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FEEDING ECOLOGY OF WATERFOWL WINTERING ON EVAPORATION PONDS IN CALIFORNIA[1]

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Abstract. We examined the feeding ecology of Northern Pintails (*Anas acuta*), Northern Shovelers (*A. clypeata*), and Ruddy Ducks (*Oxyura jamaicensis*) wintering on drainwater evaporation ponds in California from 1982 through 1984. Pintails primarily consumed midges (Chironomidae) (39.3%) and widegeongrass (*Ruppia maritima*) nutlets (34.6%). Shovelers and Ruddy Ducks consumed 92.5% and 90.1% animal matter, respectively. Water boatmen (Corixidae) (51.6%), rotifers (Rotatoria) (20.4%), and copepods (Copepoda) (15.2%) were the most important Shoveler foods, and midges (49.7%) and water boatmen (36.0%) were the most important foods of Ruddy Ducks. All three species were opportunistic foragers, shifting their diets seasonally to the most abundant foods given their behavioral and morphological attributes.

Key words: Aquatic invertebrates; evaporation ponds; feeding ecology; Northern Pintails; Northern Shovelers; Ruddy Ducks.

INTRODUCTION

Agricultural development has led to a 94% loss of historic wetlands in the Central Valley of California (U.S. Fish and Wildlife Service 1978). In the Tulare Lake and Buena Vista Lake basins, located in the southern San Joaquin Valley, about 250,000 ha of shallow wetlands have been converted to irrigated agriculture (Gilmer et al. 1982). Historically, the region was a major concentration area for waterfowl but present use is confined to habitats provided by the Kern National Wildlife Refuge (NWR), private duck clubs, water storage basins, flooded agricultural fields, and evaporation ponds. Traditional irrigation practices cause salts to concentrate in upper soil profiles, frequently limiting plant growth. As a result, farmers have installed subsurface irrigation drainage systems to remove salts from upper soil profiles of irrigated fields. This drainwater is saline and contains heavy metals and other environmental contaminants (Presser and Barnes 1985). Presently, the only economically acceptable means of disposing of subsurface drainwater is by evaporation in shallow ponds (hereafter called evaporation ponds).

There are presently about 3,000 ha of evaporation ponds in the Central Valley of California (Barnum and Gilmer 1988). This study was conceived to evaluate the diets of several species of waterfowl that used evaporation ponds. We selected Pintails (*Anas acuta*), Shovelers (*A. clypeata*), and Ruddy Ducks (*Oxyura jamaicensis*) for sampling because they commonly used evaporation ponds and each represented a distinct feeding mode (i.e., dabbling, filtering, and diving) (Bellrose 1980).

STUDY AREA

We studied waterfowl on drainwater evaporation ponds operated by the Tulare Lake Drainage District (TLDD) in Kings and Kern counties, California. This region is characterized by long dry summers with annual rainfall averaging about 15 cm (Kahrl 1979). These ponds, built in 1980–1982, consisted of three separate evaporation systems (EPS) that collectively comprised 18 separate ponds. Ponds ranged in size from 22–104 ha ($\bar{x} = 65$ ha). EPSs contained 4 or 10 interconnected ponds that allowed drainwater to flow through interconnected ponds to a terminal cell. Ponds were generally <1 m deep with flat bottoms. Drainwater entering an EPS was about 5–10 mS/cm electrical conductivity (EC) but in-

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creased in successive ponds due to evaporation to >300 mS/cm EC (TLDD, unpubl. data).

