AN EVALUATION OF SURVEY METHODOLOGY AND HABITAT USE OF WATERFOWL ON GRAND LAKE, OKLAHOMA

By

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CHAPTER I

INTRODUCTION

This thesis is composed of 2 manuscripts written in formats suitable for submission to selected scientific journals. Each manuscript is complete without supporting materials. The order of arrangement for each manuscript is text, literature cited, tables, and figures. Chapter II, "Evaluation of waterfowl survey techniques on an Oklahoma reservoir," is written in the format of the Wildlife Society Bulletin. Chapter III, "Habitat use by dabbling ducks on a 50-year-old reservoir," is written in the format of the Journal of Wildlife Management.

CHAPTER II

EVALUATION OF WATERFOWL SURVEY TECHNIQUES ON AN OKLAHOMA RESERVOIR

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Key words: aerial survey, boat survey, census, ground survey, habitat use, Oklahoma, reservoir, waterfowl trends.

Waterfowl managers need standardized and reliable data to evaluate current management plans and establish future goals. As important wetland resources dwindle because of increased pressure from agriculture and urbanization (Tiner 1984), administrators must allocate limited funds for acquisition of critically threatened wetlands. Such allocations are often based upon short-term population trends that are derived from various census methodologies. In short, proper management requires reliable estimates of waterfowl trends and abundance and identification of important habitats (Kaminiski et al. 1988, Stewart et al. 1988).

Extensive research has been conducted to determine the most reliable methods for censusing wintering waterfowl (Bateman 1971, Stott and Olson 1972, Lotter and Cornwell 1970, Conant et al. 1988, Conroy et al. 1988). Generally, habitat type and species of waterfowl in question determined which methodology was most appropriate. Survey suitability usually has been evaluated by comparing 1 survey method against a method that is assumed to be most comprehensive (Stott and Olson 1972, Lotter and Cornwell 1970, Conant et al. 1988).

Millions of hectares of reservoirs in North America provide important habitat for migrating and wintering waterfowl (Barclay 1976, Chabreck 1979, Anderson and Ohmart 1988). A variety of aerial, boat, and ground surveys are used to census these areas during mid-winter surveys (Barclay 1976), but research on the reliability of these methods for establishing waterfowl numbers and trends is lacking. Most waterfowl censuses ascertain trends in waterfowl abundance but not the absolute number of waterfowl in an area. Additionally, aerial and boat surveys have been used to determine preferred habitats of wintering waterfowl (Chabreck et al. 1974, Johnson and Swank 1981, Johnson and Montalbano 1984, Anderson and Ohmart 1988). In light of possible biases associated with detecting waterfowl in dense vegetation, results could be questioned and should be substantiated. Our objectives were to determine (1) if aerial, boat, and ground surveys provide comparable trend data in reservoir habitats and (2) if aerial, boat, and ground surveys identified the same preferred wintering habitats.

STUDY AREA

Grand Lake O' The Cherokees, commonly known as Grand Lake, is a 18,800-ha reservoir in northeastern Oklahoma (36°28'N, 95°02'W). The Pensacola Dam was completed in 1940 and impounded part of the Grand (Neosho) River system. The reservoir has 998 km of shoreline and is approximately 88 km long from the confluences of the Neosho and Spring rivers in the north to the dam in the south. The reservoir has an irregular shoreline with numerous bays and small coves. Recreational development (e.g., summer homes, marinas, and resorts) is extensive (e.g., 17.3% of the shoreline) in the southern part of the reservoir (Stancill et al. 1988). Since 1982, the Grand River Dam Authority has attempted to maintain lake elevations between 226 and 227 m (above mean sea level); however, water levels fluctuated between 225 and 228 m during our study, largely as a function of precipitation in the watershed (Stancill et al. 1988).

Terrestrial habitats on the eastern side of Grand Lake were part of the Ozark Plateau and dominated by oak (Quercus spp.) and hickory (Carya spp.); the western side was part of the oak-hickory bluestem (Andropogon spp.) parkland region and dominated by tall grasses (Bailey 1976). During construction of the reservoir, all woody vegetation around the perimeter and below elevation 230 m was removed. Secondary bottomland succession was characterized by willows (Salix spp.), eastern cottonwood (Populus deltoides), sycamore (Platanus occidentalis), and maples (Acer spp.). Limited stands of oak, hickory, and pecan (C.

illinoensis) occurred in bottomland areas that were not subjected to extended periods of inundation during the growing season.

METHODS

Waterfowl Census

We censused waterfowl on Grand Lake 3 times/month from January through December 1987. Each monthly census was completed within a 3-day period and consisted of an alternating pattern of 1 aerial, 2 boat, and 2 ground surveys. Aerial surveys were conducted in a 2-seated 152 Cessna along the entire shoreline of the reservoir at approximately 100 m above the water and at speeds of <145 km/hr. Aerial surveys were conducted between 0700-1200 hours and averaged 3.5 hours. When waterfowl were located, they were circled until all individuals were identified and enumerated, or until it was determined unsafe to continue low-elevation circling. The pilot assisted in locating waterfowl, but only the observer identified and enumerated them.

Because Grand Lake was large, we divided it in half and established 2 boat and 2 ground survey routes (Fig. 1). We surveyed a total of 109 km (45 km in north; 64 km in south) of reservoir shoreline (ca. 11% of total) (Fig. 1) by cruising a 4-m power boat approximately 100 m from the shore at 10-15 km/hr. Waterfowl were recorded only if encountered between the boat and the shoreline and an equal distance on the opposite side of the boat. The 2 ground routes covered 312 km (122 km in north; 190 km in south) and included 42 lake sites (Fig. 1). A driver and observer were used for the boat and ground surveys, and the same observer was used for all 3 surveys. Boat and ground surveys on each half of the lake took about 4 hours each to complete. The daily sequence of the 3 survey methods and direction of the routes were alternated during each 3-day period.

Species identification and enumeration were aided with 7 x 35 binoculars during boat and aerial surveys and a 15 x 60 spotting scope during ground surveys. We recorded the following information for all waterfowl sightings: species and abundance, habitat type, water conditions, and time of day. Unidentified species were enumerated as such. All information was recorded on tape and topographic maps.

Habitat Use

We sampled 4 major hydrogeological macrohabitats on the reservoir with all 3 survey methods: (1) wide river, (2) bay, (3) cove, and (4) main lake. Wide river was quasi-riverine and occurred below the source rivers where flow velocity was reduced; it was characterized by extensive mudflats due to sedimentation. Bays were semi-protected, but coves were well-protected with steep shores and little or no littoral area. The remainder of the reservoir was characterized by open expanses of water with limited cover. We estimated availabilities of macrohabitats using a planimeter on a 1:24,000 topographic map.

We identified 7 shoreline-types (microhabitats) in each of the 4 macrohabitats: (1) exposed mudflats, (2) exposed gravel bars, (3) flooded tree-shrub, (4) flooded herbaceous vegetation, (5) steep rock, (6) open water, and (7) developed areas. Developed areas referred to recreational shoreline development. Flooded tree/shrub was predominately willow with an understory of buttonbush (Cephalanthus occidentalis) and assorted herbaceous vegetation. Emergent and submergent vegetation was sparse on Grand Lake, likely due to wave action and turbidity (Peltier and Welch 1970). Smart weeds (Polygonum spp.), millets (Echinochloa spp.), and flat sedges (Cyperus spp.) dominated mudflats. Gravel bars were largely devoid of vegetation. We estimated availability of microhabitats at each 0.3 m change in surface elevation of the reservoir by identifying habitats at 5 sites/km along the entire length of both boat surveys. Because macrohabitats were sampled in proportion to their availabilities during all 3 survey types, we assumed that our estimates of microhabitat availabilities from the boat surveys also reflected those on aerial and ground surveys.

Data Analysis

Correlation analyses were used to assess similarity of the 3 survey methods in delineating trends in waterfowl abundance. Paired enumerations of waterfowl (i.e., by tribes and species--depending on their occurrence on Grand Lake) from respective survey methods that were conducted during the same 3-day census trip were correlated. Significant ($P < 0.05$), positive correlation coefficients indicated general correspondence between paired survey methods.

