EFFECTS OF MANAGEMENT PRACTICES ON WETLAND BIRDS:

AMERICAN AVOCET

Grasslands Ecosystem Initiative
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This report is one in a series of literature syntheses on North American wetland birds. The need for these reports was identified by the Prairie Pothole Joint Venture (PPJV), a part of the North American Waterfowl Management Plan. The PPJV adopted a goal to stabilize or increase populations of declining grassland- and wetland-associated wildlife species in the Prairie Pothole Region. To further that objective, it is essential to understand the habitat needs of birds other than waterfowl, and how management practices affect their habitats. The focus of these reports is on management of breeding habitat, particularly in the northern Great Plains.

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Species for which syntheses are available or are in preparation:

Eared Grebe
American Bittern
Virginia Rail
Sora
Yellow Rail
American Avocet
Willet
Long-billed Curlew
Marbled Godwit
Wilson's Phalarope
Black Tern
Marsh Wren
Sedge Wren
Le Conte's Sparrow
Nelson's Sharp-tailed Sparrow

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AMERICAN AVOCET

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ORGANIZATION AND FEATURES OF THIS SPECIES ACCOUNT

Information on the habitat requirements and effects of habitat management on wetland birds were summarized from information in more than 500 published and unpublished papers. A ***range map*** is provided to indicate the relative densities of the species in North America, based on Breeding Bird Survey (BBS) data. Although the BBS may not capture the presence of elusive waterbird species, the BBS is a standardized survey and the range maps, in many cases, represent the most consistent information available on species' distributions. Although birds frequently are observed outside the breeding range indicated, the maps are intended to show areas where managers might concentrate their attention. It may be ineffectual to manage habitat at a site for a species that rarely occurs in an area. The species account begins with a brief ***capsule statement***, which provides the fundamental components or keys to management for the species. A section on ***breeding range*** outlines the current breeding distribution of the species in North America, including areas that could not be mapped using BBS data. The ***suitable habitat*** section describes the breeding habitat and occasionally microhabitat characteristics of the species, especially those habitats that occur in the Great Plains. Details on habitat and microhabitat requirements often provide clues to how a species will respond to a particular management practice. A ***table*** near the end of the account complements the section on suitable habitat, and lists the specific habitat characteristics for the species by individual studies. The ***area requirements*** section provides details on territory and home range sizes, minimum area requirements, and the effects of patch size, edges, and other landscape and habitat features on abundance and productivity. It may be futile to manage a small block of suitable habitat for a species that has minimum area requirements that are larger than the area being managed. The section on ***brood parasitism*** summarizes information on intra- and interspecific parasitism, host responses to parasitism, and factors that influence parasitism, such as nest concealment and host density. The impact of management depends, in part, upon a species' nesting phenology and biology. The section on ***breeding-season phenology and site fidelity*** includes details on spring arrival and fall departure for migratory populations in the Great Plains, peak breeding periods, the tendency to renest after nest failure or success, and the propensity to return to a previous breeding site. The duration and timing of breeding varies among regions and years. ***Species' response to management*** summarizes the current knowledge and major findings in the literature on the effects of different management practices on the species. The section on ***management recommendations*** complements the previous section and summarizes recommendations for habitat management provided in the literature. The ***literature cited*** contains references to published and unpublished literature on the management effects and habitat requirements of the species. This section is not meant to be a complete bibliography; a searchable, annotated bibliography of published and unpublished papers dealing with habitat needs of wetland birds and their responses to habitat management is posted at the Web site mentioned below.

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American Avocet
(*Recurvirostra americana*)

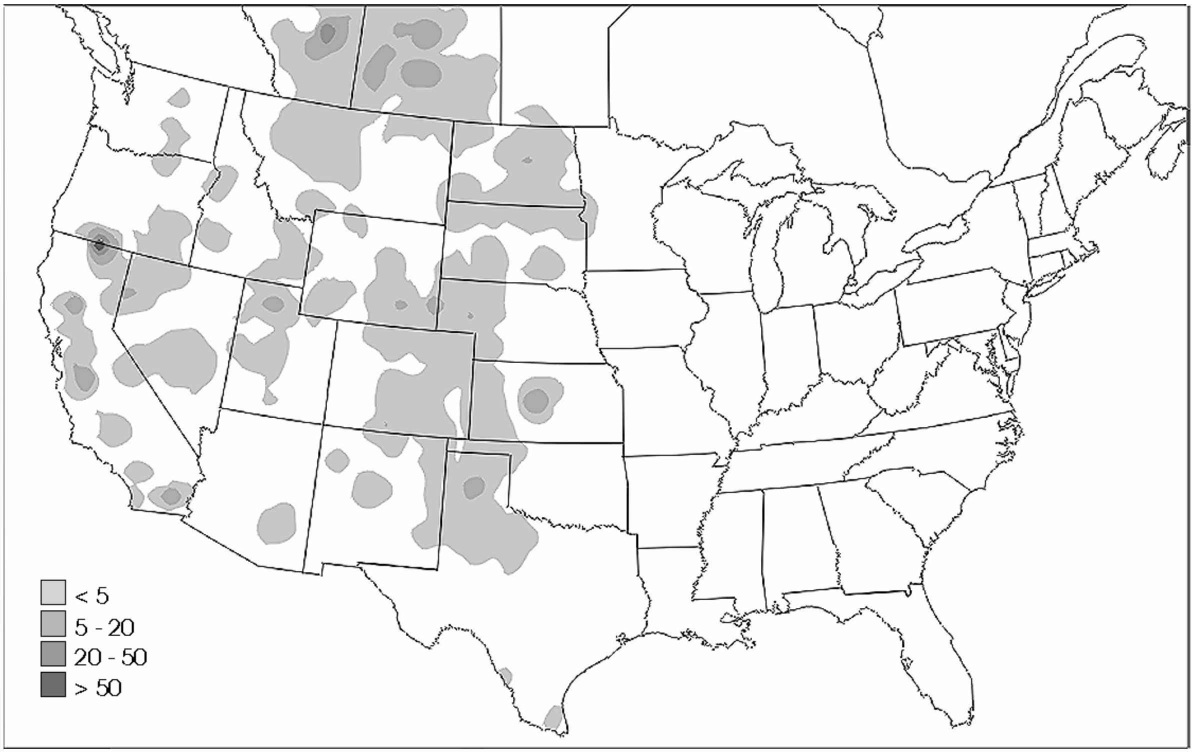

Figure. Breeding distribution of the American Avocet in the United States and southern Canada, based on Breeding Bird Survey data, 1985-1991. Scale represents average number of individuals detected per route per year. Map from Price, J., S. Droege, and A. Price. 1995. The summer atlas of North American birds. Academic Press, London, England. 364 pages.

Key to management is maintaining sparsely vegetated shorelines for nesting habitat on sandbars or islands in wetlands, lakes, or impoundments, and providing wetland complexes for migration habitat.

Breeding range:

American Avocets breed from southern Alberta east to southern Manitoba; south through North Dakota, western Nebraska, central Kansas, the panhandle of Oklahoma and into the panhandle of Texas; and in central and northwestern Washington, central and eastern Oregon, western and southern California, northern Nevada and Utah, southern Idaho, Wyoming, Colorado, and southern Arizona and New Mexico (National Geographic Society 1999). (See figure for the relative densities of American Avocets in the United States and southern Canada, based on Breeding Bird Survey data.)

