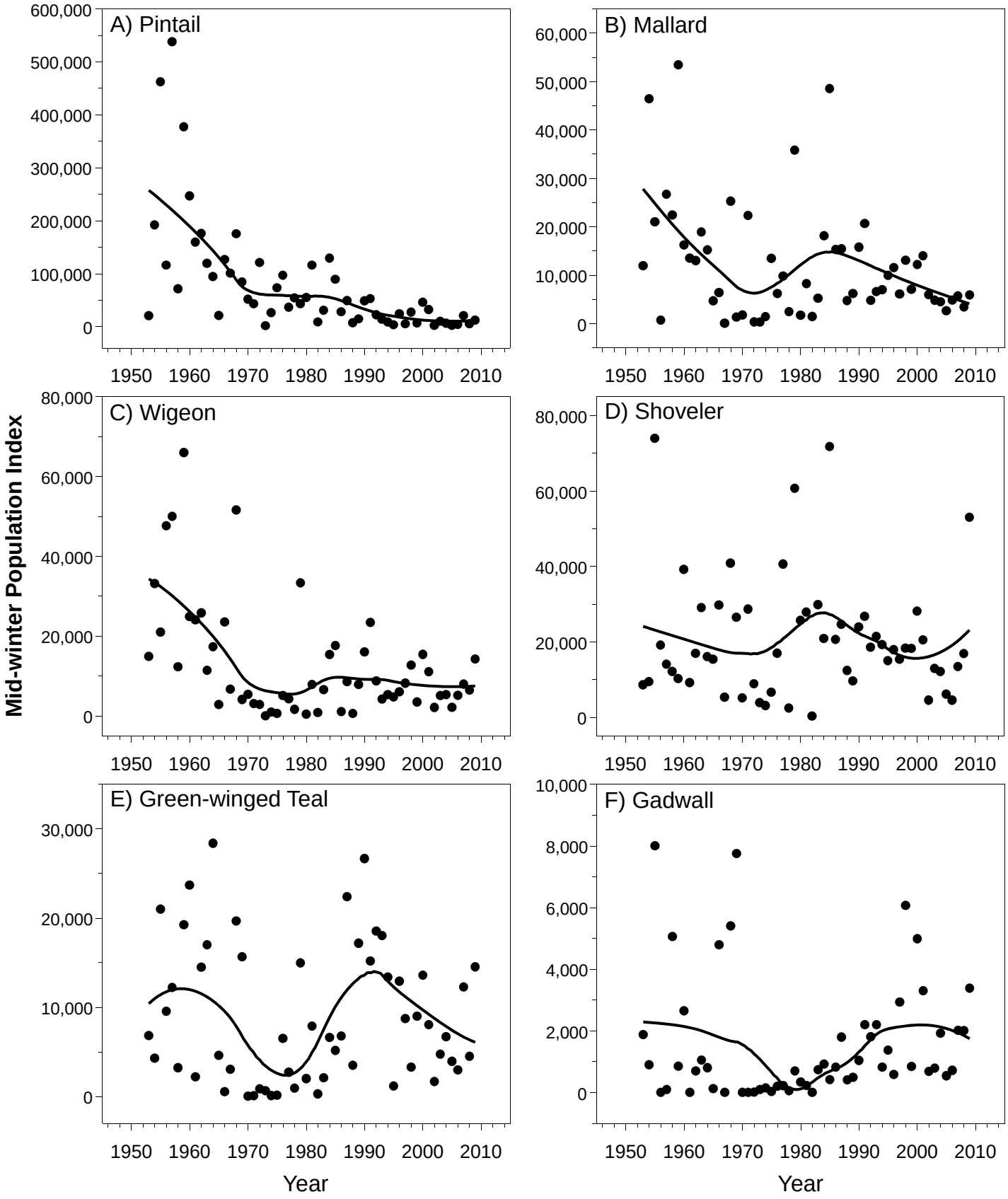


Figure 4. Suisun Species



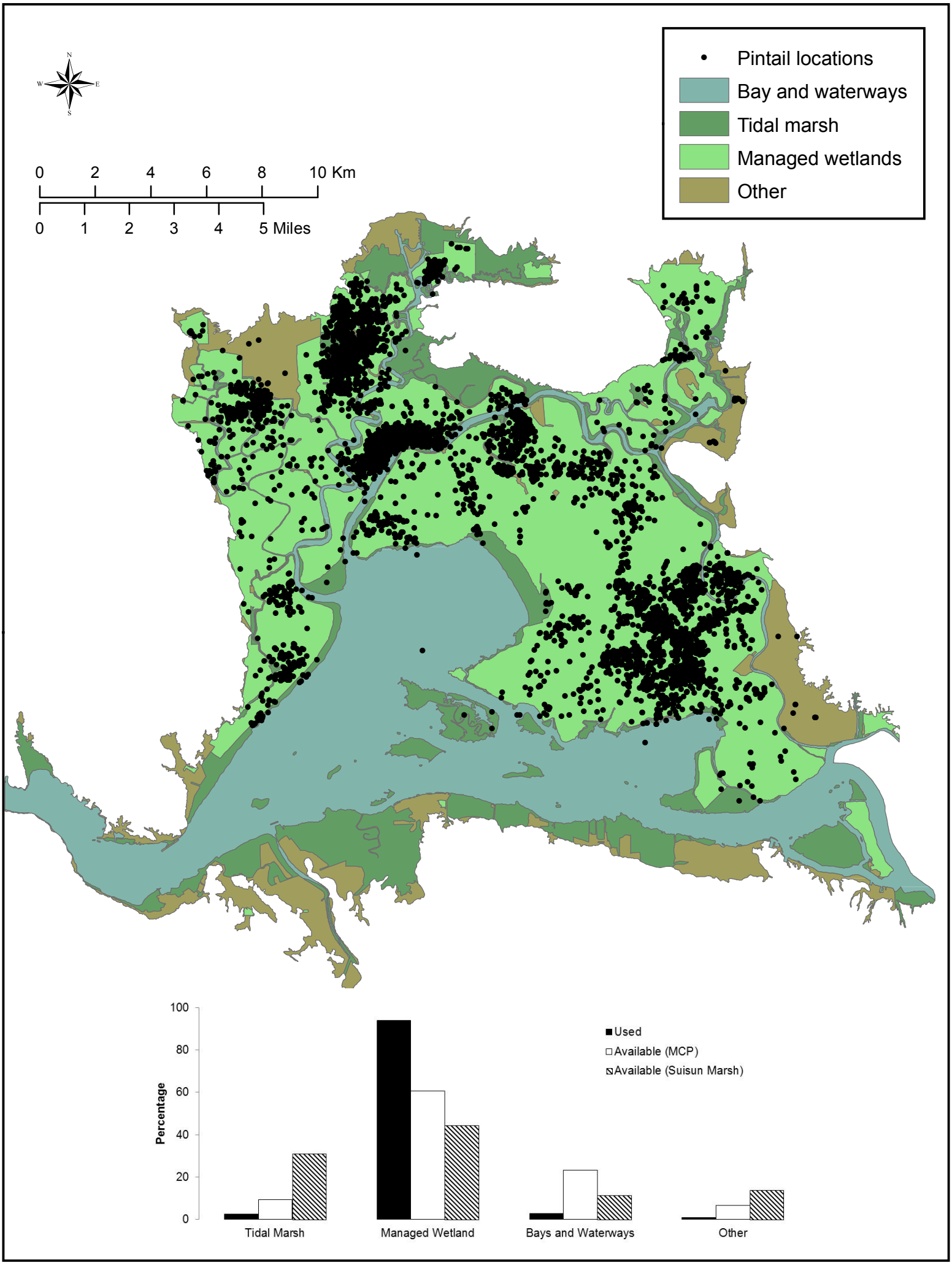
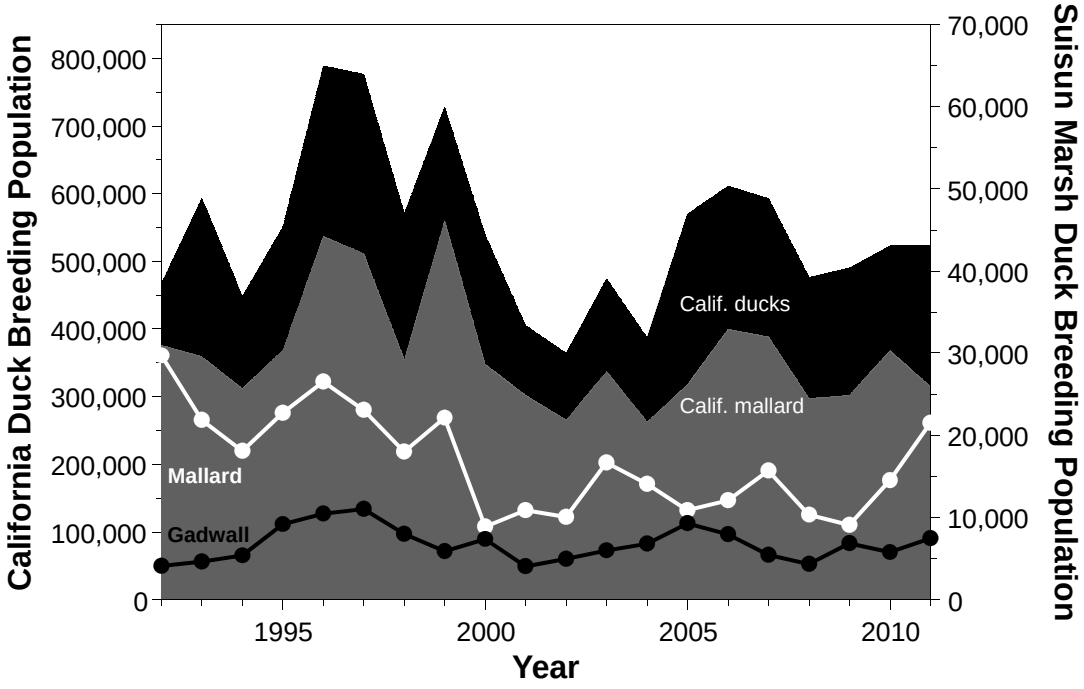
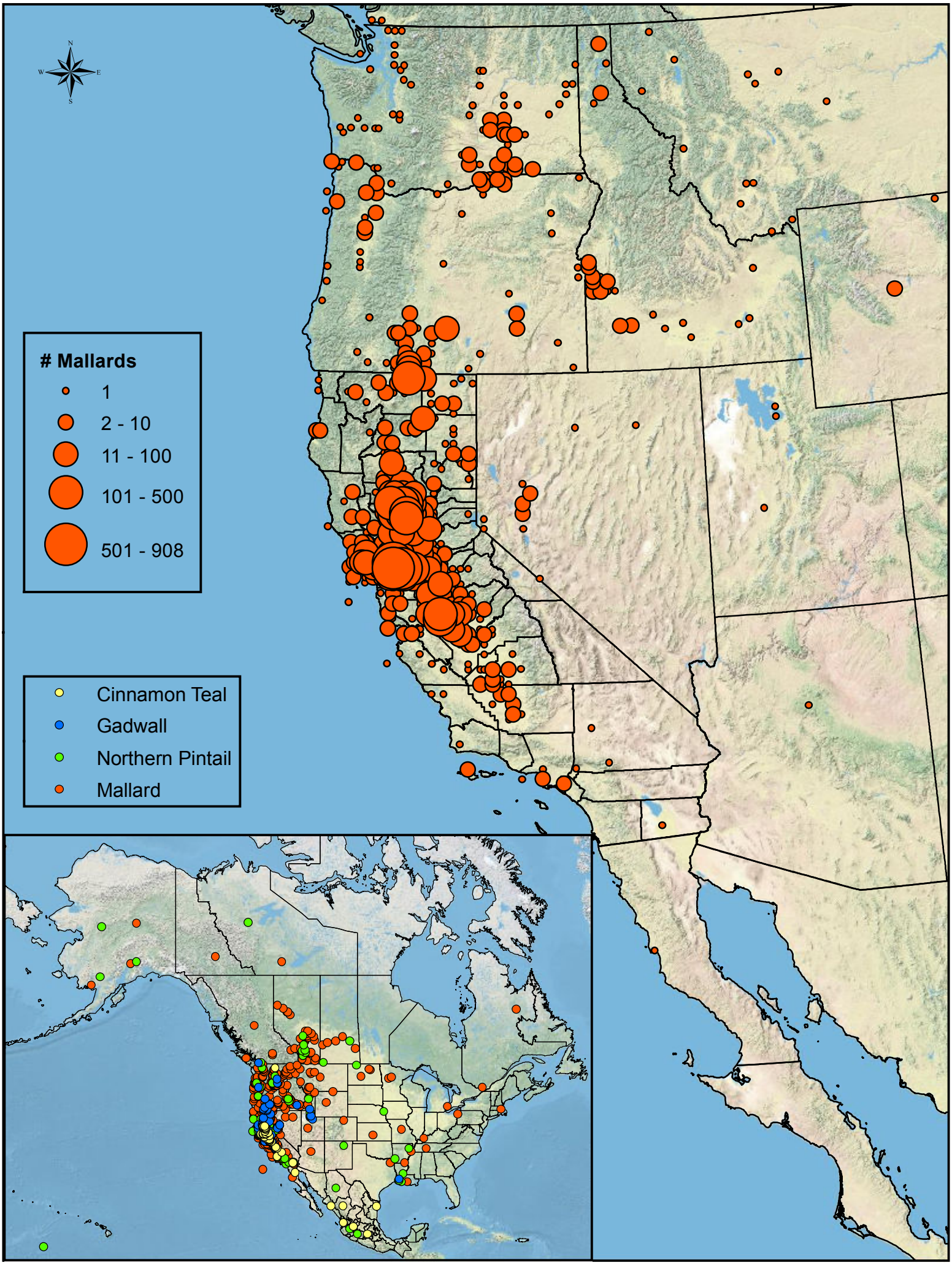

N
W
E
S
0 2 4 6 8 10 Km
0 1 2 3 4 5 Miles
Pintail locations
Bay and waterways
Tidal marsh
Managed wetlands
Other
100
80
60
40
20
0
Percentage
Used
Available (MCP)
Available (Suisun Marsh)
Tidal Marsh
Managed Wetland
Bays and Waterways
Other

Figure 6. BPOP




N
W
E
S
# Mallards
1
2 - 10
11 - 100
101 - 500
501 - 908
Cinnamon Teal
Gadwall
Northern Pintail
Mallard