Our approach to habitat analyses was hierarchical; i.e., habitat use by the most seasonally abundant species was evaluated first. We reasoned that if disparities among the 3 survey methods occurred in the largest data set, they would be exacerbated as sample size decreased. Chi-square and Bonferroni z confidence intervals (Neu et al. 1974, Byers et al. 1984) were used to determine if the 3 survey methods predicted similar habitat preferences ($P < 0.05$). Open water constituted >65% of the reservoir and was generally avoided by waterfowl; therefore, it was not included in the microhabitat analysis (Johnson 1980). Habitats with no waterfowl in them were not included in the analysis (Neu et al. 1974) and assumed to be avoided. Because flocking behavior of waterfowl may bias analyses (Alldredge and Ratti 1986), we used both the number of individuals and flocks as observations.

RESULTS

Waterfowl Census

Nineteen species of ducks and geese from 6 tribes were observed on Grand Lake in 1987; the majority (95%) used the reservoir from August through April. Only mallards (*Anas platyrhynchos*), green-winged teal (*A. crecca*), and lesser scaup (*Aythya affinis*) were observed during a sufficient number ($\geq$9) of 3-day census trips to permit correlation of the survey methods; less numerous species had $\leq$5 paired consecutive trips (Stancill et al. 1988), which was judged to be too few for correlation. We also evaluated total numbers of ducks, dabbling ducks, diving ducks, and sea ducks (Table 1).

Except for green-winged teal, all boat-to-air comparisons were highly correlated (r = 0.892-0.991, $P < 0.001$), and except for diving ducks and lesser scaup, all ground-to-air comparisons were uncorrelated (r = 0.032-0.395, P = 0.094-0.990) (Table 1, Figs. 2 and 3). Similarly, ground-to-boat comparisons were uncorrelated (r = 0.138-0.301, P = 0.257-0.654) except for diving ducks and lesser scaup. All 3 methods were correlated for diving ducks and lesser scaup (r = 0.687-0.991, P =

0.001-0.002); none of the methods were correlated for green-winged teal ($\underline{r}$ = 0.179-0.467, $\underline{P}$ = 0.645-0.243) (Table 1). Generally, ground surveys were more variable than aerial and boat surveys and failed, with a few exceptions, to enumerate ducks that were detected by the other methods (Fig. 3).

Habitat Use

Mallards were the most abundant species observed during our surveys; numbers of individuals and flocks peaked in early (30 Nov-30 Dec) and late (14 Jan-27 Feb) winter. All 3 survey methods indicated similar differential preference for macrohabitats in early and late winter ($\underline{X}^2$ = 93.2-2664.5, $\underline{P}$ < 0.001) (Table 2). Similarly, microhabitats were differentially preferred ($\underline{X}^2$ = 115.6-1219.8, $\underline{P}$ < 0.001), but correspondence among the 3 survey methods was variable (Table 2). For example, during early winter herbaceous vegetation was the preferred microhabitat from air and boat surveys, but exposed mudflats and developed areas were preferred based on ground surveys (Table 2). During late winter, mudflats and flooded tree/shrub were preferred microhabitats based on air and boat surveys, but ground surveys indicated that mudflats and developed areas were preferred (Table 2). Because such disparities existed for the most numerous species, further analyses were not conducted.

DISCUSSION

Boat and aerial surveys provided comparable estimates of waterfowl trends (except for green-winged teal) on Grand Lake. The fewest waterfowl were enumerated during ground surveys. Lack of correlation between ground surveys and the other 2 methods casts serious doubt on the reliability of ground surveys on large reservoirs. Although ground censuses have been used to correct air censuses on breeding (Diem and Lu 1960, Martinson and Kaczynski 1967) and wintering grounds (Stott and Olson 1972), they appear to provide inaccurate estimates of waterfowl trends on large reservoirs. Stott and Olson (1972) concluded that ground surveys were superior to aerial surveys for censusing sea ducks along the Atlantic Coast but concluded that aerial surveys may be better on inland bodies of water.

Lack of correlation among the 3 survey methods for green-winged teal is best explained by their inconspicuous color and small size (Bellrose 1980). Martinson and Kaczynski (1967) noted similar detection errors for green-winged teal on breeding grounds. Lack of correlation between the ground and other 2 surveys methods (except for diving ducks) was likely caused by observability biases associated with specific habitats. Dabbling ducks were normally associated with flooded herbaceous or tree/shrub habitats, which made them difficult to observe during ground surveys. Canopy cover did not obstruct aerial detection of most dabbling ducks, and the boat noise flushed waterfowl from areas that they otherwise may not have been detected in. The correlation among all 3 survey methods for diving ducks (but not sea ducks) is best explained by their different macrohabitat preferences and their proximity from the shoreline. Diving ducks tended to congregate in large rafts near the shoreline (but out of the vegetation) in the wide river macrohabitat. Sea ducks also tended to loaf in large rafts but generally preferred open expanses of the main lake, which reduced their observability during ground surveys.

Aerial surveys had the advantage of being conducted in a short time period (3.5 hr) and required fewer man-hours (7 hr) than boat surveys (8 hr and 16 hr). On the other hand, costs were lower for boat surveys (ca. $15.00/hr for fuel and maintenance [A. V. Zale, Okla. Coop. Fish and Wildl. Res. Unit, pers. commun.]) than aerial surveys ($125.00/hr rental). Boat and ground surveys required similar man-hours; equipment operation costs were similar; but ground surveys provided poor correlations for all waterfowl but diving ducks. Waterfowl tend to prefer areas where human disturbance is minimal (i.e., undeveloped areas) (Stancill et al. 1988, Korschgen et al. 1985), and access to such areas on Grand Lake was difficult and time consuming from the ground. When diving ducks are the primary species on an area, ground surveys may be the best method because they were cheaper than aerial surveys and did not disturb waterfowl as did boat surveys. Species, habitats, and equipment availability and costs need to be considered when selecting a survey methodology.

Waterfowl management seeks to identify and develop important habitats. Our data suggested that aerial and boat surveys identified comparable waterfowl habitats on Grand Lake. Aerial and boat surveys identified similar habitat preferences of mallards, and both identified similar shifts in habitat preferences between 2 seasons. Ground surveys did not identify the same habitat preferences that aerial or boat surveys did (Table 2) and generally failed to enumerate waterfowl associated with cover.

Prolonged inundation of dense bottomland hardwood forests on reservoirs or similar areas, moves succession toward open canopy tree/scrub and herbaceous vegetation that enhances detection of waterfowl from the air. Biases associated with waterfowl censusing in dense forested wetlands can still be problematic, but most deciduous trees have lost their leaves by the time numbers peak on wintering grounds. Because of the limited amount of unaltered bottomland areas on our study area, we were unable to substantiate this, and additional research is warranted.

SUMMARY

The importance of reliable waterfowl censusing is becoming a growing concern as continental populations of waterfowl decline (Stewart et al. 1988). The importance of the mid-winter surveys cannot be over emphasized as an important contribution to estimating waterfowl populations, and the reliability of methods used must be established. Both aerial and boat surveys provided comparable estimates of waterfowl trends on a large, old-aged reservoir for most waterfowl species. Ground surveys enumerated fewer waterfowl and generally were not correlated with aerial and boat surveys. Aerial and boat surveys identified similar habitat preferences and seasonal shifts, but both differed from ground surveys. These differences were probably associated with reduced observability in specific habitats during ground surveys and may vary on reservoirs of different size and shape.

Additional research is needed to determine the optimum method for censusing inconspicuous species such as green-winged teal.

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Table 1. Correlation matrices of the aerial, boat, and ground surveys of the most abundant waterfowl observed on Grand Lake, Oklahoma, during periods of occurrence in 1987.