METHODS

We collected ducks by shooting after observing them feed for ≥10 min from September through March, 1982–1984. Shotguns were used to collect birds within 40 m of shore and rifles were used to collect birds foraging >40 m of shore. Water depth was recorded (± 0.1 cm) at the feeding location when birds were retrieved. At night, we did not observe feeding behavior, but illuminated birds with a 12-volt floodlight and shot them as they flushed (Euliss 1984). Water depths at feeding locations were not determined for birds collected at night because exact foraging locations were not observed. Observation of feeding behavior prior to collection is not necessary to obtain nocturnal food habits data (Euliss 1984) because ducks mostly forage at night (Euliss and Harris 1987, Tamisier 1978/79). We removed their esophagi immediately and preserved their contents in 80% ethanol (Swanson and Bartonek 1970). Aquatic invertebrates lose dry mass when stored in ethanol (Howmiller 1972). Hence, the proportions of invertebrates in waterfowl diets reported herein are conservative. Birds were sexed and aged using plumage characteristics (Carney 1964). Bursal examinations were also considered when plumage characteristics alone were insufficient to positively classify age.

Standing biomass of potential waterfowl food items (aquatic invertebrates and seeds) present in evaporation ponds was determined from October through March, 1982–1983 and from September through March, 1983–1984. We collected samples from nine (18 ponds total) evaporation ponds throughout the study; study ponds were selected across a gradient (10 to >70 mS/cm EC) of salt content. Equally spaced transects were established in each study pond and samples were collected at random points along each transect. Water column and benthic biota were collected with samplers modified after those described by Swanson (1978a, 1978b). Benthic and water column samples were cleaned by sieving with a self-cleaning (0.5 mm mesh) screen (Swanson 1977). A benthic and a water column sample was collected from each of 10 transects in 1982–1983. To reduce within sample variance, we increased to 20 transects and collected a benthic and a water column sample per transect in 1983–1984. Each pond was sampled every three weeks and pond averages of potential food items were considered as sample replicates.

We sorted food items collected from duck esophagi and pond samples into taxonomic groups, and dried them to constant weight at 55–60°C for 24 hours. Martin and Barkley (1961), Grodhaus (1967), Pennak (1978), and Merritt and Cummins (1984) were used to identify food items.

We summarized food habits and standing biomass data as aggregate percent (Swanson et al. 1974) dry mass. Statistical analyses were performed only with birds that contained ≥5 mg of food in their esophagi. We used aggregate percent dry masses of total invertebrates consumed as the dependent variable in an analysis of variance (ANOVA) to evaluate the effect of treatments: month, year, bird age, time of collection (diurnal versus nocturnal), age of EPS, and all possible interactions. An arcsine transformation was required to stabilize the variance of aggregate percent dry masses of food items. Overall differences in use of specific foods among duck species were assessed with ANOVA, and Student-Newman-Kuels (SNK) multiple comparison test was used to locate differences. Orthogonal contrasts were used to evaluate seasonal changes in waterfowl diet. Water depths recorded at each site where birds were collected required a square root transformation to stabilize the variance. We tested transformed data for differences among duck species using a SNK multiple comparison test after the null hypothesis had been rejected using ANOVA.

RESULTS

POND BIOTA

Diversity of aquatic plants and invertebrates was low relative to that in surrounding freshwater wetlands, but the taxa present were often highly abundant (Euliss 1989). Widgeongrass (*Ruppia maritima*) was common in ponds having 40–75 mS/cm EC, and horned pondweed (*Zannichellia palustris*), occasionally observed in less saline ponds, was not abundant. Midge larvae and water boatmen composed the bulk of the foods available (Table 1). We recorded only two species of midge larvae; *Tanypus grodhausi* was the most common. Similarly, the bulk of the water boatmen biomass was formed by *Trichocorixa reticulata* although *Corisella* spp. was present during the spring. Additionally, copepods (Copepoda),

TABLE 1. Mean dry mass/m^2 (SE), and percent occurrence of potential waterfowl food items recovered from 132 samples collected from drainwater evaporation ponds in the San Joaquin Valley, California, during September through March, 1982–1983 and 1983–1984.