Suitable habitat:

American Avocets prefer exposed, sparsely vegetated salt flats, sandbars, peninsulas, mudflats, or islands adjacent to shallow (<1 m deep) water, conditions that occur in wetlands, lakes, fallow and flooded fields, or impoundments (Mitchell 1917; Bent 1962;Vermeer 1971; Maher 1974; Kondla 1977; Kondla and Pinel 1978; Grover 1979; Grover and Grover 1981; Grover and Knopf 1982; Sidle and Arnold 1982; Weber et al. 1982; Hirsch and Fouchi 1984; Giroux 1985; Koonz 1985; Dole 1986; Colwell and Oring 1988*a*, 1990; Eldridge 1992; Gunderson et al. 1992; See et al. 1992; Faanes and Lingle 1995; Robinson et al. 1997; Beaver 1998). Breeding habitat can be found in tilled, alkali, ephemeral, temporary, seasonal, semipermanent, and permanent wetlands, and in impoundments, sewage lagoons, and evaporation ponds (Stewart and Kantrud 1965, Stewart 1975, Weber 1978, Faanes 1982, Weber et al. 1982, Kantrud and Stewart 1984, Giroux 1985, Colwell 1986, Dole 1986, Prescott et al. 1995, Baylor 1996, Robinson et al. 1997). In North Dakota, density of nesting American Avocets was greatest in tilled wetlands, followed by alkali, seasonal, and semipermanent wetlands (Kantrud and Stewart 1984). In South Dakota, avocets most frequently occurred in ephemeral wetlands, followed by tilled wetlands and wetlands located in pastures (Weber 1978, Weber et al. 1982). In Alberta, avocets were most abundant in large (>8 ha) saline wetlands, followed by medium-sized (1-8 ha) saline wetlands, large (>8 ha) fresh wetlands, small (<1 ha) saline wetlands, medium-sized fresh wetlands, and small fresh wetlands (Prescott et al. 1995). Avocets may exhibit annual variation in nest site selection, moving to deeper, more permanent wetlands in dry years (Colwell 1986, 1991). In Colorado, avocets preferred seasonal wetlands and habitats dominated by Baltic rush (*Juncus balticus*), sedges (*Carex* spp.), and grasses <40 cm tall over semipermanent wetlands, habitats dominated by cattail (*Typha* spp.) and softstem bulrush (*Scirpus validus*) >40 cm tall, saltgrass habitats, or upland shrub habitats (Laubhan and Gammonley 2000).

American Avocets generally nest on unvegetated ground or in areas with short, sparse vegetation that provide an unobstructed view from the nest (Sidle and Arnold 1982, Giroux 1985, Dole 1986, Robinson et al. 1997). Of 199 American Avocet pairs in Montana, 65% nested on bare ground, 13% nested in short (<12 cm tall) grasses, 15% nested in grasses of moderate height (13-37 cm tall), 7% nested in tall (38-61 cm) grasses, and no avocets nested in very tall (>61 cm) grasses (Dole 1986). Nests often are slightly elevated (2-15 cm) above the surrounding substrate (Sidle and Arnold 1982, Dole 1986). In North Dakota and Montana, nests that were closest to the water's edge, on very wet sites, or in frequently flooded areas usually were elevated from the ground with vegetation (Sidle and Arnold 1982, Dole 1986).

Avocet nests often are placed near water and near clumps of vegetation or debris (e.g., driftwood, fence posts) (Grover 1979, Winton and Leslie 1997). Distance of American Avocet nests to water range from 0 to 300 m, although most nests are located within 60 m of water (Grover 1979, Grover and Knopf 1982, Sidle and Arnold 1982, Giroux 1985, Gunderson et al. 1992, Kuyt and Johns 1992). Nests in Oklahoma were significantly closer to water than random points on a study area (Grover 1979, Grover and Knopf 1982). Of 23 nests in Oklahoma, 57% were located within 5 cm of debris (Grover 1979). In another Oklahoma study, 52% of 41 avocet nests were found within 5 cm of clumps of driftwood or dead vegetation, 29% on human-made elevated habitat structures (e.g., plowed ridges and gravel mounds), 12% on open soil or sand, and 7% within 5 cm of live vegetation (Winton and Leslie 1997). Nest success was highest for nests located within 5 cm of live vegetation, followed by nests within 5 cm of driftwood or dead vegetation, and nests on human-made elevated structures. Nests located on open soil/sand experienced the lowest apparent nest success. Nest losses mostly were due to flooding and depredation by coyotes (*Canis latrans*) or Ring-billed Gulls (*Larus delawarensis*). In another Oklahoma study, avocets nested on alkaline, clay, and sand/stone substrates; hatch rate was similar among substrates (Hill 1985). Of 122 nests, 63% of nests were beside objects, 37% were in the open, and none were under objects. Hatch rates did not differ among clutches located in the open, beside objects, and in or under objects.

American Avocets are semicolonial nesters (Robinson et al. 1997). Nesting most often occurs in loose colonies, although solitary nests also occur (Gibson 1971, Grover 1979, Grover and Knopf 1982, Sidle and Arnold 1982, Giroux 1985, Dole 1986, Robinson et al. 1997). Avocets also may nest in association with other species. In Oklahoma, avocets nested near Snowy Plovers (*Charadrius alexandrinus*) and Least Terns (*Sterna antillarum*) (Hill 1985, Winton and Leslie 1997). Of 41 avocet nests, 63% nested <180 m and 37% nested $\geq$180 m from another active plover, tern, or avocet nest (Hill 1985). Mortality rate was highest for nests in which the nearest nest was a conspecific rather than a nest of another species. Mortality rate was lowest for nests in which the nearest nest belonged to a Least Tern, suggesting that avocets benefitted from nest defense behaviors of Least Terns. Nests of colonial and solitary avocets did not have significantly different mortality rates. In North Dakota and Montana, mean distance between nests varied according to habitat (Sidle and Arnold 1982, Dole 1986). Mean distance between nests on islands or isolated sandbars ranged from 0 to 19 m, whereas mean distance between nests on open salt flats, peninsulas, or shorelines ranged from 10 to 141 m (Vermeer 1971, Grover 1979, Grover and Knopf 1982, Sidle and Arnold 1982, Giroux 1985, Dole 1986). In North Dakota, islands occupied by American White Pelicans (*Pelecanus erythrorhynchos*), Double-crested Cormorants (*Phalacrocorax auritus*), and gulls (*Larus* spp.) were avoided by nesting American Avocets (Sidle and Arnold 1982).

In the prairie regions of Alberta, Manitoba, and Saskatchewan, and in North Dakota, breeding densities of avocets were higher on islands than along wetland shorelines (Kondla and Pinel 1978, Sidle and Arnold 1982). Nest densities of avocets on islands in Montana, North Dakota, and South Dakota were significantly and positively related to percent bare ground and to the presence of saline wetlands (Lokemoen and Woodward 1992). In Alberta, the density of nesting avocets on islands in wetlands created to enhance waterfowl production was positively related to percentage of the island surface covered by sparse vegetation and with maximum water depth between the island and the nearest shoreline (Giroux 1985). Newly constructed islands were preferred over older, more vegetated islands. Amount of sparse vegetation was inversely related to years since island construction. In Colorado, a series of newly constructed shallow wetlands and resting spots created for waterfowl contained non-vegetated areas suitable for nesting avocets (Beaver 1998).

A majority (82%) of 126 nests on islands in North Dakota were found on wet sites dominated by common threesquare (*Schoenoplectus pungens*) (Sidle and Arnold 1982). Nests also occurred in wet sites associated with inland saltgrass (*Distichlis spicata*), field sowthistle (*Sonchus arvensis*), and foxtail barley (*Hordeum jubatum*), as well as on unvegetated, pebbly mud. Shoreline nests were located in inland saltgrass, Pursh seepweed (*Suaeda calceoliformis*), kochia (*Kochia scoparia*), and Nevada bulrush (*Scirpus nevadensis*), or on unvegetated areas of pebbly mud, sand, or gravel. Nests also were found along a shoreline that had been burned the same spring. Nests on the shoreline were placed on top of burned piles of vegetation. One nest in Minnesota was placed in a fallow field near a wetland (Hirsch and Fouchi 1984). Nest sites in

Saskatchewan had significantly more bare ground cover and more vertically heterogeneous vegetation than random sites (Colwell and Oring 1990). In Alberta, American Avocets occurred in wetlands surrounded by cropland and in wetlands surrounded by newly planted dense nesting cover (Prescott et al. 1993).