		Survey type			
		Air		Boat	
Waterfowl	Survey type	*r*	*P*	*r*	*P*
Total Waterfowl	Boat	0.940	0.001	--	--
(18)[a]	Ground	0.395	0.094	0.348	0.145
Dabbling ducks	Boat	0.903	<0.001[b]	--	--
(16)	Ground	0.148	0.582	0.210	0.433
Mallards	Boat	0.892	<0.001[b]	--	--
(16)	Ground	0.316	0.232	0.301	0.257
Green-winged teal	Boat	0.467	0.243[b]	--	--
(9)	Ground	0.274	0.477	0.179	0.645
Diving ducks	Boat	0.987	<0.001	--	--
(16)	Ground	0.748	<0.001	0.687	0.003
Lesser Scaup	Boat	0.991	<0.001	--	--
(16)	Ground	0.743	0.001	0.701	0.002
Sea Ducks	Boat	0.965	<0.001	--	--
(13)	Ground	0.032	0.990	0.138	0.654

[a]Number of 3-day census trips available for correlation analyses.
[b]One outlier was removed before analysis because it artificially increased the correlation.

Table 2. Early and late winter habitat selectivity by mallards as indicated by aerial, boat, and ground surveys on Grand Lake, Oklahoma, during 1987.

		Early winter[a]												
		Air				Boat				Ground				
				Habitat Selectivity[b]				Habitat Selectivity[b]				Habitat Selectivity[b]	
Habitats	% Avail.	No. Ducks	No. Flocks	Ducks	Flocks	No. Ducks	No. Flocks	Ducks	Flocks	No. Ducks	No. Flocks	Ducks	Flocks
Macrohabitats													
Wide River	6.5	14,410	181	+	+	5,772	93	+	+	593	19	+	+
Bay	19.9	2,706	46	-	-	906	17	-	-	35	1	-	-
Cove	20.1	132	11	-	-	62	4	-	-	47	8	-	0
Main Lake	53.5	1,602	82	-	-	811	24	-	-	67	4	-	-
Totals	100.0	18,850	320			7,551	138			742	32		
Microhabitats (Wide river)													
Mudflat	5.7	486	17	-	0	160	11	-	0	309	7	+	
Rock	20.7	0	0	-	-	0	0	-	-	16	1	-	
Developed	3.8	13	2	-	-	28	4	-	0	22	1	+	
Herbaceous vegetation	28.3	11,839	116	+	+	4,502	53	+	+	103	3	-	
Tree/shrub	41.5	1,956	43	-	-	1,082	25	-	-	41	2	-	
Total	100.0	14,294	178			5,772	93			491	14		

[a] Determined primarily by lake levels; early winter = 30 Nov-30 Dec 1987, late winter = 15 Jan-27 Feb.

[b] Chi-square analyses followed by Bonferroni confidence intervals (Neu at al. 1974); + = preferred, 0 = no preference, - = avoided ($P < 0.05$).

Table 2. Extended.

		Late winter[a]												
		Air				Boat				Ground				
				Habitat Selectivity[b]				Habitat Selectivity[b]				Habitat Selectivity[b]	
Habitats	% Avail.	No. Ducks	No. Flocks	Ducks	Flocks	No. Ducks	No. Flocks	Ducks	Flocks	No. Ducks	No. Flocks	Ducks	Flocks
Macrohabitats													
Wide River	6.5	1,216	41	+	+	801	21	+	+	405	33	+	+
Bay	19.9	1,781	18	+	0	886	12	+	0	133	15	0	0
Cove	20.1	101	5	-	-	77	7	-	-	108	18	0	0
Main Lake	53.5	238	13	-	-	119	3	-	-	70	6	-	-
Totals	100.0	3,336	77			1,883	43			716	72		
Microhabitats (Wide river)													
Mudflat	58.5	726	10	+	-	871	35	+	+	455	7	+	
Gravel	11.3	116	21	-	+	137	9	0	0	124	4	+	
Rock	20.7	0	0	-	-	0	0	-	0	13	1	-	
Developed	3.8	0	0	-	-	4	1	-	-	73	5	+	
Herbaceous vegetation	2.0	18	3	0	+	21	2	0	+	22	1	0	
Tree/shrub	3.7	315	5	+	+	350	9	+	+	29	2	0	
Total	100.0	1,175	39			1,383	56			716	20		

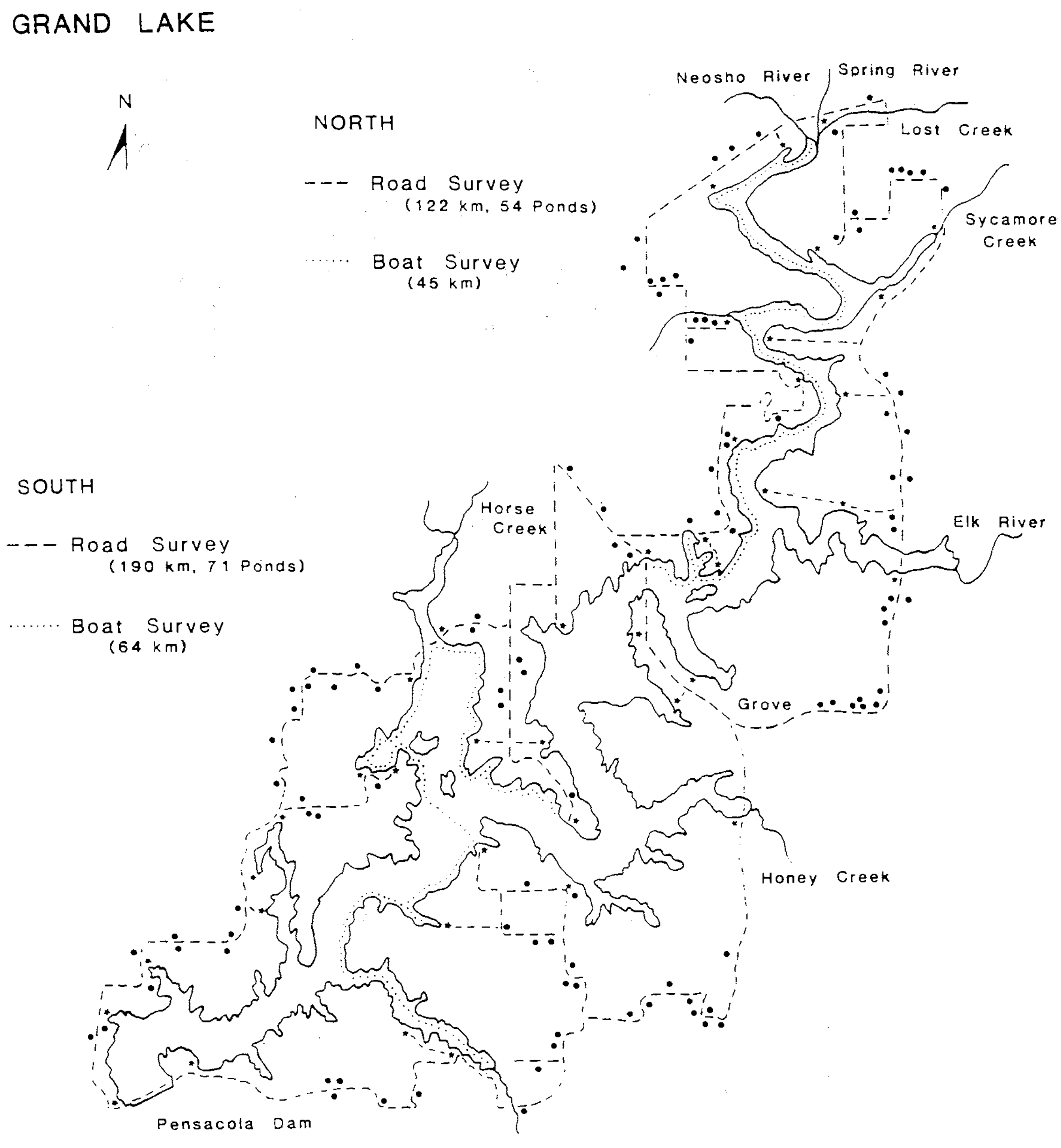

Fig. 1. Aerial, boat, and ground survey routes used to census waterfowl on Grand Lake and surrounding wetlands, 1987 (solid circles = ponds; stars = lake sites on ground survey routes).

