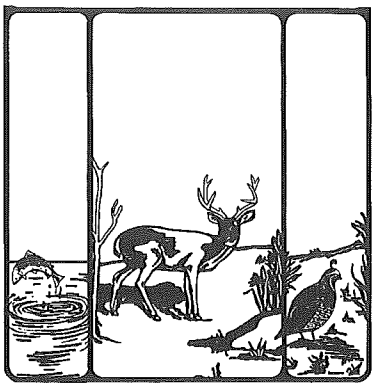
# CALIFORNIA FISH and GAME



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# THE USE OF EASTERN SACRAMENTO VALLEY VERNAL POOLS BY DUCKS

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**The published literature on the use of seasonal and semi-permanent wetlands throughout the Central Valley of California by wintering waterfowl (Anatidae) is extensive. However, few if any studies exist on the use of Sacramento Valley vernal pools by ducks. We studied ducks using vernal pools on the Vina Plains Preserve in Tehama County, California from fall 1993 through spring 2001. We conducted regular censuses of ducks on several pools during the hydroperiod in order to determine species composition and chronology of use for each species, and to quantify behavior of ducks using the pools and associated grasslands. We also collected 31 ducks from 7 species to determine food habits. Mallards, *Anas platyrhynchos*, American wigeon, *Anas americana*, and green-winged teal, *Anas crecca*, were the most common dabbling ducks using vernal pools; the ruddy duck, *Oxyura jamaicensis*, was the most common diving duck. Duck use of the pools was mostly diurnal, with the exception of nesting mallards, which often used the pools as pair-water. Ducks used vernal pools and associated uplands from January to March, with fewer observations in April as birds migrated from the area and as pools dried; maintenance and foraging were the most commonly observed behaviors of mallards, wigeon, and green-winged teal using these habitats. Chronological changes in the foraging activity of these three species combined were significant ($p=.0074$), with a decrease in foraging activity in January ($p=.00084$), and a subsequent increase in February ($p=.0031$); monthly changes in foraging activity from February through pool dessication in April were insignificant (all $p > .05$). Spikerush, *Eleocharis* spp., seeds comprised the bulk of the plant matter found in the esophagi of ducks, however, wigeon consumed mostly vegetative plant matter from grasses and forbs. Vernal pool snails, *Fossaria sonomensis*, fairy shrimp (Anostraca: *Branchinecta* spp., *Linderiella occidentalis*), and aquatic insects were the most abundant invertebrates consumed by ducks. Overall volumetric contribution of animal matter to the diet was relatively low. The use and food habits data suggest the importance of vernal pools to ducks during late winter and early spring. California's remaining vernal pool landscapes should be protected and managed for endemic taxa and migratory waterbirds.**

## INTRODUCTION

The loss and degradation of winter and nesting habitat due to urbanization and agricultural expansion is a primary cause of waterfowl (Anatidae) population declines

occurring since the mid 1800s (Baldassarre and Bolen 1994). Recent estimates suggest that only 5% of California's historic wetland habitats still exist (Gilmer et al. 1982, Heitmeyer et al. 1989, Holland 1998); among the rarest and most poorly studied of these wetland habitats are California's vernal pools (Silveira 1998, Silveira 2000).

Resident and migratory waterbirds rely heavily upon wetland complexes throughout California's Central Valley (CV) during the fall and winter and to a lesser extent during the nesting season. Up to 60% of the waterfowl migrating down the Pacific Flyway during the fall use CV wetland habitats (Heitmeyer et al. 1989); the majority of these migrants winter in the Sacramento Valley. Many studies have documented waterfowl use of managed wetland complexes of seasonal and semi-permanent marshlands in California, and the use of vernal pools by waterbirds including waterfowl has been noted by several authors (Grinnell et al. 1930, Baker et al. 1992, The Nature Conservancy 1994, Silveira 1998, Silveira 2000). Nevertheless, few studies, if any, exist on the use of Sacramento Valley vernal pools by waterfowl.

Currently, many of the Sacramento Valley's remaining vernal pools occur on state or federally administered lands such as the alkali vernal pools of the Sacramento National Wildlife Refuge Complex (Silveira 2000). Other vernal pools occur on privately-owned land such as the high terrace pools at and near The Nature Conservancy's (TNC) Vina Plains Preserve in Tehama County and those found on the University of California's Jepson Prairie Preserve in Solano County. Most of the published research on these pools has focused on endemic invertebrates (Eng et al. 1990, Syrdahl[1] 1993, Gallagher 1993, Kirn[2]1997) and vegetation (Holland and Jain 1981, Griggs and Jain 1983, Broyles 1987, Jokerst 1993, Silveira 2000, and others).