Avocets forage at various water depths, depending on age and bill length (Dole 1986). Young (0-3 wk old) chicks forage at water depths of 0-90 mm, but mainly at about 8 mm. Older (3-6 wk old) chicks forage at depths from 0 to 100 m, but mostly at about 53 mm. Adult females forage at >80 mm, and adult males forage at about 100 mm. Avocets partition food resources depending on water depth and method of prey capture. Osmundson (1990) reported that adult avocets forage at depths ranging from 90 to 160 mm. A table near the end of the account lists the specific habitat characteristics for American Avocets by study.

Postbreeding and migratory movements:

In the western Great Basin, American Avocets exhibited postbreeding movement prior to fall migration, possibly due to advantages of flocking during molt, location of an abundant food source, or assessing future potential breeding or staging sites (Plissner et al. 2000). For 25 avocets known to have remained in the survey region from early June through late September, the average number of lakes used was 2.1. Of 161 banded and radio-marked birds, the mean distance traveled between lakes within the region prior to migration was 145 km. No difference was detected between sexes in number of movements, number of lakes visited, or persistence in the region. Contrary to fall migratory movements, avocets during the premigratory period tended to move in a northerly rather than southerly direction, possibly to areas of abundant food resources. Resightings of color-banded avocets on breeding grounds in California and Utah indicated that avocets had several migratory routes, that migrating individuals spent as long as 48 days at stopover sites, that avocets traveled relatively short (about 250-500 km) distances between wetland sites as they traveled from breeding to wintering areas, and that siblings may travel together (Robinson and Oring 1996). Compared to adults, first-year avocets were more likely to be at coastal sites than at inland sites.

Based on surveys received from wildlife managers, Skagen et al. (1999) constructed two maps designed to provide land managers with a tool to identify areas critical to migrating shorebirds by highlighting key migratory stopover areas. One map depicts the maximum number of birds within a 100 km^2 cell recorded at specific stopover locations during January-June, whereas the other map depicts the maximum number of birds within a 100 km^2 cell recorded at specific stopover locations during July-December. A histogram provides relative abundance of migrating avocets in monthly periods across 5° latitudinal bands from 25° north to 55° north. The maps cover the prairie provinces of Alberta, Manitoba, and Saskatchewan, and Arizona, Arkansas, Colorado, Iowa, Kansas, Louisiana, Minnesota, Missouri, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming. At Quivira National Wildlife Refuge in Kansas, American Avocets during both spring and fall migration preferred wetlands with deep (>8 cm) and open water over wetlands characterized by wet mud and shallow (<8 cm) water or with uplands, pond margins, or dry mud (Skagen and Knopf 1994).

Area requirements:

Little is known about the area requirements of American Avocets. In a study in Manitoba examining the effects of wetland size on the occurrence of bird species, Daub (1993) found that the American Avocet occurred only on wetlands 6-19.3 ha in size. Daub sampled wetlands ranging from <1 to 19.3 ha, and considered the avocet an area-dependent species.

Brood parasitism:

Intraspecific brood parasitism commonly occurs within American Avocet colonies (Bent 1962, Vermeer 1971, Kondla 1977, Kondla and Pinel 1978, Giroux 1985, Koonz 1985, Dole 1986, Kuyt and Johns 1992, Robinson et al. 1997). The normal clutch size for American Avocets is four, but when two or more females lay eggs in the same nest, superclutches of $\geq$6 eggs can occur (Gibson 1971, Koonz 1985). The frequency of intraspecific brood parasitism is greater on islands and in more northerly portions of the breeding range (Kondla and Pinel 1978, Robinson et al. 1997). Reported frequencies of intraspecific brood parasitism ranged from 8% of 13 nests to 50% of 30 nests (Vermeer 1971, Kondla and Pinel 1978, Giroux 1985, Koonz 1985). Dole (1986) found that nest success was greater for four-egg clutches than clutches with either less than or greater than four eggs. The author suggested that clutches of <4 eggs do not stimulate adult avocets to incubate, whereas it may be physically difficult for avocets to effectively incubate clutches with >4 eggs.

Although intraspecific brood parasitism is considered common, interspecific brood parasitism rarely occurs. An incident of interspecific brood parasitism by American Avocets was noted by Kuyt and Johns (1992) on breeding grounds in the Northwest Territories. American Avocet eggs were found in two Mew Gull (*Larus canus*) nests that were located near a small group of avocet nests. No known records of brood parasitism by Brown-headed Cowbirds (*Molothrus ater*) exist. American Avocets are not suitable hosts for Brown-headed Cowbirds because avocet young are precocial, whereas cowbird young are altricial.

Breeding-season phenology and site fidelity:

American Avocets arrive on the breeding grounds from early April to mid-May and depart from mid-August to mid-October (Bent 1962, Salt and Salt 1976, Knapton 1979, Johnsgard 1980, Sidle and Arnold 1982, Hill 1985, Dole 1986, Janssen 1987, Colwell et al. 1988, See et al. 1992, Robinson et al. 1997, Svingen 1998). In Montana, peak egg-laying occurred in May (Dole 1986). The species is single-brooded but commonly will renest following failure of the initial nest (Gibson 1971, Sordahl 1984, Dole 1986, Robinson et al. 1997).

Adult American Avocets occasionally return to breeding sites in following years and may retain their mates of the previous year or years (Gibson 1971, Sordahl 1984, Colwell and Oring 1988*b*, Robinson and Oring 1997, Robinson et al. 1997). In California and Nevada, 116 of 478 adults (24%) bred one to two years after banding within 20 km of the banding site, 140 (29.3%) were seen in subsequent years as nonbreeders or as migrants, and 222 (46.4%) were never seen again (Robinson and Oring 1997). No evidence of sex difference in philopatry was detected. Of 25 females and 35 males, 13 (52%) and 14 (40%), respectively, retained their mates from previous years (Robinson and Oring 1997). In Oregon, one pair was observed with young the first year after banding, was absent the second year after banding, but was seen together again the third year after banding (Gibson 1971). One pair remained paired for at least 3 yr. In Utah, six of 21 (29%) adults returned to the study area the first year after banding (Sordahl 1984). One pair was seen in two consecutive years, and one adult male was seen during three years. In Saskatchewan, two of two males and one of two females returned to the study area one year after marking (Colwell and Oring 1988*b*).

After-hatch-year American Avocets occasionally return to natal sites to breed. In California, of 811 nestling avocets banded at one study site, 34 (4.2%) returned when they were one or two years old (Robinson and Oring 1997). Most American Avocets do not breed until they are two years old; of the 811 nestlings, 13 (1.6%) returned as breeding adults (Robinson and Oring 1997). One example of long-distance dispersal was documented: a male banded as a chick was captured on a nest 480 km from the banding location. In Saskatchewan, of 13 marked chicks, none returned to the breeding site (Colwell and Oring 1988*b*). In Utah, of 49 banded young, none returned in subsequent years (Sordahl 1984).

<u>Species' response to management</u>:

Little is known concerning the effects of burning, mowing, or grazing on American Avocets. In North Dakota, American Avocets nested along a burned shoreline (Sidle and Arnold 1982). However, nests on this shoreline had lower hatching success than nests on an island, a sandbar, and four peninsulas.

Preference for islands by American Avocets may be associated with increased nest success due to greater protection from nest predators (Sidle and Arnold 1982, Giroux 1985). Robinson et al. (1997) suggested that breeding densities of American Avocets were most influenced by the availability of nest sites, especially on islands, rather than overall wetland area. In Montana, hatching success was associated with island size and the distance of the island from shore (Dole 1986). Hatching success was lower on islands than along shorelines, mudflats, or a dry lake bed. Mammalian predators may have been able to wade or swim to islands that were near shore. Small islands with high nest densities were at risk of greater depredation because of the ease with which predators located nests (actual island sizes and distances of islands to shore were not given).

