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HABITAT USE BY PISCIVOROUS BIRDS ON A POWER PLANT COOLING RESERVOIR

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Abstract.—Densities of piscivorous birds were compared among habitats on a Texas reservoir with warm-water effluent. The reservoir had been invaded recently by the exotic submergent hydrilla (*Hydrilla verticillata*). Hydrilla was an important habitat for some piscivores, particularly Pied-billed Grebes (*Podilymbus podiceps*) and also cormorants (*Phalacrocorax* spp.) and American White Pelicans (*Pelecanus erythrorhynchos*). Wading bird (Ardeidae) densities were low in hydrilla and highest in the emergent-hydrilla interface, unvegetated shoreline/shallow water and emergent habitats. Density comparisons between the main body of the lake and an associated cooling pond with higher water temperatures did not demonstrate consistent patterns across species or seasons. Overall piscivore densities were higher in the hot lake; this was largely due to high densities of Great Blue Herons (*Ardea herodias*) and cormorants. For many piscivores, neither the presence of hydrilla nor warm-water effluent influenced habitat use.

UTILIZACIÓN DE HABITATS POR AVES PISCÍVORAS EN UN RESERVORIO DE ENFRIAMIENTO DE UNA PLANTA DE ENERGÍA

Sinopsis.—Se comparó la densidad de aves piscívoras en diferentes habitats de un reservorio con afluente de aguas templadas en Texas. El reservorio ha sido invadido recientemente por la planta *Hydrilla verticillata.* Esta planta resultó ser un habitat de importancia para aves como el zaramago (*Podilymbus podiceps*), cormoranes (*Phalacrocorax* spp.) y pelicanos blancos (*Pelecanus erythrorhynchos*). Las densidades de vadeadores (Ardeidae) resultaron bajas en la hydrilla, pero altas en la interface de la hydrilla-emergente, la playa sin vegetación/aguas de poca profundidad y habitats emergentes. La comparición de densidades entre el principal cuerpo de agua del lago y una poza de enfriamiento con agua de mayor temperatura, no mostró consistencia de patrones de uso entre especies o temporadas. En general la densidad de piscívoros resultó más alta en el lago templado; esto se debió en gran medida a las altas densidades de individuos de *Ardea herodias* y cormoranes. Para muchos de los piscívoros, la presencia de hydrilla o las aguas templadas, no tuvo influencia en la utilización de habitat.

As wetlands continue to decline, created and altered wetlands become increasingly important. Deep-water reservoirs generally are considered

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low quality habitat for wetland birds (Heitmeyer 1986, White and Malaher 1964). Reservoirs cover approximately 672,274 ha in Texas; many are in the north-central region and support large numbers of wintering waterfowl (Anatidae) and other wetland birds (Texas Parks and Wildlife Department 1982). Warm-water effluent and hydrilla (*Hydrilla verticillata*) invasion are factors that could influence the value of reservoirs for wetland birds.

Warm-water effluent from power plants can affect waterfowl distribution and migration chronology (Brisbin 1974, Haymes and Sheehan 1982, Prach and Surrendi 1978). Pied-billed Grebe (*Podilymbus podiceps*) numbers did not differ between heated and unheated areas on a South Carolina reservoir (Brisbin 1974); however, the influence of warm water on the distribution of other piscivores has not been addressed. Warm-water effluent could influence piscivore distributions through thermoregulatory functions or by modifying prey distribution.

Hydrilla is an introduced submergent able to invade and dominate quickly water bodies (Haller 1978, Haller and Sutton 1975). Hydrilla often is considered a nuisance plant although it can be of value to wetland wildlife. Hydrilla is important for herbivorous birds, including Common Moorhens (*Gallinula chloropus*) (Mulholland and Percival 1982), American Coots (*Fulica americana*) (Esler 1990a, Montalbano et al. 1979), and many waterfowl species (Esler 1990a,b; Montalbano et al. 1979). Hydrilla may have value for other water birds because it supports forage fish (Moxley and Langford 1982) and macroinvertebrates (Watkins et al. 1983).