Sacramento Valley vernal pools are well known for their invertebrate resources. Although abundant within the pools, several of the endemic crustaceans such as fairy shrimp and tadpole shrimp (Notostraca: *Lepidurus packardi*) are currently listed as endangered species (Ericksen and Belk 1999). Due to the seasonal availability of these invertebrates, it has been suggested that vernal pools may be an important source of protein and other alternative food resources for wintering and pre-migratory ducks. In addition, these vernal pools may serve as resting and foraging habitats for Pacific Flyway migrants as well as pair-water defended by male mallards during the nesting season (Heitmeyer et al. 1989, Silveira 1998).

Our objectives were to (1) determine the species composition of the duck community using high terrace vernal pools located on the eastern fringe of the Sacramento Valley, (2) estimate occurrence values for each duck species both seasonally and daily, (3) quantify the behavior of ducks using the pools and associated uplands, and (4) collect a sample of ducks for diet analysis.

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[1]Syrdahl, R. L. 1993. Distribution patterns of some key macroinvertebrates in a series of vernal pools at Vina Plains Preserve, Tehama County, California. M. S. Thesis, California State University, Chico. 83pp.

[2]Kirn, S. A. 1997. Environmental factors affecting *Notonecta kirbyi* (Hemiptera: Notonectidae) predation in vernal pools at Vina Plains Preserve, Tehama County, California. M. S. Thesis, California State University, Chico. 63pp.

## STUDY AREA

Our study area included several vernal pools located on the original 619 ha parcel of TNC's Vina Plains Preserve located adjacent to State Highway 99, 21km north of Chico in southern Tehama County, California (122:03:10W 39:55:59N) (Fig. 1). This vernal pool complex occurs on a gentle rolling landscape located on a high terrace between the foothills of the southern Cascade Mountains and the floodplain of the Sacramento River. A subterranean durapan, formed from the consolidation of eroded sediments from the Tuscan basalt formation, prevents water percolation and causes rapid accumulation of water in the heavy clay loam or silt-lined pool basins (TNC 1994). Flooded pool basins support populations of green algae (Chlorophyta), blue-green bacteria (Cyanobacteria), quillworts, *Isoetes howellii* and *I. nuttallii*., water shamrock, *Marsilea vestita*, and spikerush, *Eleocharis* spp., the only emergent plants common within the pools. Dry basins support endemics plants including Orcutt grasses, *Orcuttia pilosa* and *O. tenuis*, and Hoover's spurge, *Chamaesyce hooveri*, and other plant taxa such as downingia, *Downingia* spp., coyote-thistle, *Eryngium castrense*, and cocklebur, *Xanthium strumarium* (TNC 1994). The surrounding grassland environment, comprised of four fenced pastures, supports a community of forbs and mostly exotic grasses that are grazed by cattle on a rotational basis during winter and spring (Griggs 2000). TNC also uses prescribed burns to eradicate exotic grasses such as medusa-head, *Taeniatherum caput-medusae*. Over 40 numbered pools of various sizes (up to 100 m across and 1 m in depth when fully flooded) occur within the original

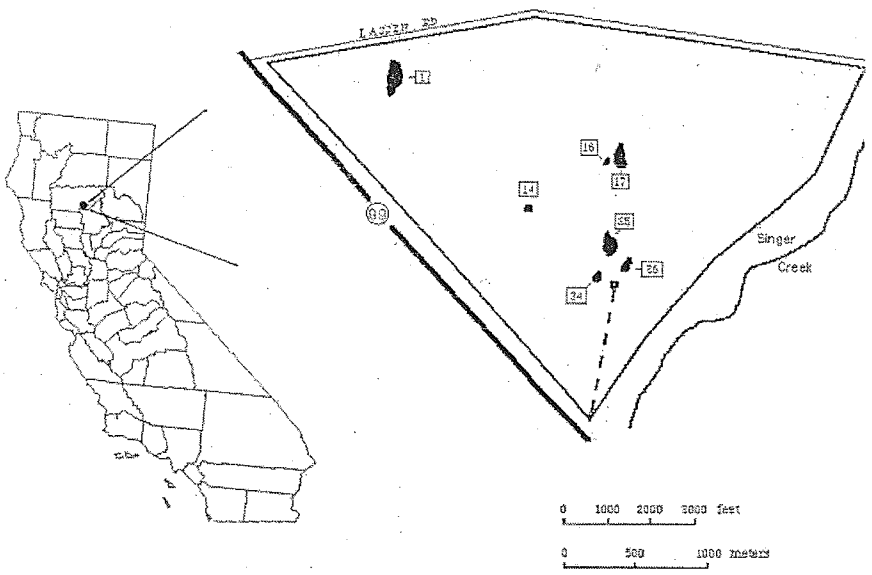


Figure 1. The original 619-ha parcel of the Vina Plains Preserve and its location in Tehama County, California (Vina Plains Preserve map from Syrdahl 1993).

preserve, with hundreds of additional smaller pools or "hog wallows". Baker et al. (1992) found that the use of vernal pools in the Santa Ana Mountains, California by waterfowl was mainly restricted to larger pools. Our preliminary observations on the Vina Plains were consistent with these findings, and as a result, our censuses were restricted to pools #1, 14, 16, 17, 34, 35, and 36, some of the largest and more accessible pools on the preserve (Fig. 1).