Elevated nest structures, such as ridges, and exclosures made of electrical fencing may increase nesting success by reducing loss of nests due to flooding and nest predation, respectively (Koenen 1995, Winton and Leslie 1997). Nest losses due to flooding and predation may be considerable. Of 193 nests in California, 84 (44%) were lost to predation and 11 (6%) to changes in water level (Ohlendorf et al. 1989). In Oklahoma, exclosures and nest ridges were used to reduce nest predation and flooding, respectively, on Snowy Plovers and Least Terns (Koenen 1995). Although the effects of exclosures and ridges on avocet nest success were not examined, avocets did nest in close proximity to the plovers and terns. Fluctuations in water levels may cause the destruction of nests because of the close proximity (usually <60 m) with which American Avocets place their nests to water (Plissner et al. 2000). Nest ridges were 10 m long by 1 m wide by 0.5 m high and were spaced 20-30 m apart. Predator exclosures were 1000-6000 volt electric fences ranging in size from 3.75 to 24 ha. Five strands of wire were placed 14-86 cm from the ground.

In California, American Avocets nested on a 130-ha mitigation site that replaced 1200 ha of evaporation ponds (Robinson et al. 1997). The mitigation site was designed with a 2:1 ratio of shallow-water feeding areas (10-15 cm deep) to elevated nesting areas. Thirty-five feeding lanes of 20 m width alternated with 34 unvegetated and gradually sloping (12:1 slope) nesting lanes of 10 m width. All lanes were 1.6 km long, and water was applied via a flow-through system. An electrical fence deterred predators. The mitigation site held 754 avocet nests at a density of 5.8 nests/ha and <1% predation, compared to previous reports of 1100 avocet nests at 0.9 nests/ha and 30% predation at the mitigated evaporation pond. The response of avocets to the mitigation site was more favorable than expected (Robinson et al. 1997).

High concentrations of selenium in eggs may cause embryotoxicity, that is, embryo deformity or death (Robinson et al. 1997). Irrigation over soils that have a high selenium content cause leaching of selenium from the soil to the groundwater (See et al. 1992). Selenium is present in evaporation ponds that receive subsurface agricultural drainage water; these ponds often attract large numbers of waterbirds (Skorupa and Ohlendorf 1991). Skorupa and Ohlendorf (1991) investigated the level of selenium that represented a significant threshold of toxicity to waterbirds. Median selenium concentration from 74 sample means (sample means based on samples of two to nine eggs) from wild birds in nonmarine wetlands was 1.9 parts per million (ppm) dry weight. The interquartile range was 1.4 to 2.4 ppm. The authors suggested that >3 ppm mean egg selenium indicated avian contamination in nonmarine environments. Avian contamination was defined as mean selenium in eggs (mean egg selenium) above normal (background) concentrations. Mean egg selenium ranging from 8 to 37 ppm indicated various levels of embryotoxicity. In California, an exposure-response relationship existed between egg selenium concentration and incidence of embryo deformity (Robinson et al. 1997, Skorupa 1998). Eggs with selenium concentrations $\leq$ 40 ppm dry weight had 0% incidence (based on 486 eggs) of deformed embryos; eggs with 41-60 ppm selenium had 5% (based on 26 eggs) deformity, eggs with 61-80 ppm selenium had 8.3% (based on 14 eggs) deformity, and eggs with 81-110 ppm had 25% (based on 15 eggs) deformity. Percentages were calculated by weighting results for each 5-ppm interval equally. Skorupa (1998) conducted a logistic regression analysis of the embryonic response for avocet eggs exposed to selenium and the reported effect concentrations of 41, 74, and 105 ppm selenium dry weight for 1%, 10%, and 50% rates of embryo deformities, respectively (i.e., in toxicological nomenclature the EC_{50}=105 ppm). These effect concentrations indicated that avocets were significantly less vulnerable to selenium poisoning than Black-necked Stilts (*Himantopus mexicanus*), a very closely related and ecologically similar species of shorebird.

In Tulare Basin, California, avian contamination of >3 ppm was associated with evaporation ponds that contained 1-3 parts per billion (ppb) waterborne selenium (Skorupa and Ohlendorf 1991). Embryotoxicity of >24 ppm mean egg selenium was associated with evaporation ponds that contained 10-20 ppb waterborne selenium.

Based on the reproductive performance of 17 breeding aggregations of Black-necked Stilt and American Avocet, significantly reduced hatchability (the proportion of eggs surviving to the end of incubation that hatched) was associated with average selenium concentrations of $\geq$8 ppm (Skorupa and Ohlendorf 1991). Results of artificial incubation studies suggested that hatchability depression in eggs of American Avocets was a result of contaminants in evaporation ponds. At a selenium-contaminated site in California, mean selenium concentration in 35 American Avocet eggs ranged from 6 to 16.4 ppm dry weight (Ohlendorf et al. 1986). These concentrations were significantly higher than the range of 0.3 to 1.2 ppm dry weight in seven eggs from a non-contaminated site.

In Wyoming, selenium levels in lakes of 38 to 54 ppb were associated with high selenium levels in eggs (>8 ppm) and livers (>30 ppm) of adult American Avocets (both live and dead birds) (Skorupa 1998, See et al. 1992). Of 102 American Avocet eggs, selenium concentrations ranged from 24.2 to 135 ppm dry weight and averaged 82.7 ppm dry weight. Mean egg concentrations of >13-24 ppm dry weight were associated with embryo deformities. No malformed embryos were found in the first year of the study, but in the second year 24% of 37 embryos had malformations. Crossed bills and malformed legs and feet were the most common types of deformities. Mean concentrations of >8 ppm dry weight were associated with impaired egg hatchability. Cause of selenium embryotoxicity was irrigation over soils derived from Cody shale, which tended to have a high selenium content. Selenium discharge from sub-basins was related to irrigation intensity (measured by the area of irrigated land) and the concentrations of selenium in groundwater.

At Freezout Lake Wildlife Management Area and Benton Lake National Wildlife Refuge in westcentral Montana, elevated levels of selenium were found in avocet embryos and livers (Nimick et al. 1996). Water sources for both lakes were irrigation return flow, surface runoff, and direct precipitation. At Freezout Lake, based on 73 embryos collected one year and 17 embryos collected the following year, geometric mean selenium concentration ranged from 6 to 17 ppm. Livers from 16 American Avocets contained selenium concentrations ranging from 13 to 43 ppm and averaged 22 ppm. At Benton Lake, based on 36 embryos collected one year and 10 embryos collected the following year, geometric mean selenium concentration ranged from 3.4 to 3.7 ppm. Livers from 28 American Avocets contained selenium concentrations ranging from 9.3 to 45 ppm and averaged 20 ppm.

American Avocet mortalities due to collisions with power transmission line have been reported in North Dakota and Montana (McKenna 1976, Malcolm 1982). In Montana, highest mortalities occurred during August and September (fall migration) (Malcolm 1982). The power transmission line structure was constructed over a wetland that was intermittently flooded. Distances from the water to the conductor wires ranged from 14 to 33 m.

Management Recommendations:

Shorebirds are highly mobile in response to the dynamic and ephemeral nature of the habitats (e.g., mudflats and wetlands) on which waterbirds are dependent. Therefore, use of habitats during migration and breeding is characterized by dispersion and opportunism rather than by concentration and predictability (Skagen and Knopf 1993, Weller 1999). These unpredictable habitat patches, however, may be crucial as stopover sites for migrating shorebirds (Skagen and Knopf 1993, Weller 1999). Rather than maintaining a few wetlands in a static condition, a network of sites that provide wetlands in various water cycles may be necessary (Skagen and Knopf 1993, Skagen et al.1999).

The ideal management strategy for waterbirds is to maintain wetland complexes and large wetlands or lakes (Weller 1999). Because of variation in water levels over seasons or years, wetland complexes are more likely to have at least some wetlands with water and plant regimes favorable to a particular species, thus ensuring diverse species' representation in a geographical area (Colwell and Oring 1988*a*, Weller 1999). Wetland complexes may increase habitat and food diversity, and in turn create species diversity (Fredrickson and Reid 1986). Diversity of wetland systems is important because of high interannual variation in use of wetlands and within-year movements between wetlands (Plissner et al. 2000).