Food item	Aggregate percent dry weight/m^2	Percent occurrence
Water boatman	35.4 (5.0)	99.2
Midge	40.5 (10.5)	74.2
Copepods	0.9 (0.3)	33.3
Water fleas	0.2 (0.2)	4.5
Seed shrimps	0.1 (0.1)	2.3
Water beetles	0.8 (0.8)	0.8
Other animals and plants (9 items)[a]	0.9 (4.2)	18.9

[a] Included aquatic invertebrates (scavenger beetles, damselflies, backswimmers), hydrophytes (widgeongrass, horned pond weed), and 4 species of terrestrial plants that grew in the ponds prior to inundation.

rotifers (Rotatoria), and brine fly larvae (Ephydridae) were seasonally abundant and were utilized by ducks.

FOOD HABITS

Within species, consumption of total invertebrates was similar among sex, age, time of collection (diurnal versus nocturnal), and age of EPS ($P = 0.13$ to 0.88). Only year and month had an effect ($P < 0.05$) on the total dry weight of invertebrates consumed.

Each duck species consumed distinct food items. Midges (Chironomidae) (39.4%) and widgeongrass nutlets (34.6%) dominated the Pintail diet and they were found in 55.2% and 44.8% of all birds examined, respectively (Table 2). Water boatmen (Corixidae) (51.6%), rotifers (20.4%), and copepods (15.2%) were the most commonly consumed foods by Shovelers. Midges (49.7%) and water boatmen (36.0%) were the most commonly consumed foods by Ruddy Ducks.

Some foods were utilized by all three waterfowl species but there were species-specific differences. Rotifers, copepods, and ostracods were consumed only by Shovelers. Water boatmen eggs were consumed only by Pintails and Ruddy Ducks with Pintails ($F = 9.55$, df = 2, 316, $P = 0.0001$) consuming more than Ruddy Ducks. Pintails consumed more widgeongrass nutlets than did the other two species ($F = 20.06$, df = 2, 316, $P < 0.05$). Each species consumed different quantities of midge larvae and water boatmen with greatest consumption of midge larvae by Ruddy Ducks ($F = 27.89$, df = 2, 316, $P < 0.05$) and greatest consumption of water boatmen by Shovelers ($F = 3.42$, df = 2, 316, $P < 0.05$).

TABLE 2. Aggregate percent dry weights of major food items found in Northern Pintail, Northern Shoveler, and Ruddy Duck esophagi collected from drainwater evaporation ponds in the San Joaquin Valley, California, during September through March, 1982–1983 and 1983–1984.

	Northern Pintails ($n = 58$)	Northern Shovelers ($n = 105$)	Ruddy Ducks ($n = 185$)
Plant			
Widgeongrass nutlets	34.6	1.5	2.6
Other (16 items)	14.9	6.0	7.2
Total plant matter	49.5	7.5	9.8
Animal			
Ostracods	—	0.5	—
Copepods	—	15.2	—
Rotifers	—	20.4	—
Midges	39.4	4.5	49.7
Brine flies	2.3	tr[a]	3.7
Water boatmen	5.9	51.6	36.0
Water boatmen eggs	2.7	—	0.7
Other (7 items)	0.2	0.3	—
Total animal matter	50.5	92.5	90.1

[a] tr = <0.5%.

SEASONAL TRENDS IN FOOD USAGE

Diets of Pintails changed from 60–100% plant foods in October through February to >80% animal foods in March (Fig. 1). Midges were important Pintail foods that were consumed in similar amounts during September, February and March ($t = 1.73$, df = 4, $P = 0.0907$). Water boatmen consumption by Pintails was not affected by season ($t = -0.34$, df = 4, $P = 0.7320$).

Water boatmen, rotifers, and copepods formed 70–90% of the foods consumed each month by Shovelers (Fig. 2). Water boatmen use decreased in January ($t = -2.87$, df = 5, $P = 0.005$), February ($t = -3.15$, df = 5, $P = 0.0022$), and March ($t = -8.48$, df = 5, $P = 0.0001$) (Fig. 2). Rotifers were most important in January ($t = 5.16$, df = 5, $P = 0.0001$) and February ($t = 3.44$, df = 5, $P = 0.0009$), but not in March ($t = 0.16$, df = 5, $P = 0.8760$). Although copepods were consumed during both January and March, only in March were they more important than in preceding months ($t = 19.48$, df = 5, $P = 0.0001$). Midge consumption showed no difference by season ($t = -0.25$, df = 5, $P = 0.8048$).