## METHODS

We conducted duck censuses from fall 1993 through spring 1996 and from fall 1997 through spring 2001, using binoculars and a 20-60X Kowa spotting scope. A minimum of four censuses were conducted per month, although the lack of flooded pools often resulted in fewer monthly censuses. Daily census periods were as follows: (1) morning census - 0.5 h pre-sunrise to 2.5 h post-sunrise; (2) mid-day census - 3 h post- sunrise to 6 h post-sunrise; and (3) afternoon census - 2.5 h pre-sunset to 0.5 h post-sunset. A total of seven additional censuses were conducted from 4 to 1 h pre-sunrise during the 1993-1994 and 1999-2000 field seasons to detect nocturnal usage of the pools. Pools were approached on foot slowly during nocturnal censuses to listen for the sound of flushing ducks. Head lamps and a 6-volt flashlight were used to facilitate nocturnal identifications.

Censusing began in the fall or winter following initial pool flooding, and was terminated in late March or April with the dessication of one or more study pools. Complete counts were made, whenever possible, of birds on the water or in the grassland within 10 m of the shoreline. Only those ducks present at the time of arrival were censused. To avoid double counting, efforts were made to avoid flushing birds from study pools, although these efforts were often unsuccessful. When flushed, ducks were followed visually to be sure they didn't land on another study pool. Percent occurrence and range values (number of individuals) for each common duck species were calculated by census time period and month.

Duck behavior was also recorded immediately upon arrival as (1) foraging, which included diving, dabbling, or grazing, (2) maintenance, which included resting, sleeping, preening, etc., or (3) reproductive, which included courtship and activities associated with pair bond maintenance. Behavior was not quantified when ducks were observed in an "Alert" (upright with neck extended) posture, with the assumption that they were responding to our presence. Behavior was quantified by species as the percentage of all individuals engaged in the various behaviors. Mean monthly percent values for each behavior were generated for each species observed during 10 or more censuses.

We used SAS software for our statistical analyses (SAS Institute 1989). We tested for chronological (monthly) differences in foraging activity of mallards, American wigeon, and green-winged teal, combined, using ANOVA. We then used a Bonferroni approach (to maintain experiment-wise error rate at alpha = .05) to test for differences in mean percent foraging values in successive months.

In addition, we collected 31 ducks of seven species between December 1997 and April 2001. All birds were collected after they had been observed foraging for a minimum

of 10 minutes (Swanson et al. 1974a). Due to the open nature of the environment, the collection method which proved the most effective was shooting following an approach from behind a pool basin ridgeline. We used a 12-gauge shotgun with #1 steel shot for our collections. Prior to collection, we obtained a Scientific Collecting permit from the California Department of Fish and Game (CDFG), and permission from TNC to collect on the preserve. Collection dates were spaced by at least a week to avoid overshooting pressure.

Gut contents were removed in the field within 5 minutes of collection, and preserved in 80% ethanol. Each individual was sexed and then aged using wing plumage criteria (Carney 1992). The remains of all ducks were then donated to the Department of Anthropology at California State University, Chico for their comparative osteological collection.

Food items removed from the mouth, pharynx, esophagus, and proventriculus were analyzed as the "esophageal sample". Esophageal contents were sorted, identified, and then quantified using volumetric displacement. Food habits data are presented taxonomically as aggregate percent and percent occurrence (Swanson et al. 1974b). The use of gizzard contents in food habits analyses will generally result in a biased assessement of diet due to the differential survivorship and identifiability of food items (Swanson and Bartonek 1970). Nevertheless, gizzard contents can provide clues as to foraging habitat type, and for that reason, forage items found in gizzards were sorted and identified.

## RESULTS

We conducted 104 diurnal and 7 nocturnal censuses during this study. Censuses were initiated as early as December and as late as February, following initial flooding. Pool dessication and the termination of censuses occurred in late March and April (Table 1).

With the exception of one mallard pair flushed from pool # 17 (Fig. 1) in March 2000, no ducks were observed during nocturnal censuses. However, Canada, *Branta*

Table 1. Flooding chronology of the census pools on the Vina Plains Preserve, 1993-2001.

| Year | Initial flooding[1] | Dessication[2] |
|---|---|---|
| 1993-94 | Dec. 12-14, 1993 | Mar. 15-17, 1994 |
| 1994-95 | Dec. 15-17, 1994 | Apr. 20-23, 1995 |
| 1995-96 | Feb. 8-10, 1996 | Mar. 29-30, 1996 |
| 1997-98 | Dec. 1, 1997 | Apr. 4-6, 1998 |
| 1998-99 | Jan. 22-24, 1999 | Apr. 20-24, 1999 |
| 1999-00 | Jan. 19-21, 2000 | Apr. 8-10, 2000 |
| 2000-01 | Jan. 10-12, 2001 | Mar. 19-Apr. 4, 2001 |

[1]All census pools flooded
[2]≥1 dry census pool

*canadensis*, and cackling geese, *Branta hutchinsii*, were regularly observed roosting on pools at night. Because our data suggest that use of these vernal pools by ducks is primarily diurnal, we present only diurnal census data here.