This study was designed to address habitat use, by both partially and exclusively piscivorous birds, on a reservoir in Texas and to assess the influences of warm-water effluent and hydrilla.

STUDY AREA

This study was conducted in 1986 and 1987 on Lake Fairfield, located 18 km east of Fairfield in Freestone County, Texas (Fig. 1). The reservoir supplies cooling water for the Big Brown Steam Electric Station, a lignite-fueled power plant. Dam construction was completed in 1969 and the lake filled to current levels by 1971. Hydrilla was first observed in 1984 (K. Strawn, pers. comm.). Mean water depth is 6.5 m and annual fluctuation <1 m. The main body of the lake encompasses 1053 ha with an adjacent 60-ha initial cooling pond known as the "hot lake" and 3.3 km of canals (Fig. 1).

Six major aquatic habitats in Lake Fairfield were identified: hydrilla, emergents (primarily *Typha* spp.), the emergent-hydrilla interface, floating leaf plants (including American lotus [*Nelumbo lutea*] and pondweed [*Potamogeton nodosus*]), unvegetated shoreline/shallow water, and open water (see Esler 1990b). Open water was the most abundant habitat, averaging 90.5% of the reservoir. Maximum hydrilla coverage during this study was 5.1% in fall 1987.

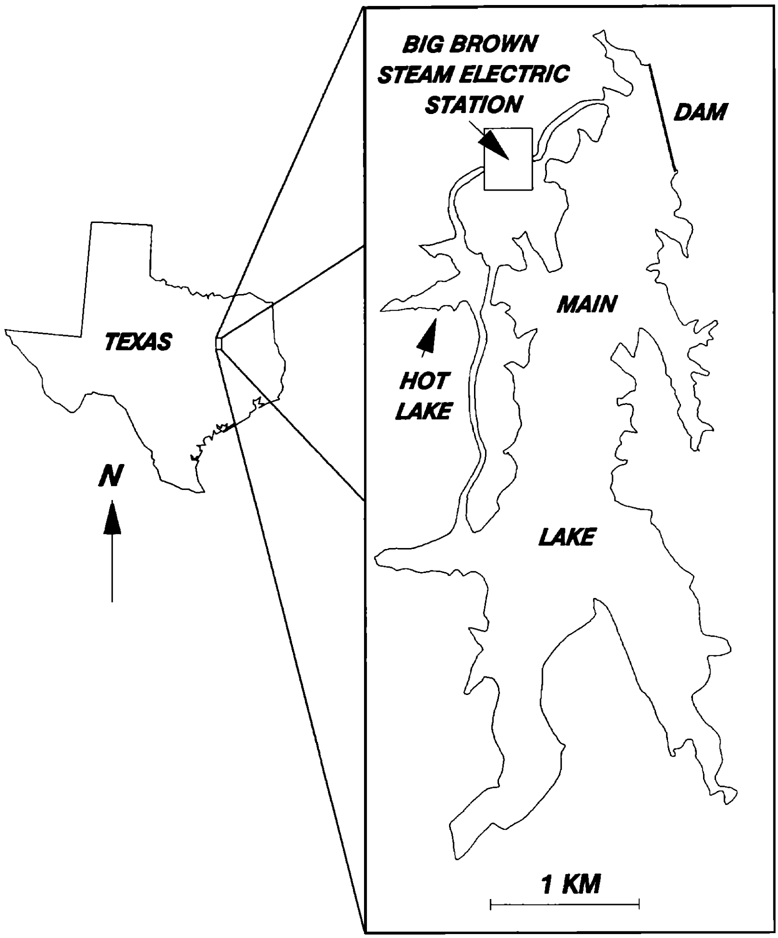

FIGURE 1. Lake Fairfield, Texas, including the main portion of the lake and the hot lake, an initial cooling pond.