Midges and water boatmen formed the bulk of the Ruddy Duck diet (Fig. 3). Consumption in February ($t = -4.28$, df = 5, $P = 0.0001$) and

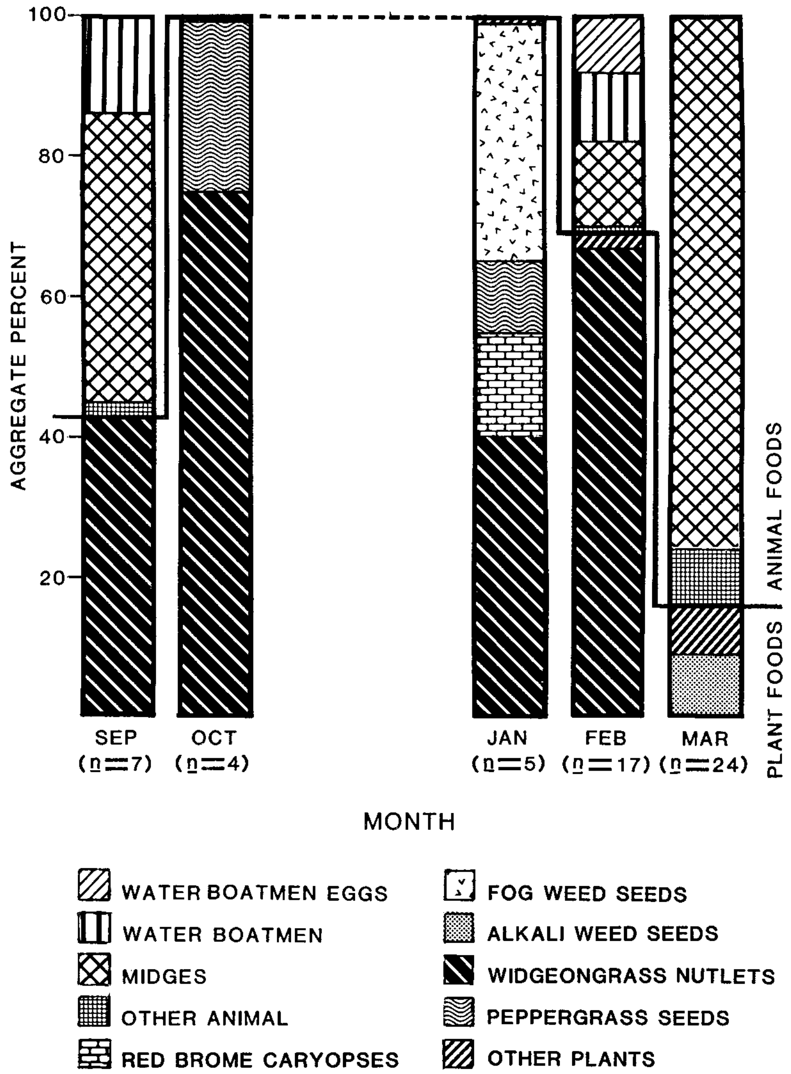

FIGURE 1. Seasonal food habits of Northern Pintails collected from agricultural drainwater evaporation ponds in the San Joaquin Valley, California, during September through March 1982–1984.

March ($t = -4.94$, df = 5, $P = 0.0001$) represented declines over previous months. Midges were consumed most frequently during the later half of the wintering period with increases over previous months occurring in February ($t = 2.83$, df = 5, $P = 0.0052$) and March ($t = 4.35$, df = 5, $P = 0.0001$).

SELECTION OF FORAGING SITES

Water depths at diurnal feeding sites were significantly different for each duck species. Mean depths at feeding sites were 2.8 cm for Pintails, 4.9 cm for Shovelers, and 9.5 cm for Ruddy Ducks (df = 525, $P < 0.05$).