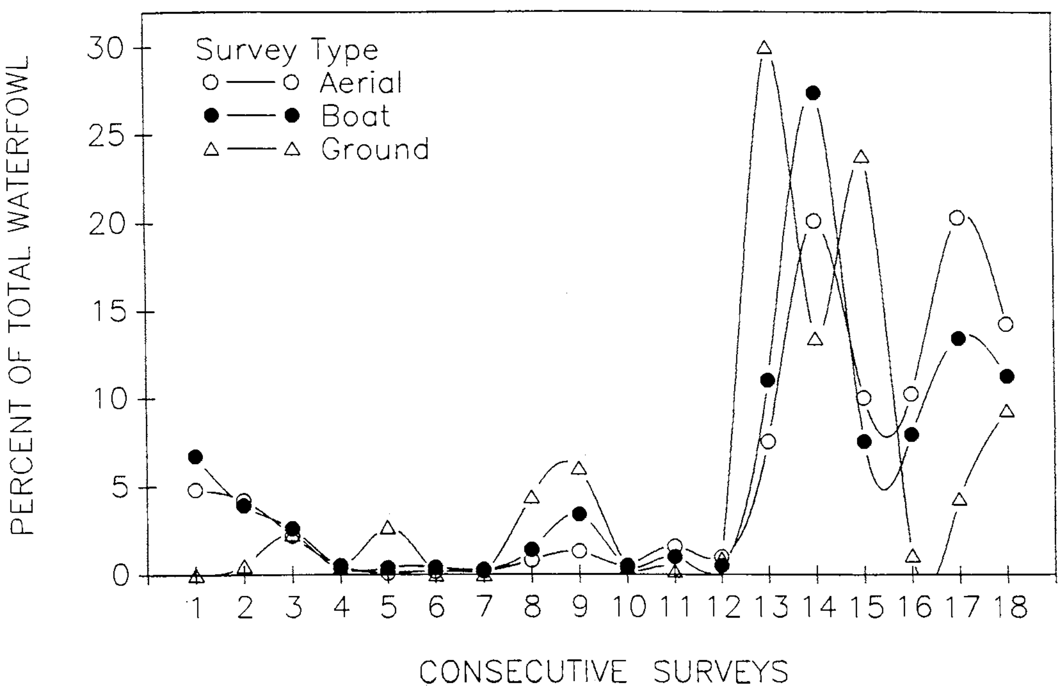

Fig. 2. Percentages of total waterfowl censused during consecutive aerial, boat and ground surveys, Grand Lake, 1987.

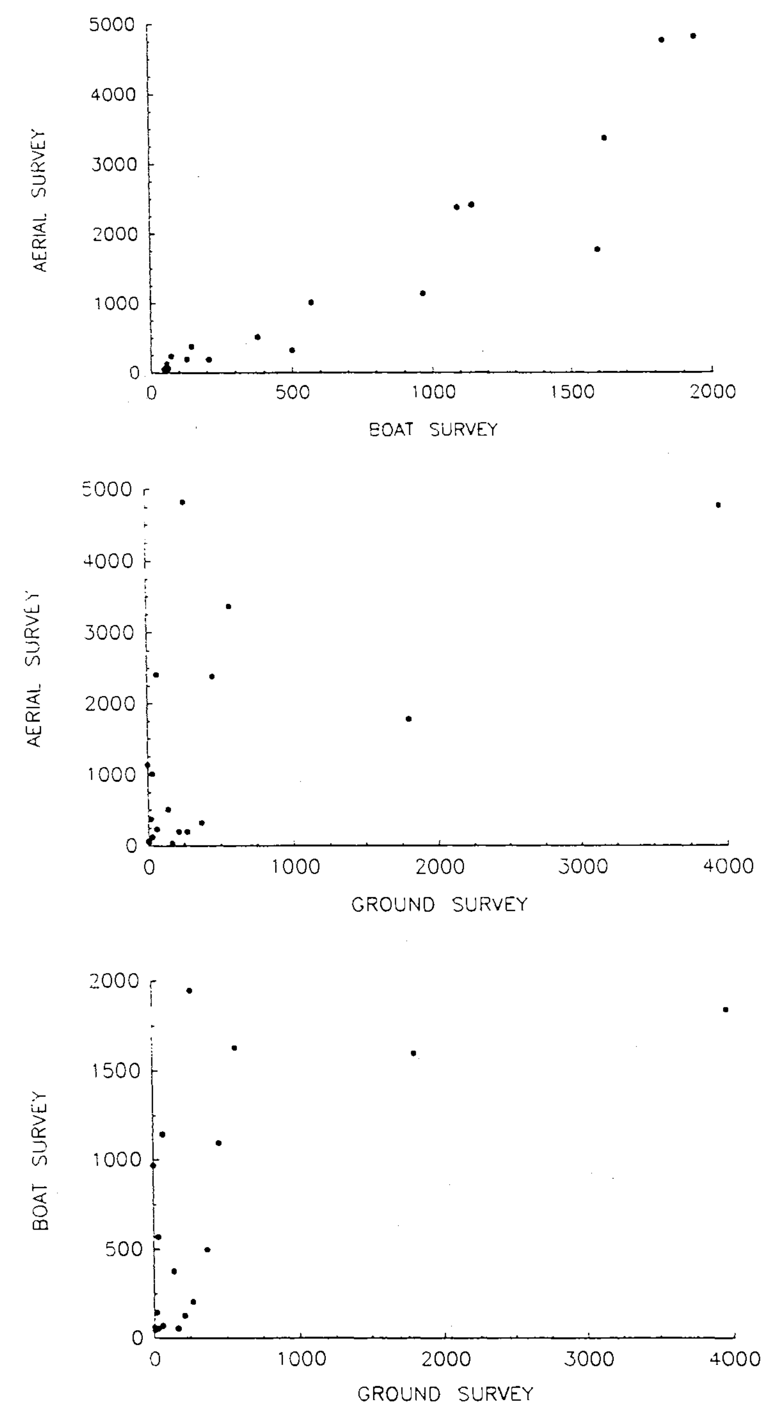

Fig. 3. Scattergram of total number of waterfowl censused during aerial, boat, and ground surveys, Grand Lake, 1987.

CHAPTER III

HABITAT USE BY DABBLING DUCKS ON A 50-YEAR-OLD RESERVOIR

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Abstract: We censused dabbling ducks on Grand Lake and surrounding wetlands in northeastern Oklahoma from January through December 1987, but relatively few were observed from May through July. We determine seasonal habitat preferences for mallards on the reservoir and compared seasonal use of these areas to the surrounding wetlands. Mallard (*Anas platyrhynchos*) was the most abundant species observed on the reservoir; surrounding wetlands were preferred by American wigeon (*A. americana*) and gadwall (*A. strepera*). Use of reservoir habitats was influenced by human disturbance and habitat availability as a function of fluctuating water levels. Vegetated mudflats under optimum water conditions provided preferred feeding areas; exposed mudflats were preferred loafing sites; and flooded tree/shrub provided loafing sites and cover from weather and human disturbance. As reservoirs age, preferred waterfowl habitats may be concentrated in the upper areas and long-term planning should include protection and enhancement of these areas.

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In <80 years of construction of large multipurpose reservoirs in the United States, >16 million ha of water have been impounded. Until recently (Anderson and Ohmart 1988), most published research on reservoir use by waterfowl has dealt with new impoundments or construction of subimpoundments (Weibe 1946, Barstow 1963, Johnson and Swank 1981). Reservoirs provide a haven for waterfowl after initial inundation, but their value as waterfowl habitat generally declines as they age (Barclay 1976, Johnson and Swank 1981). Because millions of hectares of North America's natural wetlands have been destroyed (Korte and Fredrickson 1977, Tiner 1984), existing reservoirs should be managed to maximize their suitability for waterfowl (U.S. Fish and Wildl. Serv. and Can. Wildl. Serv. 1986).

Use of an area by migrating and wintering waterfowl depends on availabilities of food and suitable habitats (e.g., loafing areas), water levels, degree of human disturbance, and weather conditions (Tamisier 1976, Burgess 1969, Cowardin 1969, Jorde et al. 1984, Bell and Austin 1985). Nevertheless, habitat preference relative to availability on human-modified environments and relationships between habitat selection and human disturbance are still poorly understood (Kaminiski et al. 1988). Our objectives were to examine these factors concurrently on a long-established, highly-modified reservoir in northeastern Oklahoma.