In all, 15 species of ducks, 7 dabblers and 8 divers, from 4 Tribes were observed during diurnal censuses, with mallards, American wigeon, and green-winged teal being the most common taxa (Table 2). Ruddy ducks, bufflehead, *Bucephala albeola*, and ring-necked ducks, *Aythya collaris*, were the most common divers, although their numbers and rates of occurrence were relatively low (Table 2).

Table 2. Number of observations, with percent occurrence values in parentheses, for duck species during 104 censuses of the Vina Plains Preserve vernal pools, 1993-2001.

| | | No. (% Occur) |
|---|---|---|
| Tribe: | Anatini - Dabbling Ducks | |
| | American Wigeon *(Anas americana)* | 39 (37.50) |
| | Eurasian Wigeon *(Anas penelope)* | 1 (0.96) |
| | Gadwall *(Anas strepera)* | 1 (0.96) |
| | Green-winged Teal *(Anas crecca)* | 24 (23.08) |
| | Northern Pintail *(Anas acuta)* | 9 (8.65) |
| | Mallard *(Anas platyrhynchos)* | 60 (57.69) |
| | Northern Shoveler *(Anas clypeata)* | 5 (4.81) |
| Tribe: | Aythyini - Pochards | |
| | Canvasback *(Aythya valisineria)* | 1 (0.96) |
| | Ring-necked Duck *(Aythya collaris)* | 3 (2.88) |
| | Lesser Scaup *(Aythya affinis)* | 1 (0.96) |
| Tribe: | Mergini - Sea Ducks | |
| | Bufflehead *(Bucephala albeola)* | 5 (4.81) |
| | Common Goldeneye *(Bucephala clangula)* | 2 (1.92) |
| | Common Merganser *(Mergus merganser)* | 4 (3.85) |
| | Hooded Merganser *(Lophodytes cucullatus)* | 3 (2.88) |
| Tribe: | Oxyurini - Stiff-tailed Ducks | |
| | Ruddy Duck *(Oxyura jamaicensis)* | 7 (6.73) |

Ducks were first observed using pools within 1-4 days of initial flooding, with extensive use of the pools continuing into March (Table 3). Whereas use by wigeon and teal declined in late March and April, mallard pairs continued to use the pools until they dried. Data for other duck taxa are limited, but in general, this chronological pattern held for most of these species as well.

The use of the Vina Plains vernal pools by ducks was mostly diurnal with a departure of all remaining birds shortly after sunset (Table 3). This pattern of post-sunset departure from diurnal habitats is consistent with the nocturnal foraging flights observed on state and federal refuges in the Sacramento Valley during the fall-winter

Table 3. Percent occurrence and numbers of individuals of common duck species[1] observed during 104 diurnal censuses of the Vina Plains Preserve vernal pools, 1993-2001.

| Species | % Occurrence (Range) Dec. | Jan. | Feb. | Mar. | Apr. |
|---|---|---|---|---|---|
| Mallard | | | | | |
| 36 AM Censuses | 20.0 (0-1) | 50.0 (0-12) | 66.7 (0-81) | 100.0 (2-14) | 80.0 (0-4) |
| 33 Midday Censuses | 60.0 (0-38) | 28.6 (0-6) | 87.5 (0-26) | 87.5 (0-31) | 100.0 (3-21) |
| 35 PM Censuses | 20.0 (0-7) | 50.0 (0-8) | 37.5 (0-23) | 87.5 (0-14) | 83.3 (0-8) |
| American Wigeon | | | | | |
| 36 AM Censuses | 0.0 (0) | 37.5 (0-36) | 77.8 (0-21) | 77.8 (0-73) | 20.0 (0-2) |
| 33 Midday Censuses | 40.0 (0-24) | 28.6 (0-30) | 37.5 (0-151) | 87.5 (0-45) | 40.0 (0-8) |
| 35 PM Censuses | 0.0 (0) | 0.0 (0) | 37.5 (0-77) | 87.5 (0-41) | 0.0 (0) |
| Green-winged Teal | | | | | |
| 36 AM Censuses | 20.0 (0-8) | 37.5 (0-43) | 22.2 (0-385) | 33.3 (0-12) | 0.0 (0) |
| 33 Midday Censuses | 60.0 (0-3) | 14.3 (0-10) | 12.5 (0-6) | 50.0 (0-29) | 0.0 (0) |
| 35 PM Censuses | 20.0 (0-19) | 0.0 (0) | 0.0 (0) | 50.0 (0-14) | 16.7 (0-2) |

[1]Those taxa observed during 10 or more censuses, 1993-2001.

hunting season (Heitmeyer and Raveling[3] 1988).