METHODS

Habitat sampling.—Coverages of each habitat type were used as availability measures for habitat selection calculations. Aquatic vegetation was sampled every 3 mo from summer 1986 through fall 1987. Seasons were defined by equinoxes and solstices, and vegetation assessments were conducted at mid-season. Sampling was concentrated in the littoral zone ($\leq$50 m from shore), which exhibited the only seasonal variability in vegetation composition and coverage. Twenty, 50 $\times$ 50-m plots were randomly placed in the littoral zone of the main lake with one edge on shore. Three plots were randomly placed in open water, >50 m from shore. The hot lake had one open water and two littoral plots. Littoral zone plots were sampled using line transects. Three randomly located, 50-m lines perpendicular to shore were established within each plot. Beginning at the shoreward edge above the high water mark, the habitat type at each 0.5 m point along each line was recorded. The proportional occurrence of each habitat in littoral and open water plots was calculated and extrapolated to the 227.4 ha of the lake ≤50 m from shore, and the 825.6 ha of the lake >50 m from shore, respectively.

Bird surveys.—Piscivorous birds were censused to determine species present, numbers of individuals and habitat associations. A motorboat was driven slowly around the perimeter of the lake to observe all birds present. Habitats were distinct enough to determine accurately habitat associations. Surveys were conducted semi-monthly during winters, springs and falls of 1986 and 1987, weekly during summer 1986, and monthly during summer 1987. Twenty-seven surveys were conducted in 1986 and 20 in 1987. Duration of surveys ranged from 3 to 6 h and direction around the lake was alternated. The hot lake portion was surveyed on 45 of the 47 survey dates.

Analyses.—Bird densities were compared among habitat types with a Friedman's two-way ANOVA (Conover 1980:299–308). These comparisons were done only from summer 1986 through fall 1987 (37 surveys), when habitat availability was sampled. Friedman's nonparametric test ranked bird densities among habitats within each survey and then applied the ANOVA to the ranks. Mean densities and mean rank densities were not always ordered exactly the same because mean densities could be influenced by few observations in a low-availability habitat; using ranked statistics weighted each survey equally and provided a more consistent evaluation of habitat use. Assessments were conducted only if there were ≥5 independent observations for the species or group of interest. Surveys in which a species or group was not present were not included in the analysis for that taxon. Differences in densities among habitats were delineated using Fisher's LSD multiple comparison procedure (Ott 1984:365–370). Rejection criteria for all tests was $P < 0.05$.

Densities of birds also were compared between the main lake and hot lake to determine if there was differential use or a seasonal shift in use from one to the other. Wilcoxon signed-rank nonparametric paired comparisons (Conover 1980:280–288) were used to compare lakes for each species within each season and over all seasons combined.

RESULTS

Densities across habitats were compared for 10 species of piscivores: Double-crested Cormorant (*Phalacrocorax auritus*), Olivaceous Cormorant (*P. olivaceus*), American White Pelican (*Pelecanus erythrorhynchos*), Pied-billed Grebe, Great Blue Heron (*Ardea herodias*), Great Egret (*Casmerodius albus*), Green-backed Heron (*Butorides striatus*), Little Blue Heron (*Egretta caerulea*), Snowy Egret (*E. thula*) and Cattle Egret (*Bubulcus ibis*). Data for Double-crested and Olivaceous Cormorants were combined due to difficulty in identification when birds were swimming and feeding. Results for cormorants and American White Pelicans were very similar and indicated that densities of these birds were high in open water, but not higher than in hydrilla (Table 1).

Over all seasons, Pied-billed Grebe densities were higher in hydrilla than all other habitats (Table 1), followed by the emergent-hydrilla interface and open water. Pied-billed Grebes primarily used hydrilla in falls of both years, when hydrilla was at its greatest abundance and closest to the surface. In other seasons, hydrilla was important but densities did not differ from other habitats.