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STUDY AREA

Grand Lake O' The Cherokees, commonly known as Grand Lake, is a 18,800-ha reservoir in northeastern Oklahoma (36°28′N, 95°02′W). The Pensacola Dam was completed in 1940 and impounded part of the Grand (Neosho) River system. The reservoir has 998 km of shoreline and is approximately 88 km long from the confluences of the Neosho and Spring rivers in the north to the dam in the south. The reservoir has an irregular shoreline with numerous bays and small coves. Recreational development (e.g., summer homes, marinas, and resorts) is extensive (i.e., 17.3% of the shoreline) in the southern part of the reservoir (Stancill et al. 1988). Since 1982, the Grand River Dam Authority has attempted to maintain lake elevations between 226 and 227 m (above mean sea level); however, water levels fluctuated between 225 and 228 m during our study, largely as a function of precipitation in the watershed (Stancill et al. 1988).

Terrestrial habitats on the eastern side of Grand Lake were part of the Ozark Plateau and dominated by oak (Quercus spp.) and hickory (Carya spp.); the western side was part of the oak-hickory bluestem (Andropogon spp.) parkland region and dominated by tall grasses (Bailey 1976). Rangeland with interspersions of wheat and sorghum was common on the western side of Grand Lake. During construction of the reservoir, all woody vegetation around the perimeter and below elevation 230 m was removed. Secondary bottomland succession was characterized by willows (Salix spp.), eastern cottonwood (Populus deltoides), sycamore (Platanus occidentalis), and maples (Acer spp.). Limited stands of oak, hickory, and pecan (C. illinoensis) occurred in bottomland areas that were not subjected to extended periods of inundation during the growing season.

METHODS

Waterfowl Census

We censused waterfowl on Grand Lake 3 times/month from January through December 1987. Each monthly census was completed within a 3-day period and consisted of an alternating pattern of 1 aerial, 2 boat, and 2 ground surveys. Aerial surveys were conducted in a 2-seated 152 Cessna along the entire shoreline of the reservoir at approximately 100 m above the water and at speeds of <145 km/hr. Aerial surveys were conducted between 0700-1200 hours and averaged 3.5 hours. When waterfowl were located, they were circled until all individuals were identified and enumerated, or until it was determined unsafe to continue low-elevation circling. The pilot assisted in locating waterfowl, but only the observer identified and enumerated them.

Because Grand Lake was large, we divided it in half and established 2 boat and 2 ground survey routes (Fig. 1). We surveyed a total of 109 km (45 km in north; 64 km in south) of reservoir shoreline (ca. 11% of total) (Fig. 1) by cruising a 4-m power boat approximately 100 m from the shore at 10-15 km/hr. Waterfowl were recorded only if encountered between the boat and the shoreline and an equal distance on the opposite side of the boat. The 2 ground routes covered 312 km (122 km in north; 190 km in south) and included 125 ponds, 9 creeks, and 1 permanent wetland (Fig. 1). A driver and observer were used for the boat and ground surveys, and the same observer was used for all 3 surveys. Boat and ground surveys on each half of the lake took about 4 hours each to complete. The daily sequence of the 3 survey methods and direction of the routes were alternated during each 3-day period.

Species identification and enumeration were aided with 7 x 35 binoculars during boat and aerial surveys and a 15 x 60 spotting scope during ground surveys. We recorded the following information for all waterfowl sightings: species and abundance, habitat type, water conditions, and time of day. Unidentified species were enumerated as such. All information was recorded on taperecorder and topographic maps. Wind speed and direction were recorded at the beginning and end of the aerial surveys and at each sighting during the boat and ground surveys. Ambient air temperatures were recorded at weather stations on the north and south ends of the lake. An index of recreation boating was developed by recording the number and location of boats observed during each waterfowl survey. Seasons were delineated by lake levels but generally coincided with climatic seasons: fall = 31 August-17 November (lake level range during surveys = 225.8-226.2 m), early winter = 30 November-30 December (227.1-227.7), late winter = 15 January-27 February (225.7-226.2), and spring = 10 March-27 April (226.5-226.8).

Habitat Use

We sampled 5 major hydrogeological macrohabitats on the reservoir: (1) flowing river, (2) wide river, (3) bay, (4) cove, and (5) main lake. Flowing river was furthest upstream from the dam and most characteristic of the area before impoundment. Wide river was quasi-riverine and occurred below the source rivers where flow velocity was reduced; it was characterized by extensive mudflats due to sedimentation. Bays were semi-protected, but coves were well-protected with steep shores and little or no littoral area. The remainder of the reservoir was characterized by open expanses of water with limited cover. We determined the proportion of the 5 macrohabitats with a planimeter on a 1:24,000 topographic map.

We identified 7 shoreline-types (microhabitats) in each of the 5 macrohabitats: (1) exposed mudflats, (2) exposed gravel bars, (3) flooded tree-shrub, (4) flooded herbaceous vegetation, (5) steep rock, (6) open water, and (7) developed areas. Developed areas referred to recreational shoreline development. Flooded tree/shrub was predominately willow with an understory of buttonbush (Cephalanthus occidentalis) and assorted herbaceous vegetation. Emergent and submergent vegetation was sparse on Grand Lake, likely due to wave action and turbidity (Peltier and Welch 1970). Smart weeds (*Polygonum* spp.), millets (*Echinochloa* spp.), and flat sedges (*Cyperus* spp.) dominated mudflats. Gravel bars were largely devoid of vegetation. Areas with herbaceous or tree/shrub vegetation that were not inundated were classified as mudflats or gravel bars; when inundated to a depth >0.3 m (i.e., suitable foraging areas for dabbling ducks [White and James 1978]) they were classified as flooded herbaceous vegetation or tree/shrub microhabitats. If an area with herbaceous vegetation was inundated to a depth that waterfowl could no longer feed (>5 cm above the top of the vegetation), it was classified as open water.

We estimated availabilities of microhabitats at each 0.3-m change in surface elevation of the reservoir by identifying habitats at 5 sites/km along the entire length of both boat surveys. Because macrohabitats were sampled in proportion to their availabilities during aerial and boat surveys, we assumed that our estimates of microhabitat availabilities during boat surveys also reflected those on aerial surveys.

Data Analysis

Aerial and boat surveys identified similar preferred reservoir habitats and shifts in seasonal habitat preferences (Chapter 2), but aerial surveys were more extensive and therefore used to identify preferred reservoir habitats on Grand Lake. Our approach to habitat analyses was hierarchical; i.e., macrohabitats were evaluated first. We reasoned that if macrohabitats were avoided, then microhabitats within these areas were similarly avoided. Chi-square and Bonferroni *z* confidence intervals (Neu et al. 1974, Byers et al. 1984) were used to identify habitat preferences ($P < 0.05$). Open water constituted >65% of the reservoir and was generally avoided by waterfowl; therefore, it was not included in the microhabitat analysis (Johnson 1980). Habitats with no waterfowl in them were not included in the analysis (Neu et al. 1974) and assumed to be avoided. Because flocking behavior of waterfowl might bias analyses (Alldredge and Ratti 1986), we used both the number of individuals and flocks as observations. Wind speed and ambient air temperatures were averaged for each survey day and converted to wind chill factor. Seasons were used as treatments and a 1-way analysis of variance and Duncans's multiple-range test were used to identify differences in wind chill among seasons.

RESULTS

Habitat Availability

Changing lake levels altered habitat availabilities (Table 1). The flowing river, wide river, and bay macrohabitats contained the greatest proportion of mudflats when lake levels were low. The main reservoir and coves contained the greatest proportion of rock microhabitats; bays contained none. Gravel bars were generally an unsuitable substrate for herbaceous vegetation but were colonized by tree/shrub in densities less than those on mudflats. In general, macrohabitats that contained the greatest proportion of mudflats when lake levels were low contained the greatest proportion of flooded herbaceous and tree/shrub habitats when lake levels were high (Table 1). The main reservoir was devoid of flooded herbaceous vegetation at lake levels <227 m but contained tree/shrub in similar proportions to that of bays and coves at lake levels > 226m (Table 1).