DISCUSSION

FOOD HABITS AND FORAGING STRATEGIES

Average feeding depths we recorded for Pintails were similar to those reported by Euliss and Harris (1987). Thus, feeding in the TLDD ponds ($\bar{x}$ 60–80 cm depth) was restricted to shallow areas along pond margins. Further, overall diurnal use by Pintails of TLDD evaporation ponds was low

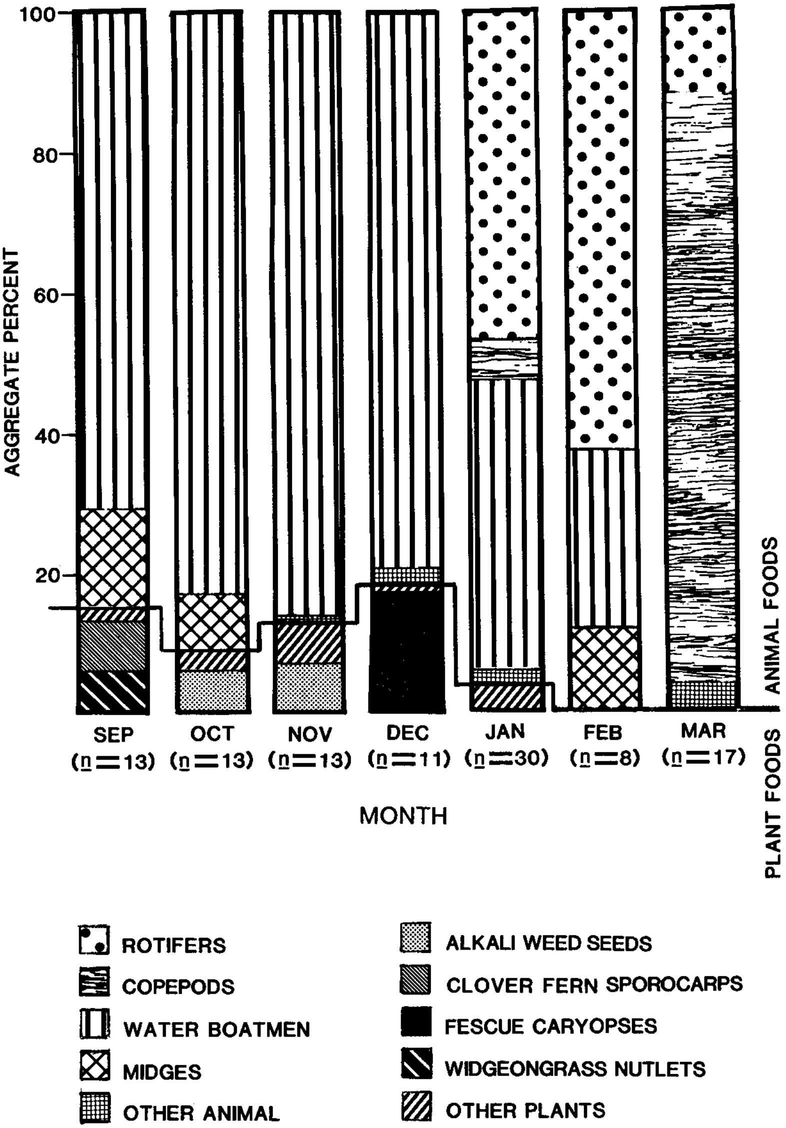

FIGURE 2. Seasonal food habits of Northern Shovelers collected from agricultural drainwater evaporation ponds in the San Joaquin Valley, California, during September through March 1982–1984.

relative to use of other available habitats, with most use occurring in September and again in February and March (Coe 1990). Only 4% of the Pintails surveyed in the Tulare Lake Basin during 1981–1987 were on evaporation ponds (Barnum and Euliss 1991). Moreover, Pintails forage extensively on plant seeds during winter in California (Connelly and Chesemore 1980, Euliss and Harris 1987, Miller 1987) and the low availability of plant seeds in TLDD evaporation ponds (Euliss 1989) may have affected use of the ponds. Animal foods were used by Pintails during September and then again in March, a seasonal pattern that may relate to protein requirements of feather molt (Heitmeyer 1988) or reproduction (Krapu 1979, 1981). Thus, the importance of TLDD ponds to Pintails may relate to the abundance and availability of animal foods during time periods when their need for animal proteins is high (Euliss 1989).