Overall ardeid habitat use is based on the six heron and egret species listed in Table 1. Densities of wading birds were highest in three habitats (emergent, unvegetated shoreline/shallow water and emergent-hydrilla interface) for all seasons combined. Densities in these habitats were highest in all seasons except fall 1987 when the emergent-hydrilla interface and hydrilla habitats held the highest densities. In fall 1986 wading bird densities in the emergent-hydrilla interface were higher than in any other habitat.

Densities of Great Blue Herons and Green-backed Herons were highest in emergent, unvegetated shoreline/shallow water and the emergent-hydrilla interface (Table 1). In falls of both years, Great Blue Heron densities were higher in the emergent-hydrilla interface than any other habitat. Emergent was the top-ranked habitat for Green-backed Herons in all seasons, although densities were similar to the emergent-hydrilla interface and unvegetated shoreline/shallow water.

Habitats with highest densities of Great Egrets were emergent, the emergent-hydrilla interface and unvegetated shoreline/shallow water; however, floating-leaf did not differ from the latter two habitats (Table 1). Great Egrets occasionally were observed feeding while standing on thick hydrilla beds in deep water.

Snowy Egret and Little Blue Heron densities were higher in unvegetated shoreline/shallow water and emergent habitats than all others (Table 1). Little Blue Herons occasionally fed on top of dense hydrilla mats. Cattle Egrets were most dense in unvegetated shoreline/shallow water.

Overall densities of piscivores (Table 1) were highest in the emergent-hydrilla interface, emergent and unvegetated shoreline/shallow water habitats, and were largely influenced by wading bird densities in these habitats. Floating leaf and open water were rarely used. In fall 1987, the season of greatest hydrilla abundance, hydrilla and the emergent-hydrilla interface were selected over all other habitats.

Density comparisons across the main and hot lakes (Table 2) did not demonstrate consistent patterns. Great Blue and Green-backed Heron densities were higher in the hot lake than the main lake over all seasons combined. Cormorant densities averaged more than four times higher in the hot lake, although this difference was not statistically significant ($P = 0.084$). Only Great Blue Heron densities were consistently higher in the hot lake within each season. Pied-billed Grebe and Little Blue Heron

TABLE 1. Mean rank densities (n/ha) of piscivorous birds across habitats and over all seasons on Lake Fairfield, Texas, 1986–1987. Values range from 1 (lowest use) to 6 (highest use). Row values not sharing a common letter differed ($P < 0.05$).

Species (n)	Surveys	Habitat: Open water	Habitat: Hydrilla
Cormorant spp.[a] (2446)	37	4.68A	4.10AB
American White Pelican (158)	7	5.00A	3.93AB
Pied-billed Grebe (676)	21	3.91B	5.67A
Total ardeids (1856)	37	1.46C	2.80B
Great Blue Heron (861)	37	1.64D	2.93C
Great Egret (622)	31	1.92D	2.79C
Green-backed Heron (127)	18	2.33C	2.94C
Little Blue Heron (117)	17	2.83B	3.21B
Snowy Egret (102)	15	2.77C	2.93C
Cattle Egret (27)	6	2.67B	2.67B
Total piscivores (5136)	37	1.62D	3.62B

[a] Data for Double-crested and Olivaceous Cormorants combined.

densities were higher in the main lake. For all species and seasons combined, densities were higher in the hot lake than the main lake; these results are influenced strongly by cormorant and Great Blue Heron numbers.

DISCUSSION

Although the use of density figures as a measure of habitat quality has been questioned, they are appropriate for describing habitat use for this study because they are not subject to the biases identified by Van Horne (1983). No seasonal bias could occur because this study was conducted year-round. Long-term site tenacity probably was not a bias because of

TABLE 2. Mean densities (n/100 ha) of piscivorous birds on the main and hot lake portions of Lake Fairfield, Texas, across 45 surveys through 1986 and 1987.

