A STUDY OF MIGRATORY AMERICAN COOTS,

FULICA AMERICANA, IN OKLAHOMA

By

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TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

Table | Page

Table Page

Chapter V

LIST OF FIGURES

Figure Page

Chapter II

CHAPTER I

INTRODUCTION

This thesis is composed of 4 manuscripts written in formats suitable for submission to selected scientific journals. Each manuscript is complete without supporting materials. The arrangement of each manuscript is text, literature cited, tables, and figures. Chapters II and IV, 'Migration chronology of American coots in Oklahoma' and 'Interactions between American coots and waterfowl during fall migration' are written in the format of the JOURNAL OF WILDLIFE MANAGEMENT. Chapters III and V, 'Habitat use patterns of American coots during fall migration in Oklahoma' and 'Determining age and sex of American coots' are written in the format of the JOURNAL OF FIELD ORNITHOLOGY.

CHAPTER II

MIGRATION CHRONOLOGY OF AMERICAN COOTS IN OKLAHOMA

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Abstract: The autumnal and spring migrations of American coots (*Fulica americana*) were studied on large reservoirs in north-central Oklahoma in 1979-82 to determine migration chronology of sex and age classes. Coots began migrating into Oklahoma in mid-September, numbers peaked in early to mid-October, and few birds were seen after 1 November. Some late migrants appeared in mid-December. In spring, coots began migrating in late February, numbers peaked in mid-April, and the last birds were seen in mid-May. Generally, coots of all age and sex classes migrated simultaneously in fall, although adult females completed migration by 1

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November and a few juveniles migrated in December. Adult coots migrated before immatures in spring. Despite annual and between-lake differences in migration chronology, 80% of coots migrated before waterfowl seasons in Oklahoma. If the management goal is higher harvest, coot seasons in mid-latitude states should commence before the general waterfowl season.

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Key words: American coot, *Fulica americana*, Oklahoma, migration, differential migration, hunting regulations, age and sex ratios

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Precise information on the chronology of migration of game birds is essential to determine proper harvest regulations (Crissey 1965). For example, changes in regulations have provided hunters with greater harvest opportunities for waterfowl species migrating earlier than others (Martinson et al. 1966) or species not as vulnerable to shooting pressure (Crissey 1965). The migration chronology of American coots has received little attention in relation to harvest regulations and migration of different age and sex classes (Fredrickson et al. 1977:143, Gorenzel 1979:69). Male coots winter farther north than females (Brisbin et al. 1973), but this phenomenon may change between years (Harris 1981:30). Some evidence suggests that adult males and nonbreeders may move south ahead of females and juveniles (Ward 1953, Ryder 1963). Juveniles represented 92% of October band recoveries from Wisconsin, suggesting differential autumnal migration by age (Burton 1959), but differential habitat use or differential vulnerability to harvest might also explain this observation (Thompson 1973).

We determined the chronology (by age and sex) of autumnal and spring migration of coots in Oklahoma, especially relative to fall hunting seasons. Oklahoma was an excellent site for the study as few coots breed or winter in the state (Sutton 1967:166).

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STUDY AREAS

Field work was conducted in Payne, Noble, and Pawnee counties of north-central Oklahoma. The principal upland vegetation types are tallgrass prairie and post oak-blackjack oak forest (Duck and Fletcher 1943). Cattle grazing is the principal land-use. Migration chronology of coots was studied on Sooner Lake (Noble-Pawnee counties), Lake Carl Blackwell (Payne-Noble counties), Perry Lake (Noble County), Lake McMurtry (Noble County), Boomer Lake (Payne County), Cushing Lake (Payne County), and Ham's Lake (Payne County). Intensive studies were conducted at Lake Carl Blackwell and Sooner Lake. Lake Carl Blackwell has been previously described (Baumgartner 1942). At the time of the present study the principal aquatic vegetation at Lake Carl Blackwell was filamentous algae (*Cladophora* sp.), naiad (*Najas guadalupensis*), and stands of flooded smartweeds (*Polygonum* spp.). The abundance of these species varied seasonally; filamentous algae was the principal vegetation in spring (Patterson 1982:5). Sooner Lake is a 2,168-ha lake providing cooling water for the coal-fired Sooner Generating Station operated by Oklahoma Gas and Electric Company. Most water in the lake is pumped from the Arkansas River, and water is maintained at stable levels by constant pumping. During our study, filamentous algae was common along shore in fall 1979 and in spring 1980, growing on submerged grasses and other vegetation. Sparse beds of naiad were found along the shore. In fall 1979, the level of Sooner Lake was lowered and only sparse beds of naiad were present. In spring, aquatic vegetation was algae, with stands of Johnson grass (*Sorghum halapense*), curly dock (*Rumex crispus*), sunflowers (*Helianthus* spp.), and grasses occurring frequently along the shoreline. Three large ponds near Sooner Lake were also surveyed. Aquatic plants on these ponds were naiad, pondweeds (*Potamogeton* spp.), muskgrass (*Chara vulgaris*), and filamentous algae.

METHODS

Coots on Lake Carl Blackwell were counted during the autumns of 1979 through 1981 and springs of 1980 and 1982. Coot migration was monitored on Sooner Lake in fall 1979 and 1980 and spring 1980. During fall 1979 and 1980, all lakes were surveyed by aircraft every 5 days to count coots. Correction factors (Bartelt 1977:5) were not used because no lake surveyed had emergent cover capable of concealing birds. Aerial counts were supplemented with ground counts at Lake Carl Blackwell and Sooner Lake every 1-5 days. In spring, ground counts were made every 1-7 days. Numbers of coots present on each lake were plotted through time from early September through the end of December in fall and from mid-February through mid-May in spring.