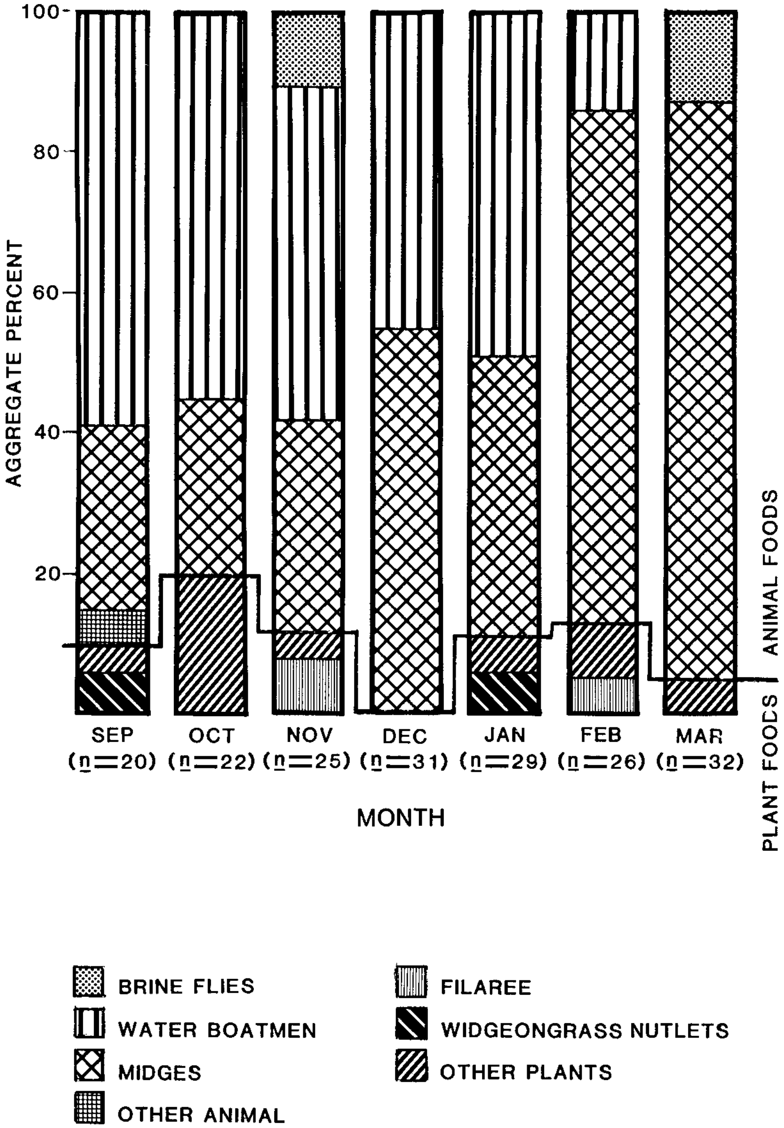

FIGURE 3. Seasonal food habits of Ruddy Ducks collected from agricultural drainwater evaporation ponds in the San Joaquin Valley, California, during September through March 1982–1984.

Shovelers and Ruddy Ducks consumed large quantities of animal foods; both species consumed water boatmen with more being consumed early in the winter than during late winter to early spring. For Ruddy Ducks, reduced consumption of water boatmen was offset by increased consumption of midges. Shovelers increased consumption of rotifers in December and February and copepods during March as consumption of water boatmen declined. Filter feeding by Shovelers allowed them to exploit small foods, such as rotifers and copepods, that probably were not consumed by Pintails or Ruddy Ducks.