Species	Lake type: Main lake	Lake type: Hot lake	P[a]
Cormorant spp.[b]	25.60	103.70	0.084
American White Pelican	0.41	2.33	0.879
Pied-billed Grebe	1.52	0.48	0.001
Great Blue Heron	3.01	12.30	<0.001
Great Egret	1.88	4.41	0.247
Green-backed Heron	0.31	1.70	<0.001
Little Blue Heron	0.45	0.11	<0.001
Snowy Egret	0.39	0.44	0.506
Cattle Egret	0.10	0.07	0.084
Total piscivores	33.68	125.55	<0.001

[a] Results of Wilcoxon signed-rank procedure.
[b] Data for Double-crested and Olivaceous Cormorants combined.

TABLE 1. Continued.

Habitat			
Emergent	Emergent-hydrilla interface	Floating leaf	Unvegetated shoreline/shallow water
3.10C	2.70C	2.50C	3.93B
3.57B	2.64B	2.64B	3.21B
2.76C	3.93B	2.17C	2.57C
4.81A	4.51A	2.82B	4.60A
5.00A	4.19B	2.62C	4.62AB
4.58A	4.13AB	3.60B	3.98AB
5.08A	4.08B	2.69C	3.86B
4.38A	3.15B	2.82B	5.06A
3.60B	2.77C	2.93C	6.00A
3.83B	2.67B	3.67B	5.50A
4.35A	4.74A	2.34C	4.32A

the age of the reservoir and the tendency for wetland birds to respond quickly to habitat change (Weller and Spatcher 1965, Esler 1990a). Finally, the distribution of habitat in concentric rings around the reservoir basin and the small study area size allowed unlimited movement between habitats, eliminating the biases of differential survivability among habitats and exclusion by conspecifics. The density figures in this study incorporated both habitat availability and bird use and are an appropriate measure of habitat use.

Feeding strategy was the most important determinant of habitat use. Piscivores that locate prey by swimming or diving, such as Pied-billed Grebes, American White Pelicans and cormorants, often utilized the foraging opportunities presented by hydrilla and open water habitats. Pelicans and cormorants often were observed feeding in or near the outside edge of hydrilla beds. Pied-billed Grebes were exceptional among piscivores in their close association with hydrilla. They feed on fish and macroinvertebrates (Wetmore 1924), which are abundant in hydrilla (Moxley and Langford 1982, Watkins et al. 1983). The number of Pied-billed Grebes on Lake Fairfield increased across years of increasing hydrilla and grebes preferred experimental plots with hydrilla over plots where hydrilla was removed (Esler 1990a).

Wading birds, whose habitat use is closely related to water depth (Kushlan 1976), were more likely to select shallow water habitats. In seasons when hydrilla was most abundant and in areas more conducive to wading bird feeding strategies (e.g., the emergent-hydrilla interface, areas of thick hydrilla at the surface, or hydrilla beds near shore), however, wading birds often selected hydrilla, presumably to utilize the associated food (Moxley and Langford 1982).

Piscivore densities between the main and hot lakes did not show consistent patterns among species or seasons. No behavioral or food habits data were collected, thus, the explanations for the observed differences are speculative. Fish studies also have not demonstrated clear patterns of fish populations or distribution (Hanifen 1981, Starling 1986); however, the heated effluent is important for some fish that otherwise would suffer cold shock (Starling 1986). Perhaps these species are important food items for the birds with higher densities in the hot lake. Although Pied-billed Grebe numbers were similar between heated and unheated portions of a South Carolina lake (Brisbin 1974), in this study they were more dense on the main lake, perhaps as a result of their attraction to hydrilla. Hydrilla was not present in the hot lake.

Neither hydrilla nor warm-water effluent appeared to influence greatly habitat use of piscivorous birds, with the exception of the use of hydrilla by Pied-billed Grebes. Herbivorous birds on Lake Fairfield were affected by these factors to a much greater degree based on population changes across years (Esler 1990a), habitat selection data (Esler 1990b), and lack of herbivores in the hot lake.

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