Waterfowl Abundance and Habitat Use

Mallard was the most abundant and frequently observed species during our surveys; seasonal totals peaked in early winter (30 Nov-30 Dec) at 26,174 (Table 2). Mallards also dominated (62%) the fall (31 August-17 November) and late winter (97%) (15 January-27 February) dabbling duck populations. Gadwall, blue-winged teal (A. discors), American wigeon, and northern shoveler (A. clypeata) totaled <1,000 each during fall, and their numbers declined in the subsequent seasons (Table 2). Northern pintail (A. acuta) were rarely observed and always in low numbers. Large numbers of green-winged teal (A. crecca) were observed for a short period during early winter, but only mallards were numerous enough seasonally to evaluate habitat use.

Significant differences in wind chill were observed among seasons ($F = 11.6$; 3,39 df; $P < 0.001$). The coldest mean wind-chill factor was recorded during late winter ($\bar{x} = -7.7$ C), followed by early winter ($\bar{x} = 3.8$ C), spring ($\bar{x} = 8.3$ C), and fall ($\bar{x} = 15.5$ C).

Fall.--We observed the second highest seasonal total of dabbling ducks during fall; mallards, gadwalls, and blue-winged and green-winged teal were the most numerous (Table 2). Mallards, both total numbers and flocks, displayed differential habitat preference for macrohabitats ($P < 0.001$) (Table 3) and for microhabitats ($P < 0.001$) (Table 4). Mallards preferred flowing and wide river macrohabitats, and the flooded tree/shrub microhabitat (Tables 3 and 4). Based on total numbers of ducks, mudflats also were preferred in the wide river macrohabitat (Table 4).

Early Winter.--The greatest number of dabbling ducks (primarily mallard and green-winged teal) were observed during early winter (Table 2). Mallards, both total numbers and flocks, again showed differential habitat preference for macrohabitats ($P < 0.001$) and microhabitats ($P < 0.001$); they preferred flowing and wide river macrohabitats (Table 2). Flooded herbaceous microhabitat was preferred in the wide river (total ducks and flocks) and the flowing river (total ducks) (Table 4).

Late Winter.--Mallard was the only species observed in great abundance during late winter (Table 2) and showed differential habitat preference (both total numbers and flocks) for macrohabitats ($P < 0.001$) and microhabitats ($P < 0.001$). Mallards preferred the flowing and wide river macrohabitats, but also showed preference for bays based on total numbers of ducks (Table 3). They preferred flooded tree/shrub (total ducks and flocks) and mudflats (total ducks) microhabitats in the wide river (Table 4). Tree/shrub in the flowing river (total ducks) also was preferred (Table 4).

Spring.--With the exception of northern pintail (that were rarely observed), all dabbling ducks used the Grand Lake area intermittently during spring, but relatively few individuals were observed on the reservoir. During spring, the surrounding wetlands were more important, particularly given the relative differences in availabilities (Table 5). Approximately 19 ha of ponds contained >57% of the total dabbling ducks observed (Table 5) and <20% of those ponds accounted for >97% of the dabbling ducks observed on the surrounding wetlands.

Human Disturbance

Shoreline development (i.e., homes, marinas, and resorts) was greatest in the main reservoir, coves, and bays, and almost nonexistent in the wide and flowing river areas (Table 1). Development on the south end of the reservoir was typically associated with rock shoreline (i.e., deep water shorelines) and least abundant in bays with mudflats (Table 1).

Recreational boating was most intense during fall (fishing) and spring (fishing and pleasure boating), and generally coves, main lake, and bays received the greatest use (Table 6). The greatest number of boats observed in the flowing and wide river areas were during early winter (Table 6) during the waterfowl hunting season.

DISCUSSION

Blue-winged teal and northern shovelers used Grand Lake during fall but departed with the onset of inclement weather. Submergent and emergent vegetation was sparse on Grand Lake (Stancill et al. 1988) as it is on most large reservoirs (Chabreck 1979), and likely contributed to the low numbers of gadwall and American wigeon (Bellrose 1980). Although green-winged teal will remain in the central Great Plains when food and weather are optimal, Oklahoma is north of the major wintering areas for all dabbling ducks except mallards (Bellrose 1980). Our results indicated that Grand Lake was used primarily by mallards during fall and winter, and surrounding wetlands were preferred by all dabbling ducks during spring. A shift to small wetlands during spring migration has been noted previously (Barclay 1976, Heitmeyer and Vohs 1984), but reasons are not well documented. We observed waterfowl courting and feeding more on the surrounding wetlands during spring (Appendix 1); such areas may be important for pairbond maintenance (Hepp and Hair 1984) and provide adequate food (Logan 1975).

Reservoir macrohabitats were determined by their hydrogeological position, and their availability did not change with lake levels. Conversely, availabilities of herbaceous vegetation and tree/shrub macrohabitats were influenced significantly by available substrates and fluctuating water levels. Of course, properly-timed manipulations can benefit waterfowl (Kadlec 1962, Burgess 1969, Chabreck et al. 1974). We identified flooded vegetation and tree/shrub as primary habitats of migrating and wintering mallards on Grand Lake; the importance of similar habitats also have been noted on large reservoirs in Texas (Johnson and Swank 1981) and Tennessee (Barstow 1963). Flooded habitats provide food and cover, and their availabilities increased on Grand Lake (due to higher water levels) during early winter, which coincided with peak numbers of mallards and green-winged teal.

Waterfowl numbers on Grand Lake were significantly influenced by availabilities of microhabitats, which were not distributed evenly in the macrohabitats. Lack of herbaceous vegetation and abundant tree/shrub habitats on the main reservoir were probably due to willow's ability to withstand wave action. Coves provided protection from waves and inclement weather but lacked suitable substrate for herbaceous and tree/shrub growth. Johnson and Swank (1981) found coves to be preferred loafing areas for dabbling ducks on reservoirs, but we found that flooded tree/shrub and mudflats were preferred (Appendix 1), as did Cowardin (1969) and Tamisier (1976). Macrohabitats devoid of these loafing areas were generally avoided. Development of large mudflats and associated wetlands in the upper portions of reservoirs and bays appears to be a general phenomenon of aging reservoirs (Silvey and Stanford 1978, Kimmel and Groeger 1986), and these areas appear to be critical to waterfowl habitat management on old-aged reservoirs.

Mallards are considered moderately susceptible to disturbance (Tuite et al. 1984). Johnson and Montalbano (1984) and Tuite et al. (1984) found that habitat use was not affected by hunting, but others have noted that excessive hunting pressure (Lampio 1982) and recreational boating (Bell and Austin 1985, Korschgen et al. 1985) can drive waterfowl from preferred areas. During fall and early winter, recreational boating was concentrated in bays, coves, and the main reservoir, and waterfowl tended to avoid these areas. On the other hand, mallards continued to use flowing and wide river areas during early winter (and their numbers steadily increased), which indicated that hunting pressure was too low to influence habitat use (although a threshold probably exists). Mallards spent more time alert and less time feeding and loafing in bays than in flowing and wide river areas, but they spent less time alert in the tree/shrub microhabitat (where presumably waterfowl would be less vulnerable) than in mudflats and herbaceous vegetation (Appendix 1 and 2). Thus, tree/shrub microhabitats may be important for escape cover. During late winter, boating activity decreased throughout the reservoir, and mallards began using bays that contained microhabitats similar to the upper reservoir areas.

Most shoreline development on Grand Lake was associated with deep water habitats along steep rocky shorelines (likely due to enhanced marina operations); therefore, destruction of other shoreline substrates suitable for vegetation was minimal. Water-based recreation and shoreline development were concentrated on the southern half of the lake, and waterfowl tended to avoid these areas.

MANAGEMENT IMPLICATIONS

With the current rate of natural wetland destruction in North America, a greater reliance will have to be placed on man-made wetlands, and long-range planning should include habitat enhancement and protection. Managing large reservoirs for feeding areas may be unnecessary for some waterfowl species (e.g., mallard and green-winged teal) that can shift to field feeding (Tamisier 1976, Baldassarre 1984), but protection of disturbance-free loafing areas should be a management goal on reservoirs in agricultural areas. Tree/shrub and mudflats were preferred by mallards during late winter (primarily as loafing areas [Appendix 1]), which was likely a response to declining reservoir feeding areas and a switch to field feeding. Mallard numbers also declined during this period, which was probably associated with a lack of preferred row crops (Jorde et al. 1983, Baldassarre 1984). Because mudflats are limited on reservoirs and often the predominate substrate for plant growth, planting preferred row crops around these areas should be considered as a late winter management practice.