Maintenance and foraging were the most common behaviors of mallards, American wigeon, and green-winged teal using the Vina Plains vernal pools during the winter and spring hydroperiod (Table 4). Monthly changes in foraging activity for these three species combined were significant ($F_{4,7}=8.7475$, p=.0074) (Table 4). Foraging activity decreased from December to January (t=4.96, df=7, p=.00084), and increased in February (t=3.973, df=7, p=.0031). No significant change in foraging activity was observed from February to March (t=0.198, df=7, p=0.4243), or from March to the time of pool dessication in April (t=0.788, df=7, p=0.2283) (Table 4). Although we did not test for chronological differences in the foraging activity of each species independently, our data suggest the same chronological pattern for mallards, wigeon, and teal (Table 4). Although dabbling and diving were the most commonly observed duck foraging behaviors, wigeon shifted to an upland grazing strategy near vernal pool shorelines by mid-January, as new-growth grasses and forbs became available.

We collected 7 mallards (1 immature male, 3 adult males, and 3 immature females), 11 American wigeon (4 immature males, 4 adult males, and 3 adult females), 3 green-winged teal (1 immature male, 1 adult male, and 1 immature female), 7 ruddy ducks (3 immature males, 1 adult male, 1 immature female, and 2 adult females), 1 adult male ring-necked duck, 1 adult male bufflehead, and 1 adult male common merganser for our food habits analysis (Tables 5, 6). With the exception of the bufflehead which was collected in December, all ducks were collected in January (n=6), February (n=2), March (n=17), and April (n=5).

Plant matter was present in all mallard and wigeon esophagi; spikerush seeds and the vegetative parts of grasses and forbs comprised the bulk of the plant material in their diets respectively (Table 5). Spikerush seeds accounted for the greatest percentage of the plant material consumed by teal as well. Vernal pool snails and the immature and adult stages of aquatic insects were the most abundant invertebrates in the esophagi of dabbling ducks, although the overall volumetric contribution of animal relative to plant matter was low (Table 5). However, the esophageal sample from one immature female mallard collected in March 1998 contained over 300 snails. Plant and animal matter comprised 75.1% and 24.9% of the ruddy duck diet respectively, with spikerush seeds and fairy shrimp (Anostraca) being the most abundant food items (Table 6). Food habits data for other divers are extremely limited (Table 6), but provide evidence of successful foraging efforts on vernal pool vegetation and invertebrates.

Gizzard contents also provided evidence of foraging within vernal pools as well as other disjunct wetland habitats. For example five of seven ruddy duck gizzards contained the remains of vernal pool tadpole shrimp; only two of these five birds had tadpole shrimp in their esophagi. Tadpole shrimp remains were also present in the gizzard of the single ring-necked duck. As all ruddy and ring-necked ducks collected

[3]Heitmeyer, M. E., and D. G. Raveling. 1988. Winter resource use by three species of dabbling ducks in California. Department of Wildlife and Fisheries Biology, U.C., Davis, California (Final Report prepared for Delta Waterfowl and Wetlands Research Station, Portage La Prairie, Manitoba, Canada. 201pp.

Table 4. Percent of all mallards, American wigeon, and green-winged teal, observed during daylight hours on the Vina Plains vernal pools (1993-2001) engaged in various activities.

| Month, Activity, Number of individuals, Number of censuses[1] | Percent of all Individuals Observed | | |
|---|---|---|---|
| | Mallards | American Wigeon | Green-winged Teal |
| December | | | |
| Foraging | 30.7 | 100.0 | 90.0 |
| Maintenance | 69.3 | - | 10.0 |
| Reproductive | - | - | - |
| Total % | 100.0 | 100.0 | 100.0 |
| Number of Birds | 75 | 9 | 30 |
| Number of Censuses | 5 | 1 | 3 |
| January | | | |
| Foraging | 13.3 | 27.3 | 20.6 |
| Maintenance | 86.7 | 54.5 | 79.4 |
| Reproductive | - | 18.2 | - |
| Total % | 100.0 | 100.0 | 100.0 |
| Number of Birds | 83 | 33 | 34 |
| Number of Censuses | 9 | 3 | 2 |
| February | | | |
| Foraging | 28.2 | 78.5 | 79.1 |
| Maintenance | 71.8 | 20.1 | 20.9 |
| Reproductive | - | 1.4 | - |
| Total % | 100.0 | 100.0 | 100.0 |
| Number of Birds | 156 | 293 | 344[2] |
| Number of Censuses | 9 | 7 | 3 |
| March | | | |
| Foraging | 25.4 | 84.3 | 82.5 |
| Maintenance | 71.6 | 13.7 | 17.5 |
| Reproductive | 3.0 | 2.1 | - |
| Total % | 100.0 | 100.1[3] | 100.0 |
| Number of Birds | 134 | 388 | 40 |
| Number of Censuses | 19 | 12 | 8 |
| April | | | |
| Foraging | 47.5 | 100.0 | - |
| Maintenance | 52.5 | - | - |
| Reproductive | - | - | - |
| Total % | 100.0 | 100.0 | - |
| Number of Birds | 61 | 40 | - |
| Number of Censuses | 7 | 2 | - |

[1]Number of censuses during which behavioral data were collected.
[2]Total of 344 teal includes one estimate of 300 birds on pool #17 (February 10, 1996); all other numbers in this table are the result of direct counts.
[3]Error due to rounding.