Because shorebirds are highly mobile, a number of wetlands of different types and sizes may be used for various life history requirements, and thus, the spatial and temporal interconnectedness of wetlands should be considered (Haig et al. 1998). Duration of use of a wetland should not be a basis for judging the value of a wetland because many waterbird species are highly mobile and wetlands used for short periods of time may still be vital elements of the habitat needed by migrating waterbirds (Weller 1999). Use of ephemeral habitats may be determined by examining the length and duration of movements of individuals, which could reveal both movements within and among seasons (Haig et al. 1998). Determining connectivity of patches is important so that all relevant patches are conserved (Plissner et al. 2000). Even small wetlands may be important, as they may be abundant and reduce isolation between patches of wetland habitats (Gibbs 1993).

The spatial array of a wetland complex also may be important (Haig et al. 1998). Different sites may be used by an individual for pre-breeding inspections of possible nest-site locations, breeding, renesting, territory switching, foraging, and brood rearing. Wetlands also are needed for molt-migration, postbreeding dispersal, migration, and wintering. Adults may exhibit breeding-site fidelity, and juveniles may exhibit natal fidelity for their first breeding attempt.

Habitat use may vary due to environmental factors, such as amount of annual rainfall or water allocated to a particular area, or in quality, such as degree of salinization or contamination (Haig et al. 1998). Water quantity and quality should be monitored, and amount of habitat variability within a wetland complex should be noted (Haig et al. 1998). Water quality must be maintained to minimize sedimentation, effluents, and pollutants (Weller 1999). Effects of increased salinization in freshwater wetlands on wetland birds are unknown, and management to control salinization or techniques to manage saline wetlands are poorly studied (Rubega and Robinson 1997). Wetland plant succession dictates whether habitat for cover, nesting sites, and food will be maintained or provided (Weller 1999). Drought may necessitate the need for alternative breeding sites (Weller 1999). During periods of drought, water release into wetlands in spring creates breeding habitat and reduces predation pressure (Alberico 1993).

Habitat manipulations necessary for providing needs for one species may be detrimental to another species (Weller 1999). Undertaking multi-species studies enhances an understanding of a system, and the information gained may lessen the impact that management for one species may have on another (Weller 1999, Laubhan and Gammonley 2000). Large wetland areas would make it possible to meet the needs of multiple species (Weller 1999). Stable wetland types may be no more or less desirable than dynamic wetlands. Each type supports different wetland bird assemblages. Areas managed for waterfowl can be made more amenable to shorebirds, such as American Avocets, by the construction of sparsely vegetated nesting islands with gently sloping beaches surrounding deep-water zones (Colwell and Oring 1988*a*). The islands and beaches can provide nesting habitat for avocets and loafing areas for waterfowl. Unless vegetation is managed to maintain sparseness, islands created for waterfowl may be unsuitable for avocets after vegetation has become established (Giroux 1985). Fluctuations in water levels place avocet nests at risk (Plissner et al. 2000); careful consideration of human-caused changes in water levels, or construction of nest ridges to elevate nests, may be necessary to prevent nest losses. Construction of sparsely vegetated islands and protection from predators may increase nesting success of American Avocets (Sidle and Arnold 1982, Dole 1986).

To reduce risk of avian contamination and toxicity due to drainage water, either the amount of contaminants in drainage water should be reduced, or avian use of contaminated ponds should be reduced (Skorupa and Ohlendorf 1991, Skorupa 1998). To prevent avian toxicity but not avian contamination, drainage water should be purified to <10 ppb waterborne selenium. To minimize avian contamination, drainage water should be purified to <2.3 ppb waterborne selenium. However, as these standards cannot be met with current technology, deterring avian use of contaminated drainage water may be the only option. Drainage water containing 3-20 ppb selenium should be considered potentially hazardous to waterbirds, whereas >20 ppb selenium should be considered definitely hazardous to waterbirds.

Skagen et al. (1999) provided distribution maps that show where species and groups of shorebirds migrate through the Great Plains and a chronological histogram that describes the timing of migration. Knowing when shorebirds migrate through a particular area will aid resource managers' decisions on when to enact certain management techniques. For example, drawdowns that expose bloodworms (*Chironomus*), a food source for shorebirds, can be linked to local migration phenology (Eldridge 1992). Water drawdowns provide the mudflat substrate and concentration of invertebrates on which many shorebirds forage (Fredrickson and Reid 1986). The timing of drawdown depends upon target species and whether they are present during the breeding or migrating period. Eldridge (1992), Helmers (1992), and Rehfisch (1994) provided general management suggestions for optimizing invertebrate abundance in wetlands through drawdowns, disking, and flooding. Development and management of seasonally flooded impoundments for waterbirds was discussed by Fredrickson and Taylor (1982).

Power lines should not be constructed through or within 1 km of known historical high-water marks of wetlands, through dry basins known to hold water intermittently, or through heavily used waterbird migration routes (Malcolm 1982). In cases where power lines must cross flyways, an attempt should be made to mask the lines with structures such as bridges (McKenna 1976). Power lines should be buried where possible and corridors established where power lines can be congregated to reduce their proliferation (McKenna 1976).

Table. American Avocet habitat characteristics.

Author(s)	**Location(s)**	**Habitat(s) Studied***	**Species-specific Habitat Characteristics**
Baylor 1996	South Dakota	Impoundment, wetland	Adults with young were observed in a shallow-water impoundment and a wetland
Beaver 1998	Colorado	Island, wetland complex	Nested on a bare mudflat and a sparsely vegetated island
Bent 1962	Rangewide	Island, salt flat, wetland	Nested near (distance not given) water on sparsely vegetated, dry mudflats, salt flats, shorelines, and islands
Dole 1986	Montana	Island, wetland	Nested on islands, shorelines, mudflats, and in a dry lake bed; 65% of 199 nests were located on bare ground;13% nested in short (<12 cm tall) grasses,15% nested in medium (13-37 cm tall) grasses, 7% nested in tall (38-61 cm) grasses, and none nested in very tall (>61 cm) grasses; nests on islands were <5 m from their nearest neighbor; nests on shorelines were associated with large expanses of alkali flats between 10 and 20 m apart; nests on shoreline with only a narrow band of suitable habitat between the water's edge and tall, dense grass were between 20 and 30 m apart; mean distance to nearest neighbor was greater (24 m) for 127 successful nests than 46 unsuccessful nests (19.5 m)
Faanes 1982	North Dakota	Wetland	Occurred in alkali wetlands
Faanes and Lingle 1995	Nebraska	Wetland	Nested near shallow (depth not given), permanent

			wetlands that supported little or no herbaceous cover
Giroux 1985	Alberta	Impoundment, island wetland	Nested on unvegetated ground or in areas with short (not defined), sparse vegetation on islands; mean distance of 204 nests from water was 7.6 m; mean distance to nearest nest was 14 m; density of avocets was positively related to percentage of the island surface covered by sparse vegetation and to maximum water depth between the island and the nearest shoreline
Grover 1979, Grover and Grover 1981, Grover and Knopf 1982	Oklahoma	Impoundment, salt flat, stream	Nested exclusively on non-vegetated areas of the salt flat; of 23 nests, mean distance to water was 60 m, which was significantly closer to water than expected by chance; of 22 nests, mean distance to nearest nest of a conspecific nest was 141 m; of 23 nests, mean distance of nearest nest of any species' nest was 75 m; 57% of 23 nests were located within 5 cm of debris (driftwood, fence posts, etc.)
Gunderson et al. 1992	Minnesota	Lake	Nested 18 m from water on dried mud near cluster of grass
Hill 1985	Oklahoma	Salt flat	Nested on alkaline and clay substrates; of 122 nests, 63% were within 30 cm of an object and 37% were in the open; of 41 avocets, 63% nested <180 m from any other active nest and 37% nested ≥180 m; daily nest mortality rates did not increase linearly with increasing inter-nest distances; nests of colonial and solitary avocets did not have significantly different mortality rates; mortality rate