The decline in waterfowl use of older reservoirs has been documented (Barclay 1976, Johnson and Swank 1981), but research into management of these areas has been neglected. Most old-aged reservoirs develop mudflats and associated wetlands in their upper sections and management of such areas could benefit waterfowl. Mudflats are key areas for food production and probably the limiting factor for waterfowl use, but maintenance of flooded tree/shrub and exposed mudflats are also necessary for loafing cover. Protected areas (such as coves) without shoreline habitat do not provide adequate loafing cover nor do they contain adequate littoral area for food production. Human disturbance and shoreline development both play an important role in diminishing the quality of reservoirs as waterfowl habitat, and in light of the fact that reservoirs contain limited areas preferred by waterfowl, long-term planning should include protection and enhancement of these important areas.

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Table 1. Changes in availabilities of shoreline habitats relative to lake level fluctuations on Grand Lake, Oklahoma, 1987.

Macro-habitats	Lake Levels[a]	Shoreline Habitats					
		Mudflat	Gravel	Rock	Developed	Herbaceous	Tree/shrub
Flowing River (4.2%)[b]							
	225	55.5	0.0	13.9	0.0	19.4	11.1
	226	27.7	0.0	13.9	0.0	38.9	19.5
	227	11.1	0.0	13.9	0.0	38.9	36.1
Wide River (6.1%)							
	225	58.5	11.3	20.7	3.8	1.9	3.8
	226	37.8	5.7	20.7	3.8	15.1	17.0
	227	5.7	0.0	20.7	3.8	28.3	41.5
Bay (19.1%)							
	225	31.9	33.7	0.0	12.0	16.3	6.1
	226	25.3	27.7	0.0	12.0	22.9	12.0
	227	17.5	16.3	0.0	12.0	30.7	23.5
Cove (19.3%)							
	225	6.5	13.7	47.0	22.6	3.6	6.5
	226	3.6	7.7	47.0	22.6	6.5	12.5
	227	1.2	4.2	47.0	22.6	8.9	16.1

Table 1. Continued.

Macro-habitats	Lake Levels[a]	Shoreline Habitats: Mudflat	Gravel	Rock	Developed	Herbaceous	Tree/shrub
Main Reservoir (51.3%)							
	225	11.8	30.0	38.0	17.2	0.0	2.9
	226	8.9	23.3	38.0	17.2	0.0	12.5
	227	5.1	14.3	38.0	17.2	7.4	17.9

[a]Meters above sea level.
[b]Percent of total survey area.

Table 2. Seasonal dabbling duck abundance on Grand Lake, Oklahoma, from aerial surveys (3/mo) during 1987.

	Seasons[a]							
	Fall		Early winter		Late winter		Spring	
Species	n	%	n	%	n	%	n	%
Mallard	4940	62.4	26,174	88.8	4,737	96.7	344	59.0
Green-winged teal	667	8.4	2,160	7.4	133	2.7	0	
Gadwall	929	11.8	921	3.1	0		77	13.2
Blue-winged teal	637	8.0	0		0		3	0.5
Wigeon	445	5.6	155	0.5	0		0	
Northern shoveler	304	3.8	25	0.1	13	0.3	159	27.3
Pintail	0		25	0.1	16	0.3	0	
Total	7,922		29,460		4,899		583	

[a]Determined primarily by lake levels; fall = 31 Aug-17 Nov, early winter = 30 Nov-30 Dec, late winter =15 Jan-27 Feb, and spring = 10 Mar-27 Apr.

Table 3. Seasonal habitat selectivity by mallards in macrohabitats on Grand Lake, Oklahoma, during 1987.

		Seasons[a]											
		Fall				Early winter				Late winter			
				Habitat Selectivity[b]				Habitat Selectivity[b]				Habitat Selectivity[b]	
Macrohabitats	% Avail.	No. Ducks	No. Flocks	Ducks	Flocks	No. Ducks	No. Flocks	Ducks	Flocks	No. Ducks	No. Flocks	Ducks	Flocks
Flowing River	4.2	1,114	56	+	+	7,324	98	+	+	1,401	36	+	+
Wide River	6.1	3,083	54	+	+	14,410	181	+	+	1,216	41	+	+
Bay	19.1	471	26	-	0	2,706	46	-	-	1,781	18	+	0
Cove	19.3	115	12	-	-	132	11	-	-	101	5	-	-
Main Lake	51.3	157	10	-	-	1,602	82	-	-	238	13	-	-
Totals	100.0	4,940	158			26,174	418			4,737	113		

[a] Determined primarily by lake levels; fall = 31 Aug-17 Nov, early winter = 30 Nov-30 Dec, late winter = 15 Jan-27 Feb.

[b] Chi-square analyses followed by Bonferroni confidence intervals (Neu at al. 1974); + = preferred, 0 = no preference, - = avoided ($P < 0.05$).

Table 4. Seasonal habitat selectivity by mallards in available microhabitats in flowing and wide river macrohabitats on Grand Lake, Oklahoma, during 1987.

	Season[a]														
	Fall					Early winter					Late winter				
				Habitat Selectivity[b]					Habitat Selectivity[b]					Habitat Selectivity[b]	
Macrohabitat Microhabitat	% Avail.[c]	No. Ducks	No. Flocks	Ducks	Flocks	% Avail.[c]	No. Ducks	No. Flocks	Ducks	Flocks	% Avail.[c]	No. Ducks	No. Flocks	Ducks	Flocks
Flowing River[d]															
Mudflats	22.5	630	15	-	0	4.5	94	1	-	-	22.5	316	27	-	0
Rock	5.6	0	0	-	-	5.6	0	0	-	-	5.6	0	0	-	-
Herbaceous Vegetation	7.9	176	6	-	-	15.8	4,357	32	+	0	7.9	63	2	-	0
Tree/shrub	4.5	283	33	+	+	14.6	2,758	61	0	+	4.5	1,007	6	+	0
Wide River															
Mudflats	34.8	1,875	27	+	0	3.4	486	17	-	0	34.8	726	10	+	-
Gravel	6.7	62	2	-	-	0[e]					6.7	116	21	0	+
Rock	12.4	0	0	-	-	12.3	0	0	-	-	12.4	0	0	-	-
Developed	2.2	7	2	-	0	2.2	13	2	-	0	2.2	0	0	-	-
Herbaceous Vegetation	1.2	75	3	0	0	16.9	11,839	106	+	+	1.2	18	3	-	0
Tree/shrub	2.2	113	16	+	+	24.7	1,956	43	-	0	2.2	315	5	+	+

[a] Determined primarily by lake levels; fall = 31 Aug-17 Nov, early winter = 30 Nov-30 Dec, late winter = 15 Jan-27 Feb.

[b] Chi-square analyses followed by Bonferroni confidence intervals (Neu et al. 1974); + = preferred, 0 = no preference, - = avoided ($\underline{P} < 0.05$).

[c] Sum of habitats in flowing and wide river areas = 100.0%

[d] Gravel and developed habitats did not occur in the flowing river area.

[e] Unavailable at lake levels during early winter.

Table 5. Spring[a] dabbling duck abundance on Grand Lake and surrounding wetlands, Oklahoma, during 1987.

Area	Hectares (%)	No. Ducks in Area (%)
Reservoir	18,818 (99.1)	583 (37.8)
Ponds	19 (0.1)	885 (57.4)
Permanent Wetland	<1 (tr)	60 (3.9)
Creeks	<1 (tr)	14 (0.9)

[a]Spring = 10 Mar-27 Apr.

Table 6. Mean number of boats observed during aerial surveys in macrohabitats on Grand Lake, Okalhoma, 1987.