Table 5. Food habits of dabbling ducks (n=21) collected on vernal pools at the Vina Plains Preserve, Tehama County, California, 1997-2001.

| | N = 7 Mallard | | N-11 American Wigeon | | N=3 Green-winged Teal | |
|---|---|---|---|---|---|---|
| Food Item | V[1] | O[1] | V | O | V | O |
| Plant | | | | | | |
| Cyperaceae | | | | | | |
| *Eleocharis* spp. – seed | 45.2 | 71.4 | 9.1 | 18.2 | 33.3 | 66.7 |
| *Eleocharis* spp. – vegetative | 7.1 | 14.3 | - | - | - | - |
| Poaceae | | | | | | |
| Unid. Seed | tr[2] | 14.3 | 1.3 | 9.1 | - | - |
| Unid. Vegetative | 14.3 | 14.3 | 46.1 | 72.7 | - | - |
| Unid. Plant – Seed | 7.1 | 42.9 | 22.7 | 27.3 | tr | 33.3 |
| Unid. Plant – Vegetative | 0.2 | 42.9 | 16.2 | 45.5 | - | - |
| Total Plant | 74.0 | 100.0 | 95.4 | 100.0 | 33.3 | 66.7 |
| Animal | | | | | | |
| Gastropoda | | | | | | |
| *Fossaria sonomensis* | 13.8 | 14.3 | 1.5 | 9.1 | 33.3 | 33.3 |
| Crustacea | | | | | | |
| Ostracoda | tr | 28.6 | - | - | tr | 33.3 |
| Notostraca | | | | | | |
| *Lepidurus packardi* | 0.2 | 14.3 | - | - | - | - |
| Copepoda | - | - | tr | 9.1 | - | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| Insecta | | | | | | |
| Coleoptera | | | | | | |
| Dytiscidae | tr | 14.3 | - | - | - | - |
| Dryopidae | 7.1 | 14.3 | - | - | - | - |
| Unknown | 4.8 | 14.3 | - | - | - | - |
| Unid. Insecta | - | - | 3.1 | 18.2 | - | - |
| Total Animal | 26.0 | 42.0 | 4.6 | 45.5 | 33.3 | 33.3 |

[1]V = Aggregate percent volume, O = percent occurrence.
[2]tr = trace amounts < 0.1 ml; trace items not included in calculation of aggregate percent volume.

Table 6. Food habits of diving ducks (n=10) collected on vernal pools at the Vina Plains Preserve, Tehama County, California, 1997-2001.

| | N = 7 Ruddy Duck | | N=1 Ring-necked Duck | | N=1 Common Merganser | | N=1 Bufflehead | |
|---|---|---|---|---|---|---|---|---|
| | V[1] | O[1] | V | O | V | O | V | O |
| Food Item | | | | | | | | |
| Plant | | | | | | | | |
| Cyperaceae | | | | | | | | |
| *Eleocharis* spp. – seed | 53.7 | 71.4 | - | - | - | - | - | - |
| Poaceae | | | | | | | | |
| Unid. Seed | 15.9 | 28.6 | 100.0 | 100.0 | - | - | - | - |
| Unid. Plant – Seed | 3.3 | 57.1 | - | - | - | - | - | - |
| Unid. Plant – Vegetative | 2.2 | 14.3 | - | - | - | - | - | - |
| Total Plant | 75.1 | 100.0 | 100.0 | 100.0 | - | - | tr[2] | 100.0 |
| Animal | | | | | | | | |
| Nematoda | - | - | - | - | 100.0 | 100.0 | - | 100.0 |
| Gastropoda | | | | | | | | |
| *Fossaria sonomensis* | 1.6 | 14.3 | - | - | - | - | - | - |
| Crustacea | | | | | | | | |
| Anostraca | 11.5 | 42.9 | - | - | - | - | - | - |
| Notostraca | | | | | | | | |
| *Lepidurus packardi* | 0.3 | 28.6 | - | - | - | - | - | - |
| Copepoda | - | - | - | - | - | - | - | - |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Insecta | | | | | | | | |
| Coleoptera | | | | | | | | |
| Dytiscidae | 1.6 | 14.3 | - | - | - | - | - | - |
| Hemiptera | | | | | | | | |
| Corixidae | - | - | - | - | - | - | tr | 100.0 |
| Unid. Insecta | tr | 14.3 | - | - | - | - | - | - |
| Total Animal | 24.9 | 71.4 | - | - | 100.0 | 100.0 | tr | 100.0 |