			was higher for nests for which the nearest nest was a conspecific than a nest of another species; nest survival was highest if the nearest nest belonged to a Least Tern (*Sterna antillarum*)
Kantrud and Stewart 1984	North Dakota	Wetland complex	Highest densities occurred in undifferentiated tillage wetlands (wetlands with frequently tilled soils), followed by alkali, seasonal, and semipermanent wetlands
Kondla and Pinel 1978	Alberta, Manitoba, Saskatchewan	Island, wetland	Majority (56%) of 228 nests occurred on islands
Koonz 1985	Manitoba	Island, lake	Nested along the shore of a rocky island
Kuyt and Johns 1992	Northwest Territories	Island, lake	Nested in short (measurements not reported) grass and sedge (*Carex*) clumps or on wet ground; nests were within 0.2 m of water on a 6-m-wide island
Laubhan and Gammonley 2000	Colorado	Wet meadow, wetland, shrubland	Preferred seasonal wetlands and habitats dominated by Baltic rush (*Juncus balticus*), sedges (*Carex* spp.), and grasses <40 cm tall over semipermanent wetlands, habitats dominated by cattail (*Typha* spp.) and softstem bulrush (*Scirpus validus*) >40 cm tall, saltgrass habitats, or upland shrub habitats
Lokemoen and Woodward 1992	Montana, North Dakota, South Dakota	Island, wetland	Nest densities on islands were significantly and positively related to percent bare ground and to the presence of saline wetlands
Maher 1974	Saskatchewan	Wetland	Nested on a mudflat
Mitchell 1917	Saskatchewan	Island, lake	Nested on a sandy island of a lake

Plissner et al. 2000	California, Nevada, Oregon	Lake	Used multiple wetlands during the premigratory period and moved in a northerly direction, contrary to migratory movements; of 185 birds, 17% were observed at >2 lakes, and 26% used $\geq$2 lakes; of 161 birds detected after banding, mean distance traveled between lakes within the region was 145 km; for 25 avocets known to have remained in the survey region through the last week of September, the average number of lakes used was 2.1; no difference in number of movements, number of lakes visited, or persistence in the region was detected between sexes
Prescott et al. 1993	Alberta	Cropland, dense nesting cover (idle seeded-native), mixed-grass pasture, tame pasture, wetland, wetland (restored)	Occurred in wetlands surrounded by cropland and in wetlands surrounded by newly (<1 yr) planted dense nesting cover
Prescott et al. 1995	Alberta	Wetland	Were most abundant in large (>8 ha) saline wetlands, followed by medium (1-8 ha) saline wetlands, large (>8 ha) fresh wetlands, small (<1 ha) saline wetlands, medium (1-8 ha) fresh wetlands, and small (<1 ha) fresh wetlands
Sidle and Arnold 1982	North Dakota	Burned shoreline, island, lake	Nested on exposed wetland shorelines, peninsulas, a sandbar, an island, and on burned piles of emergent vegetation; mean height of 126 nests above the ground was 5.3 cm; of 126 nests, 82% were on islands with wet sites dominated by

			common threesquare (*Schoenoplectus pungens*), 13% in wet sites among inland saltgrass (*Distichlis spicata*), field sowthistle (*Sonchus arvensis*), and foxtail barley (*Hordeum jubatum*), and 5% on unvegetated, pebbly mud
Stewart 1975	North Dakota	Wetland	Breeding occurred in wetlands and lakes with exposed, sparsely vegetated shorelines or mudflats adjacent to shallow (not defined) water; these conditions were found on alkali wetlands and subsaline semipermanent wetlands
Vermeer 1971	Alberta	Lake	Nested on an unvegetated sandbar; of 30 nests, mean distance to nearest nest was 3.4 m
Weber 1978, Weber et al. 1982	South Dakota	Cropland, idle mixed-grass, idle shortgrass, idle tallgrass, mixed-grass pasture, shortgrass pasture, tallgrass pasture, tame hayland, wetland, woodland	Most frequently occurred on ephemeral ponds, followed by tilled ponds, ponds in pastures, and temporary ponds; presence was positively related to the presence of tilled ponds, ponds in pastures, ephemeral ponds, hectares of alfalfa/hayland within a 64-ha area, and grazing intensity

Winton and Leslie 1997	Oklahoma	Impoundment, salt flat, stream	Of 41 avocet nests, 52% were found $\leq$5 cm from clumps of driftwood or dead vegetation, 29% on human-made elevated habitat structures (e.g., plowed ridges and gravel mounds), 12% on open soil or sand, and 7% $\leq$5 cm from live vegetation; nest success was highest for nests located $\leq$5 cm from live vegetation, followed by nests $\leq$5 cm from driftwood or dead vegetation, and nests on human-made elevated structures; nests located on open soil/sand experienced the lowest apparent nest success

*In an effort to standardize terminology among studies, various descriptors were used to denote the management or type of habitat. “Idle” used as a modifier (e.g., idle tallgrass) denotes undisturbed or unmanaged (e.g., not burned, mowed, or grazed) areas. “Idle” by itself denotes unmanaged areas in which the plant species were not mentioned. Examples of “idle” habitats include weedy or fallow areas (e.g., oldfields), fencerows, grassed waterways, terraces, ditches, and road rights-of-way. “Tame” denotes introduced plant species (e.g., smooth brome [*Bromus inermis*]) that are not native to North American prairies. “Hayland” refers to any habitat that was mowed, regardless of whether the resulting cut vegetation was removed. “Burned” includes habitats that were burned intentionally or accidentally or those burned by natural forces (e.g., lightning). In situations where there are two or more descriptors (e.g., idle tame hayland), the first descriptor modifies the following descriptors. For example, idle tame hayland is habitat that is usually mowed annually but happened to be undisturbed during the year of the study.

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Effects of Management Practices on Wetland Birds:
Bibliography on Survey Methods for American Avocet

Note: Few sources were found that explained detailed methods for conducting population surveys specific to American Avocets (but see Grover 1979, Skagen and Knopf 1994, Robinson and Oring 1997). Most methods involved finding nests, recording vegetation measurements or avocet behavior, or banding individuals. Some sources of methods were not reviewed. They are listed at the end of the annotated bibliography.

Annotated articles

Colwell, M. A., and L. W. Oring. 1988. Habitat use by breeding and migrating shorebirds in southcentral Saskatchewan. Wilson Bulletin 100:554-566.

Shorebird use of habitats was studied in southcentral Saskatchewan during drought conditions in 1984. Censuses were conducted from late April to late August at a permanent wetland and in surrounding pasture from late May to Autumn. Shorebird censuses at wetlands and mudflats were conducted using 1-3 observers in 3-m towers using 20-25x spotting scopes and 7x binoculars. At a beach site, an observer walked the beach and recorded data at points that maximized observations of shorebirds. A stratified random sampling scheme was used to schedule censuses at two sites. During successive weeks, observations were made during random sampling periods that included all daylight hours (0500 to 2100 hr). At a site, observers scanned the site and recorded each bird's behavior and habitat. Habitats were based upon a scale relating water level to an individual's upper tarso-metatarsal joint (Baker, M. C. 1979. Morphological correlates of habitat selection in a community of shorebirds [Charadriiformes]. Oikos 33:121-126).

Colwell, M. A., and L. W. Oring. 1988. Return rates of prairie shorebirds: sex and species differences. Wader Study Group Bulletin 55:21-24.