	Seasons[a]							
	Fall		Early winter		Late winter		Spring	
Macrohabitats	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Flowing river	1.4	1.4	4.8	1.2	1.4	1.7	1.6	1.4
Wide River	0.5	0.7	4.4	1.1	1.8	1.3	1.0	1.2
Bay	27.0	8.9	9.6	3.1	1.6	1.6	14.8	11.5
Cove	64.9	15.2	8.4	3.1	6.4	6.1	30.1	20.1
Main Lake	38.0	15.7	13.0	4.8	2.2	3.1	20.4	16.4

[a]Determined primarily by lake levels; fall = 31 Aug-17 Nov, early winter = 30 Nov-30 Dec, late winter =15 Jan-27 Feb, and spring = 10 Mar-27 Apr.

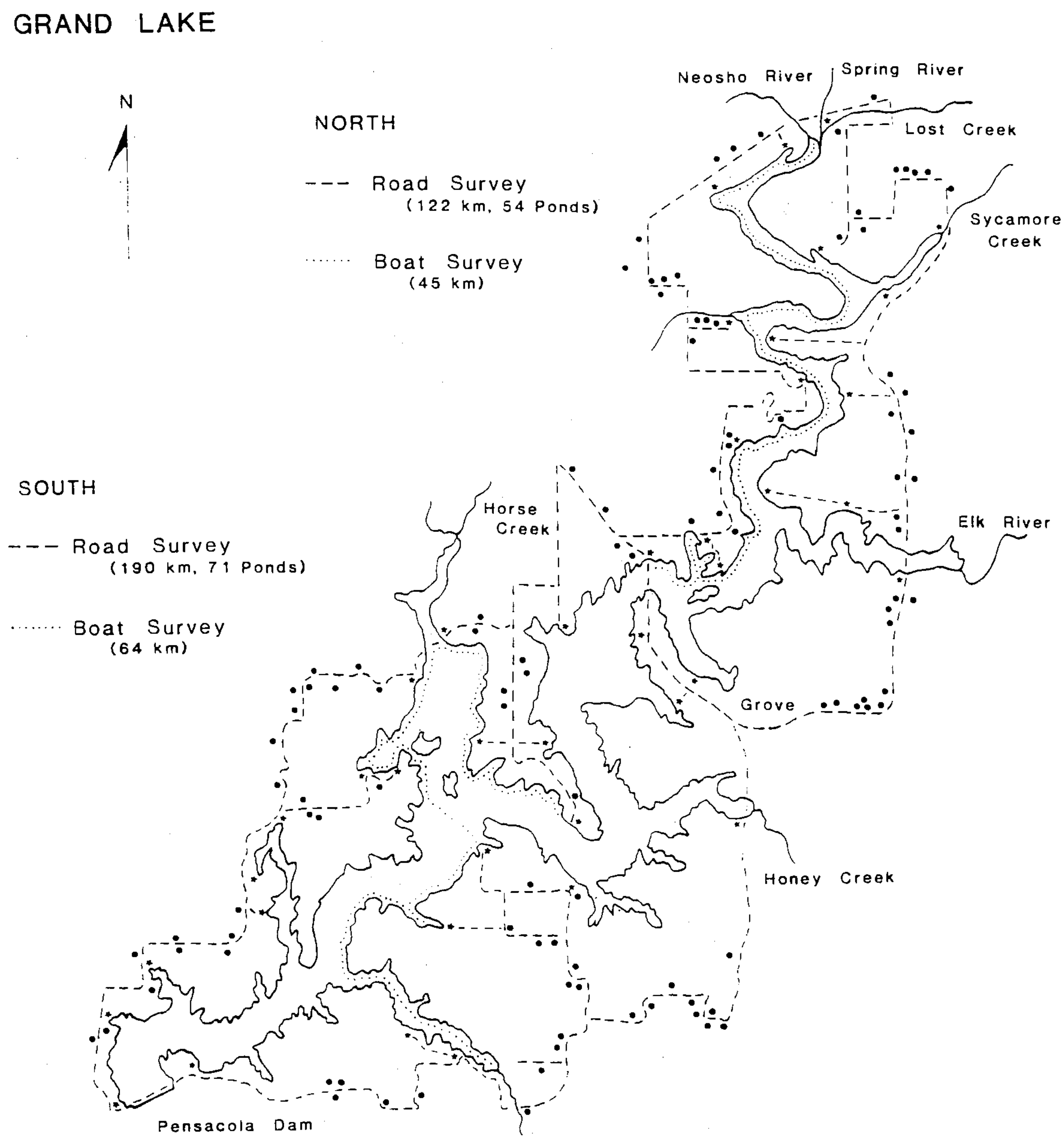

Fig. 1. Aerial, boat, and ground survey routes used to census waterfowl on Grand Lake and surrounding wetlands, 1987 (solid circles = ponds; stars = lake sites on ground survey routes).

APPENDIXES

APPENDIX A. SEASONAL TIME BUDGETS[a] FOR MALLARDS IN WIDE RIVER MICROHABITATS AND SURROUNDING WETLANDS ON GRAND LAKE, OKLAHOMA, 1987.

Season	Behavior (% of Time Observed)						
Habitat	Feed	Loafing	Locomotion	Alert	Comfort	Courting	Other
Fall							
Tree/shrub	39	36	9	<1	9	<1	5
Mudflats	26	46	8	4	11	<1	3
Herbaceous	56	22	13	<1	3	<1	5
$\bar{x}$	40	35	10	2	8	<1	4
Early Winter							
Tree/shrub	18	67	7	2	4	<1	2
Mudflats	11	63	3	6	9	2	6
Herbaceous	59	20	13	7	1	0	<1
$\bar{x}$	29	50	8	5	5	1	3
Late Winter							
Tree/shrub	3	59	12	<1	11	13	2
Mudflats	0	62	11	<1	12	9	6
Herbaceous	6	57	12	<1	5	16	4
$\bar{x}$	3	60	12	<1	10	12	4

APPENDIX A. CONTINUED.

Season / Habitat	Behavior (% of Time Observed)						
	Feed	Loafing	Locomotion	Alert	Comfort	Courting	Other
Spring							
Tree/shrub	19	46	13	2	5	6	6
Mudflats	25	51	11	4	7	<1	2
Herbaceous	17	48	19	3	6	2	5
$\bar{x}$	17	48	14	3	6	3	4
Spring							
Wetlands	36	36	7	4	5	11	1

[a] Methods described by: Jorde, D. G., G. L. Krapu, R. D. Crawford, and M. A. Hay. 1984. Effects of weather on habitat selection and behavior of mallards wintering in Nebraska. Condor 86:258-265.

APPENDIX B. SEASONAL TIME BUDGETS[a] FOR MALLARDS IN BAY MICROHABITATS ON GRAND LAKE, OKLAHOMA, 1987.

Season	Behavior (% of Time Observed)						
Habitat	Feed	Loafing	Locomotion	Alert	Comfort	Courting	Other
Fall							
Tree/shrub	28	27	15	20	7	<1	3
Mudflats	13	29	19	29	5	<1	2
Herbaceous	26	15	23	29	3	<1	3
$\bar{x}$	22	24	19	26	5	<1	3
Early Winter							
Tree/shrub	24	37	17	16	2	<1	2
Mudflats	11	29	31	21	4	0	4
Herbaceous	27	24	26	16	1	0	5
$\bar{x}$	21	30	25	18	2	0	4
Late Winter							
Tree/shrub	7	52	12	3	16	9	2
Mudflats	3	69	7	<1	10	7	4
Herbaceous	6	63	6	<1	9	12	4
$\bar{x}$	5	61	8	1	12	9	3

APPENDIX B. CONTINUED.

Season Habitat	Behavior (% of Time Observed)						
	Feed	Loafing	Locomotion	Alert	Comfort	Courting	Other
Spring							
Tree/shrub	10	25	34	18	7	2	4
Mudflats	6	17	43	21	11	<1	2
Herbaceous	9	13	36	33	4	2	3
$\bar{x}$	8	18	38	24	7	1	3

[a]Methods described by: Jorde, D. G., G. L. Krapu, R. D. Crawford, and M. A. Hay. 1984. Effects of weather on habitat selection and behavior of mallards wintering in Nebraska. Condor 86:258-265.

VITA

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