[1]V = Aggregate percent volume, O = percent occurrence.
[2]tr = trace amounts < 0.1 ml; trace items not included in calculation of aggregate percent volume.

during this study were present and foraging at the time of our arrival, we suspect that these shrimp were likely consumed at either the collection pools or other pools on the Vina Plains. Seeds of willow smartweed, *Polygonum lapathifolium*, were found in the gizzards of the single bufflehead, three ruddy ducks, one American wigeon, and three mallards, and watergrass, *Echinochloa crus-galli*, seeds were found in the gizzard of a male mallard. These plant species do not occur on the Vina Plains Preserve, but are associated with valley marshlands and agricultural (i.e., rice) habitats. Their presence in gizzards suggests nocturnal foraging in these adjacent habitat types.

## DISCUSSION

Eastern Sacramento Valley high-terrace vernal pools are used diurnally by most of the duck species that winter in the CV (Table 2). Although Heitmeyer and Raveling (1988) found a decrease in night foraging flights away from diurnal habitats on the Sacramento National Wildlife Refuge following the end of the hunting season, we found no evidence of nocturnal usage of these pools by ducks during the hydroperiod other than as pair-water by nesting mallards. Also, the presence of watergrass and smartweed seeds in several duck gizzards provides additional evidence of nocturnal foraging in other wetland habitats.

The most common and abundant duck species using vernal pools in our study area were mallards, American wigeon, and green-winged teal (Tables 2, 3). Baker et al. (1992) found these three species, along with cinnamon teal, *Anas cyanoptera*, to be the most common ducks using vernal pools on the Santa Rosa Plateau in Riverside County. Silveira (1998) also included the cinnamon teal as well as the wood duck, *Aix sponsa*, on the list of CV vernal pool ducks. We suspect that the lack of cinnamon teal and wood duck observations on the Vina Plains is due in large part to the proximity of these pools to valley marshland complexes and riparian habitats preferred by cinnamon teal and wood ducks respectively (Bellrose 1980).

We observed regular diurnal use of vernal pools by ducks during the winter and early spring months, with a significant increase in the foraging activity of mallards, American wigeon, and green-winged teal beginning in February (Tables 3, 4). These observations are consistent with suggestions that vernal pools may be most important to ducks dispersing from dense Fall-Winter aggregations following pair-bonding and the possible depletion of winter food resources (Heitmeyer and Raveling 1988, Silveira 1998), and also that waterfowl spend more time foraging prior to spring migration and reproduction (Drobney 1980, McLandress and Raveling 1981). This pre-migratory hyperphagia follows a period of winter weight loss due to the energetic costs of thermoregulation, courtship (e.g, courtship flights), pair-bond maintenance (e.g., mate defense), and molt. As a result, ducks require high energy foods such as fruits and seeds needed to restore endogenous reserves prior to migration, and invertebrates, which provide needed protein and calcium (e.g., crustaceans and snails) for plumage development and egg production (Heitmeyer and Raveling 1988). Although we lack the necessary food habits data needed to make comparisons among the sexes, our data show that energy and protein-rich food items are being consumed by both male and

female dabbling and diving ducks while foraging within these vernal pools (Tables 5, 6). Also, upland grasses and forbs in an early stage of phenological development were regularly consumed by wigeon during this study (Table 5). In addition to being more digestable (Raveling 1979, Buchsbaum et al. 1986), this new-growth or recently grazed herbaceous material is relatively high in protein needed by wigeon during this phase of their annual energy cycle (Mattson 1980).

Future research focusing on the differential utilization of Central Valley vernal pools by male and female ducks, both chronologically and with respect to diet, would provide additional insight into the relative importance of these unique wetland habitats. Additionally, the use of vernal pools and associated grassland habitats by geese (Anserini), tundra swans, *Cygnus columbianus*, and other waterbirds (e.g., shorebirds) would fill a significant gap in the vernal pool literature.

## RECOMMENDATIONS

Due to the potential importance of these ephemeral vernal pool wetlands to wintering, molting, migrating, and nesting ducks, we feel that management and conservation issues relating to California's remnant vernal pool habitats should be given additional attention in the future (Silveira 1998, Griggs 2000). Continued management of state, federal, and privately owned vernal pool landscapes through the wise use of prescribed burns, rotational grazing, restrictions to unregulated public access, etc., as well as the development of new conservation easements (e.g., TNC's conservation easement on the Earl Foor Ranch, located immediately north of the Vina Plains Preserve) are necessary in order to protect these important historic wetlands.

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## LITERATURE CITED

Baker, W. S., F. E. Hayes, and L. W. Lathrop. 1992. Avian use of vernal pools at the Santa Rosa Plateau Preserve, Santa Ana Mountains, California. The Southwestern Naturalist 37: 392-403.

Baldassarre, G. A., and E. G. Bolen. 1994. Waterfowl Ecology and Management. John Wiley & Sons, Inc., New York. 609pp.