Shovelers and Ruddy Ducks relied on water boatmen. However, competition was seemingly avoided because simultaneous use occurred only during periods when water boatmen were extremely abundant; numbers of individuals often exceeded 200,000 individuals/m^2 in certain locations within ponds (Euliss 1989). While water boatmen have been reported as important foods of Shovelers (Tietje and Teer 1988), Ruddy Ducks are considered mostly as predators of midge larvae (Siegfried 1973, Hoppe et al. 1986). Thus, what may appear as competition for a food item may instead be an opportunistic response by Ruddy Ducks to an extremely abundant food. Filtering seems more adaptive and efficient in capturing small swimming prey, including water boatmen, whereas diving for foods appears to be more profitable in obtaining midges and other less mobile prey items along sediment interfaces.

FOOD USAGE

Food availability and nutritional need influence food use given behavioral and morphological differences of individual duck species (Euliss and Harris 1987, Miller 1987). Each species was opportunistic and foraged on foods that were concentrated. Wind was an important factor in concentrating floating foods along windward shores and making them readily available to feeding ducks. Pintails responded to food availability on study ponds by feeding on widgeongrass nutlets windrowed as the result of foraging activities of Redheads (*Aythya americana*) and American Wigeon (*Anas americana*).

Wind also altered the availability of several invertebrate taxa in the ponds. Pupae of midges, ephydrids, and other diptera float to the surface just prior to emergence where they are vulnerable to predation. Pintails and Shovelers were observed to take advantage of this phenomenon and foraged on these insects where concentrations existed, for example along shores where wind concentrated emerging diptera adults. One male Pintail we observed feeding in this manner had consumed nearly 27,000 freshly emerged midges. We did not observe surface feeding by Ruddy Ducks.

Feeding on several invertebrates was also enhanced by numerical abundance. Rotifers consumed by Shovelers during this study may be the smallest foods consumed by any North American waterfowl. Other filter-feeding anatids such as the Pink-eared Duck (*Malacorhynchos membranaceus*) can feed efficiently on foods as small as 110 μm (Crome 1985); rotifers (*Keratella*) consumed by Shovelers in this study averaged only about 100 μm (Hutchinson 1967). Shovelers adjust their lamellae spacing to facilitate straining different sized foods (Zweers 1980). Because of their small size, we did not attempt to quantify standing crops of rotifers in this study. However, pumping water through extremely fine lamellae gaps to consume small foods would be costly and would not be worthwhile unless they were sufficiently abundant to offset the energetic expense.

The two most abundant macroinvertebrates in TLDD ponds were water boatmen and midges. Collectively, these taxa were observed to exceed 400,000 individuals/m^2 in certain locations within ponds (Euliss 1989). These two insects were readily available to foraging ducks as a result of this abundance.

Evaporation ponds in the San Joaquin Valley will continue to attract waterfowl because of abundant food production and the availability of large areas that provide sanctuary. These invertebrate-rich wetlands are well suited to ducks such as Shovelers and Ruddy Ducks that consume large quantities of animal foods throughout their annual cycles. Evaporation ponds provide ready sources of protein-rich invertebrate foods that are required by dabbling ducks to satisfy protein requirements during reproduction and feather molt. However, the effect of environmental contaminants on water birds, including waterfowl, needs to be considered. Drainwater used to fill evaporation ponds is known to contain selenium (Presser and Barnes 1985), that has been associated with embryonic mortality and deformity of water birds (Ohlendorf et al. 1986a, 1986b). Further, high concentrations of $CaCO_3$ in TLDD evaporation ponds have been observed to precipitate on and result in severe erosion of Ruddy Duck rectrices (Euliss et al. 1989). In areas where environmental contaminants or excessive salts pose threats to waterfowl, clean, food-rich, alternate freshwater habitats could be created adjacent to EPSs to reduce waterfowl exposure to contaminants. Further, water depths in contaminated EPSs could be held at $\geq$2m to reduce attractiveness of the areas as foraging sites to shallow water feeding waterfowl and shorebirds.

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