Return rates were determined for five species of juvenile and adult shorebirds at Last Mountain Lake National Wildlife Area, Saskatchewan, during 1982 through 1987. Adult and young Killdeer, American Avocet, Willet, Marbled Godwit, and Wilson's Phalaropes were color-banded. Birds were captured using mist nets, nest traps, decoy traps, and walk-in funnel traps. Each adult was banded with three colored plastic leg bands and a metal band. Some birds were marked with colored nylon patagial tags. Some females were fitted with radio transmitters. Blood was taken from the brachial vein of Wilson's Phalaropes. Chicks were banded after hatching with brood-specific combinations of one color and one metal band.

Colwell, M. A., and L. W. Oring. 1990. Nest-site characteristics of prairie shorebirds. Canadian Journal of Zoology 68:297-302.

Nest sites were characterized for Piping Plover, Killdeer, American Avocet, Willet, Upland Sandpiper, Marbled Godwit, Common Snipe, and Wilson's Phalarope at Last Mountain Lake National Wildlife Refuge, southcentral Saskatchewan. Nests were located and site characteristics measured from 1982-1984. Nests were located by watching birds from observation posts. These posts were either towers 3 m high or field vehicles. One to four observers conducted observations in the mornings or evenings using 7x binoculars and 22-25x spotting scopes. Nests usually were located by watching pairs of birds as they chose nest sites, or by observing laying or incubating birds returning to nests. A few nests were found by observers when they flushed birds off nests. Birds were marked with colored bands and a metal band.

Nest-site characteristics measured on the day a clutch was completed were distance to nearest patch of unvegetated soil >1 m^2, distance to standing water of the wetland, distance to wetland edge (major aquatic/vegetative or aquatic/terrestrial interface), distance to active conspecific nest, and distance to active shorebird nest. Several vegetative measurements also were taken. These included percent cover of grass, forb, bare ground, and cow pies; vertical and horizontal structure (e.g., maximum vegetation height, total number of vegetation hits, average litter depth, and average number of contacts by vegetation in the 1-dm height interval nearest the ground on a 5 mm diameter rod); and heterogeneity of vegetation as measured by coefficients of variation for total number of vegetation hits and maximum vegetation height.

Dole, D. A. 1986. Nesting and foraging behavior of American Avocets. M.A. thesis. University of Montana, Missoula, Montana. 85 pages.

Breeding biology and foraging behavior of American Avocets were studied at Benton National Wildlife Refuge in northern Montana during 1983 and 1984. Birds were observed from mid-April through mid-July. Nests were located by daily nest searches on foot during the first few weeks of the breeding season. Nests on shorelines were marked by placing a numbered stake 15 paces inland. Nests on islands were marked by placing a 5 cm high wooden marker 15 cm from the nest. After incubation started, nests were checked every other day until near hatching, at which time nests were checked daily. Eggs were marked with identifying symbols with a marking pen. Eggs were labeled in order of the sequence by which eggs were laid, if known. Date each egg was laid (if known), number of eggs in each clutch, and date at which incubation commenced were recorded. Length and breadth of eggs was measured and egg volume estimated.

Binoculars and spotting scopes were used to observe behavior, and a tape recorder was used to record observations. Most observations were taken from inside a vehicle, but some were taken when the observer was in view of the birds. Male and females avocets were distinguished by bill morphology.

Nest measurements were taken.

Gibson, F. 1971. The breeding biology of the American Avocet (*Recurvirostra americana*) in central Oregon. Condor 73:444-454.

Spring arrival period, chronology of breeding activities, courtship, territory, nesting, incubation, hatching, care of young, and preparation for fall migration of the American Avocet were studied on the Summer Lake Management Area, Lake County, in southcentral Oregon during spring and summer from 1967 to 1969. A 3.75-km census route, in which number of avocets was recorded, was conducted in the mornings, daily from 1 April to 17 May and on alternate days through 10 July, to obtain an index of the seasonal flux of breeding activities. Time budget data and behavioral observations were made throughout the breeding cycle. Behavioral observations were made from an automobile or from 3-m tall observation towers. Time budget data of a pair of avocets were recorded at 10-sec intervals for 30-min observation periods, with time measured by a metronome. Nests were located, eggs were marked with fingernail polish, and fate monitored during twice-daily visits during egg-laying and hatching and daily or alternate-day checks during incubation. Territory position, boundaries, and patterns were observed by recording positions of a pair every 10 sec within a grid system.

Giroux, J. F. 1985. Nest sites and superclutches of American Avocets on artificial islands. Canadian Journal of Zoology 63:1302-1305.

Use by breeding American Avocets of 80 artificially created islands was examined in southeastern Alberta from 1976 to 1978 and in 1980. Monthly nest searches were conducted on artificial islands between late April and early July by walking parallel transects 2-3 m apart. For each nest, the number of eggs was recorded and the nest location was indicated on a scaled map using a coordinate system. Distances from each nest to the nearest conspecific nest and to the shoreline were recorded. Five variables were used in a stepwise multiple regression analysis that examined variation in nest density among islands: the size of the island, the distance between the island and the nearest shoreline, the maximum water depth between the island and the nearest shoreline, the percentage of the island surface covered with sparse colonizing vegetation, and the percentage of the island surface covered with emergent plants.

Grover, P. B. 1979. Habitat requirements of charadriiform birds nesting on salt flats at Salt Plains National Wildlife Refuge. M.S. thesis. Northeastern Oklahoma State University, Tahlequah, Oklahoma. 38 pages.

Density, distribution, nest site selection, and reproductive success were studied for the American Avocet, Snowy Plover, and Least Tern on the Salt Plains National Wildlife Refuge in northern Oklahoma during the breeding seasons of 1977 and 1978. Direct censuses were conducted using a 20x field telescope or 7x binoculars in order to determine absolute minimum numbers of breeding birds. Counts were performed bi-weekly. Salt flats were scanned systematically. Grover assumed that all adult birds were paired; population size was based on direct counts of adult birds. Field studies were conducted from 29 April through 20 July the first year, and from 1 May through 7 August the second year.

Nests of the species were located and plotted on a map. The distances of nests to the nearest body of water, nearest nest of any species, and to the nearest nest of a conspecific were recorded after nesting activities were completed. The authors tested whether nests were preferentially placed near debris (driftwood, fenceposts, or discarded refuse) or near the water. Samples of aquatic and terrestrial invertebrates were taken and direct observations of feeding birds were used to estimate food habits. Nests were checked every 1-3 days and six time-lapsed cameras monitored six selected nests each year.

Hill, L. A. 1985. Breeding ecology of Interior Least Terns, Snowy Plovers, and American Avocets at Salt Plains National Wildlife Refuge, Oklahoma. M.S. thesis. Oklahoma State University, Stillwater, Oklahoma. 106 pages.

Trapping techniques were described and effects of capture, handling, and radio transmitters on Interior Least Terns and Snowy Plovers were examined in 1983 and 1984. Nests were found and monitored every 1 to 3 days. Least Terns and Snowy Plovers were captured using T-traps and divided into two groups. Birds in group one were marked with a USFWS band and, in addition, plovers were marked with three plastic bands. Group one individuals were marked in all stages of incubation. Birds in group two were marked with a USFWS band and equipped with a back-mounted radio transmitter during late incubation. Before release, birds were placed inside a release box. Traps were set and left overnight at 15 tern and 20 plover nests to determine if trap presence affected nest depredation. Effects of trapping and radiomarking were examined by comparing depredation and desertion rates, daily nest survival, and daily egg survival of experimental groups and control groups that were not trapped, handled, or marked.

A method for determining incubation stage for Least Tern, Snowy Plover, and American Avocet clutches was described. For each species, eggs from 20 known-age nests were measured at 3-5 day intervals throughout incubation. Egg length, breadth, and weight were measured. Eggs were placed in a beaker of distilled water and the angle of flotation measured. Diameter of the shell protruding above the water also was measured. Linear regression models were then developed to predict hatching dates.