Bellrose, F. C. 1980. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania. 540pp.

Broyles, P. F. 1987. A flora of Vina Plains Preserve, Tehama County, California. Madrono 34: 209-227.

Buchsbaum, R. J., J. Wilson, and I. Valiela. 1986. Digestibility of plant constituents by Canada

geese and Atlantic brant. Ecology 67: 386-393.
Carney, S. M. 1992. Species, age, and sex identification of ducks using wing plumage. U.S. Department of the Interior, U.S. Fish and Wildlife Service Publication. 144pp.
Drobney, R.D. 1980. Reproductive bioenergetics of wood ducks. Auk 97: 480-490.
Eng, L. L., D. Belk, and C. H. Eriksen. 1990. Californian Anostraca: distribution, habitat, and status. Journal of Crustacean Biology 10: 247-277.
Eriksen, C., and D. Belk. 1999. Fairy shrimps of California's puddles, pools, and playas. Mad River Press, Eureka, CA. 196pp.
Gallagher, S. P. 1993. Life history variation in the temporary pool snail, *Fossaria sonomensis*, in the Northern Sacramento Valley. American Midland Naturalist 130: 372-385.
Gilmer, D. S., M. R. Miller, R. D. Bauer, and J. R. LeDonne. 1982. California's Central Valley wintering waterfowl: concerns and challenges. Transactions of the North American Wildlife and Natural Resources Conference 47: 441-452.
Griggs, F. T., and S. K. Jain. 1983. Conservation of vernal pool plants in California II - Population biology of a rare unique grass genus. Biological Conservation 27: 171-193.
Griggs, F. T. 2000. Vina Plains Preserve: eighteen years of adaptive management. Fremontia 27(4), 28(1): 48-51.
Grinnell, J., J. Dixon, and J. M. Linsdale. 1930. Vertebrate natural history of a section of northern California through the Lassen peak region. University of California Publications of Zoology 35:1-594.
Heitmeyer, M. E., D. P. Connelly, and R. L. Pederson. 1989. The Central, Imperial, and Coachella Valleys of California. Pages 475-505 *In* Habitat management for migrating and wintering waterfowl in North America. L. M. Smith, R.L. Pederson, and R. M. Kaminski, editors. Texas Tech. University Press, Lubbock, Texas.
Holland, R. F. 1998. Great Valley vernal pools, photorevised, 1996. Pages 71-75 *In* Ecology, Conservation, and Management of Vernal Pool ecosystems. C. W. Witham, E. T. Bauder, D. Belk, W. R. Ferren Jr., and R. Ornduff, editors. Proceedings from a 1996 Conference, California Native Plant Society, Sacramento, CA.
Holland, R. F., and S. Jain. 1981. Conservation of vernal pool plants in California I - A report on Pixley Reserve. California Fish and Game 67: 254-256.
Jokerst, J. D. 1993. An alternatve approach to vernal pool mitigation in Sacramento County. Pages 227-237 in J. Keeley (Editor). Interface between ecology and land development in California. Southern California Academy of Science. Los Angeles, California.
Mattson, W. J. 1980. Herbivory in relation to plant nitrogen content. Annual Review of Ecology and Systematics 11: 119-161.
McLandress, M. R., and D. G. Raveling. 1981. Hyperphagia and social behavior of Canada geese prior to spring migration. Wilson Bulletin: 93: 310-324.
Raveling, D. G. 1979. The annual cycle of body composition of Canada geese with special reference to control of reproduction. Auk 96: 234-252.
SAS Institute. 1989. SAS/IML software: usage and reference. Version 6. SAS Institute, Cary, North Carolina, USA.
Silveira, J. G. 1998. Avian uses of vernal pools and implications for conservation practice. Pages 92-106 *In* Ecology, Conservation, and Management of Vernal Pool ecosystems. C. W. Witham, E. T. Bauder, D. Belk, W. R. Ferren Jr., and R. Ornduff, editors. Proceedings from a 1996 Conference, California Native Plant Society, Sacramento, CA.
Silveira, J. G. 2000. Alkali vernal pools at Sacramento National Wildlife Refuge. Fremontia 27 (4), 28 (1): 10-18.
Swanson, G. A., and J. C. Bartonek. 1970. Bias associated with food analysis in gizzards of blue-winged teal. Journal of Wildlife Management 34: 739-746.

Swanson, G. A., M. I. Meyer, and J. R. Serie. 1974a. Feeding ecology of breeding blue-winged teals. Journal of Wildlife Management 38: 396-407.

Swanson, G. A., G. L. Krapu, J. C. Bartonek, J. R. Serie, and D. H. Johnson. 1974b. Advantages in mathematically weighting waterfowl food habits data. Journal of Wildlife Management 38: 302-307.

The Nature Conservancy. 1994. Vina Plains Preserve Handbook. Compiled by the Vina Plains Preserve Docent Committee, revision 2.1. 62pp.

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