Effects of weather, nest substrate, nest cover, nearest neighbors, and inter-nest distances on reproductive success were examined for Least Terns, Snowy Plovers, and American Avocets. Distance and direction to nearest reference point, substrate type, and relative distance to objects or vegetation was recorded at each nest. Nests within 30 cm of an object were categorized as beside the object, nests covered from above were categorized as under the object, and nests within a cowpie or other object were considered inside the object. Nearest inter- and intraspecific-neighbor distances were measured. Nests were checked every 3-5 days, and nests were considered successful if at least one chick hatched. Failed nests were those for which a clutch disappeared or egg remains or predator signs were found.

Plissner, J. H., S. M. Haig, and L. W. Oring. 2000. Postbreeding movements of American Avocets and implications for wetland connectivity in the western Great Basin. Auk 117:290-298.

The postbreeding movements of radio-marked American Avocets were examined in the major alkali lake systems of the western Great Basin (Oregon, Nevada, and California) in 1996 and 1997. A total of 185 breeding adult avocets were banded and color-marked from five wetlands. Adults were captured while incubating clutches that were $\geq$10 days old, using walk-in nest traps or custom-designed, spring-loaded traps. All birds were given a unique combination of colored leg bands that identified the year, site, and individual bird. Radio transmitters were put on aluminum bands. Air and ground surveys were conducted on a weekly basis, in most cases, and radio-tagged birds were located. Ground surveys were conducted beginning 1 June. From mid-June through September, aerial surveys were conducted.

Robinson, J. A., and L. W. Oring. 1996. Long-distance movements by American Avocets and Black-necked Stilts. Journal of Field Ornithology 67:307-320.

Returns of banded American Avocets and Black-necked Stilts to locations in California and Utah were used to determine migration and winter locations. Avocet and stilt young and adults were color-banded with unique combinations of UV-resistant colored bands. Avocets were sexed by bill curvature and stilts by plumage. Adults were trapped on the nest after 14 days of incubation and banded. Set traps were visually monitored from a portable blind or a vehicle and birds removed from traps immediately. Trapping occurred during the hottest part of the day when adults would be most likely to incubate. Adults were not kept off the nest for more than 20 min. Eggs were replaced with painted wooden imitations during trapping to prevent overheating. The real eggs were kept in the shade or stored in an egg carton in the blind, and were replaced after trapping. Members of a breeding pair were not trapped on consecutive days; the second bird was trapped after eggs had pipped. Chicks were banded within 6 h of hatching or after leaving the nest.

The banding effort was publicized in magazines and by verbal contact to increase reports of sightings. Sightings from the time of departure of breeding areas through October were classified as migratory, whereas sightings from November through February were classified as winter observations.

Robinson, J. A., and L. W. Oring. 1997. Natal and breeding dispersal in American Avocets. Auk 114:416-430.

Natal philopatry of male and female American Avocets, social and temporal aspects of reproduction, and dispersal and mate retention were examined from 1992 through 1994 in Honey Lake Valley, northeastern California. Banding was conducted in 1991 at Lahontan Valley in Nevada. American Avocets were trapped on nests after 14 days of incubation and at the heat of the day, when they were apt to be incubating. Birds were not kept off nests for more than 20 min. Eggs were replaced with wooden imitations and were placed back in the nest immediately after trapping. Members of a pair were not trapped on consecutive days; the second bird was usually trapped when eggs were hatching. Chicks were banded at the nest within 6 h of hatching or were caught by hand after leaving the nest. Adults were banded with unique combinations of three to five colored bands and a numbered federal, metal band. Chicks were banded with brood-specific combinations of one to two colored bands and a federal band. Colored plastic tape placed over the band distinguished individuals within broods.

Resightings were taken daily and weekly. Daily resightings were done by 1-2 person field crews that surveyed 3-4, 0.6 - 1.1 km^2 ponds from vehicles or portable blinds using 15-60x spotting scopes. Each crew spent about 8 hr/day, 6 days/wk, in their assigned area. Each site also was systematically surveyed every seven days and the identity and location of each marked bird sighted.

Numbers of nesting birds were estimated using weekly counts and estimating clutch initiation dates from all known nests. Median dates by wetland complex differed by 1-2 weeks, so the number of nesting birds was estimated by counting the number of birds present 2 weeks prior to the median clutch initiation date for a particular site, on the median initiation date, and 2 weeks after the median initiation date.

Proportion of chicks banded, probability of detecting fledged young, and dispersal and survivorship measurements also were estimated.

Sidle, J. G., and P. M. Arnold. 1982. Nesting of the American Avocet in North Dakota. Prairie Naturalist 14:73-80.

Breeding biology of the American Avocet was studied on two natural saline lakes in Stutsman County, North Dakota during the breeding season of 1981. Data were collected at Chase Lake National Wildlife Refuge and Mud Lake Waterfowl Production Area, which were located on the Missouri Coteau of the Prairie Pothole Region. Searches for nests were conducted by foot on lakeshores and islands. Plant communities were examined using color, low-level aerial photographs and ground surveys. Plant species within 0.3 m of the nest were recorded. A Lietz level was used to determine elevation above nest and of various vegetation zones above water level on the islands. Nests were marked with flags placed 4 m from the nests. Nearest nest distance, distance to water, height above ground, construction material, various egg measurements, and nest fate were recorded for each nest. A successful nest was identified by tiny egg shell fragments at the bottom of the nest cup.

Skagen, S. K., and F. L. Knopf. 1994. Migrating shorebirds and habitat dynamics at a prairie wetland complex. Wilson Bulletin 106:91-105.

Opportunistic use of wetlands by migrating shorebirds was examined at Quivira National Wildlife Refuge in Stafford County, Kansas, from 1989 to 1992. Shorebird censuses were conducted from a vehicle or on foot 1-2 times a week during fall migration (from August through mid-October) and spring migration (April to early June). Complete counts of shorebirds were possible because of the openness of the vegetation. Where possible, all individuals were identified. When large numbers of shorebirds were present, or when birds were too distant to identify individually, total numbers of birds based on relative body size were estimated. Subsamples of birds were extrapolated to estimate the number of birds in large groups.

Percentage of a wetland that consisted of dry mud, wet mud, mud-water film (1-2 cm of water mixed with mud), shallow water (2-8 cm) and deep water (>8 cm) was estimated. Availability of suitable foraging habitat (i.e., wet mud-shallow water) during six migration periods (3 spring and 3 fall) was examined, and was based on unit-seasons (each wetland was one water unit for one migration season). Availability ranged from 36 unit-seasons having no wetlands with suitable foraging habitat (either due to flooding or to drying) to 4 unit-seasons having available habitat throughout the breeding season. Within the wetland complex, however, there was usually at least one wetland with wet mud/shallow water at any given time.

Winton, B. R., and D. M. Leslie, Jr. 1997. Breeding ecology of American Avocet (*Recurvirostra americana*) in north-central Oklahoma. Bulletin of the Oklahoma Ornithological Society 30:25-32.

Habitat use and nest success of American Avocets were examined at Salt Plains National Wildlife Refuge in northern Oklahoma in 1995 and 1996. Nests were located during systematic searches and monitored with the aid of an all-terrain vehicle, binoculars, nest markers (dowels), and a tape recorder. Nests were visited every 1-6 days until nest fate was determined.

The following sources may provide more information.

Altmann, J. 1974. Observational study of behavior: sampling methods. Behaviour 49:227-265.

Hands, H. M., M. R. Ryan, and J. W. Smith. 1991. Migrant shorebird use of marsh, moist-soil, and flooded agricultural habitats. Wildlife Society Bulletin 19:457-464.

Harrington, B. A. 1992. A coastal aerial winter shorebird survey on the Sonora and Sinaloa coasts of Mexico. Wader Study Group Bulletin 67:44-49.

Shuford, W. D., V. L. Roy, G. W. Page, and D. S. Paul. 1994. A comprehensive survey of shorebirds in wetlands at Great Salt Lake, Utah, 10-11 August 1994. Contribution no. 655. Point Reyes Bird Observatory, Stinson Beach, California.

Warnock, N., S. M. Haig, and L. W. Oring. 1998. Monitoring species richness and abundance of shorebirds in the western Great Basin. Condor 100:589-600.