To determine the age and sex of migratory coots, we collected birds from migrant flocks every 5-7 days in fall 1979-80 and spring 1980 and 1982 on Lake Carl Blackwell, and fall and spring 1980 on Sooner Lake. Whenever possible, coots were sampled from all habitats and all flocks on the lakes on each collection date. Birds were taken to the laboratory and dissected; sex was determined by internal examination; and age was determined by examination of the bursa of Fabricius (Fredrickson 1968), plumage (Gullion 1954), and other external and internal characteristics (Eddleman and Knopf in prep.).

To test the hypothesis of no difference in migration chronology between both lakes and between years on Lake Carl Blackwell, we used 2-sided 2-sample Smirnov tests to compare cumulative frequency distributions of the proportions of total coots seen vs. date (Conover 1980:369). Cumulative frequency distributions of birds of different age (AHY, hereafter referred to as adult; HY, hereafter referred to as juvenile) and sex were compared using the Smirnov test to determine differential migration. Because statistical tables were not available to compare cumulative frequency distributions of 4 samples of unequal size (Conover 1980:384), we compared migration chronology of all 4 age-sex classes using chi-square tests for independence. The 6 possible pairs of age and sex classes were then compared by the Smirnov tests.

RESULTS

Fall migrant coots first appeared in mid-September (Figure 1). Successively larger peaks in numbers occurred until early October in 1979 and 1980 and mid-October in 1981. Peaks in numbers of birds were on days following the passage of cold fronts; most coots stayed only 1-4 days before departing. As coots are night migrants (Ryder 1963), birds merely stopped for 1 or 2 days and continued migrating south on subsequent nights if northerly winds prevailed. Most coots migrated before 1 November (Figure 1), although a few appeared in mid-December.

Coots began spring migration in late February (Figure 2). Birds arrived after southerly winds prevailed on previous nights. Numbers of birds increased slowly until late March, peaked in mid-April, and declined until mid-May. Migrational movements appeared more leisurely in spring, without obvious rapid turnover of flocks.

Because migration chronology differed between lakes and years on the same lake (Table 1), data for each season and lake were analyzed separately for differential migration. Coots of different age and sex migrated simultaneously in autumn (Tables 2, 3). A significant difference was found between age classes in 1979, but this may be attributed to the predominance of juveniles of both sexes in December samples. The number of migrants present in December, however, was small relative to the total number of fall migrants. Extrapolating the age-sex ratios of samples to the total number of coots present on Lake Carl Blackwell for all collection dates in fall 1979 and graphing the percentage of all birds of that age-sex class seen on a given day (Figure 3) revealed that migration of the age-sex classes was synchronous.

Comparisons of each pair of age-sex classes indicated no differences in migration chronology between juvenile males and females or between adult males and females in fall (Table 4). Differences between adult females and juveniles of both sexes indicated earlier migration of adult females. Only 2 of 72 (2.8%) adult females were collected after 1 November from both lakes in all years, further suggesting earlier fall migration of adult females.

In contrast to autumn, coots migrated in differential patterns in spring (Table 4). Adults predominated in February and March samples; few juveniles were present. Age ratios shifted gradually until juveniles predominated in late-April and May samples. Analysis of the 6 pairs of age-sex classes (Table 5) confirmed that adults migrated before juveniles each year except 1982. However, only 10 juveniles of each sex were collected in the spring of 1982.

DISCUSSION

Migration Chronology

Fall migration of coots progresses across a broad front in North America (Ryder 1963). Early migrants may arrive on migration areas in early August (Gorenzel et al. 1981), but usually do not arrive until early September in the northern United States (Jahn and Hunt 1964:93) and late September in the south (Eley 1975:15). Peak numbers of migrants occur from late August (Gorenzel et al. 1981) in Colorado to December in South Carolina (Brisbin 1974). The peak of migration of early to mid-October in our study was up to 3 weeks later than the peak in Colorado (Gorenzel et al. 1981).

Spring migration of coots begins in February or early March (Fredrickson 1969, Gorenzel et al. 1981) with peaks occurring from February in the southern United States (Eley 1975:15) through the end of April in the northern United States (Bartelt 1977:22). The migration peak in mid-April in Oklahoma corresponds to that in Colorado (Gorenzel et al. 1981).

The difference between turnover of coots during fall and spring migration may reflect birds lingering longer in spring and being counted more than once. However, the change in age ratios of birds collected through time sheds doubt on this speculation. Likewise, we doubt that coots migrated along different routes in the Central Flyway in fall and spring (Ryder 1963). Most likely, coots migrated at a more leisurely pace and stopped more frequently in spring. Coots follow the breakup of ice in their migrational movements in spring (Fredrickson 1969); therefore such a slow movement might be a response to the latitudinal disappearance of ice in northern breeding areas. The relative speed of movement and proportion of coots lingering on a given lake may also be a response to abundance of food or to seasonal differences in physiological condition of birds (Cherry 1982), as fall migration appeared more leisurely in comparison to spring migration in Colorado (Gorenzel et al. 1981).

Factors Affecting Censuses

Peak numbers of coots observed in other studies of fall migration occurred over a span of 4 months (Table 6). Although peaks tended to be later at southern sites, latitude is not necessarily the chief determinant of perceived timing of migration. Yearly variations in weather conditions, availability of food resources, continued presence of breeding or wintering birds (Ward 1953, Brisbin 1974), and physiological condition of individual birds (Cherry 1982) could cause shifts in abundance or mask movements of migrants.

Since no coots nested on our study lakes and <150 wintered on Sooner Lake each year, virtually all birds we observed were migrants. Inflated counts of migrants may result when food resources are abundant.

For example, whereas the pattern of migration chronology was similar on study lakes, coots lingered on Sooner Lake, where they ate aquatic vegetation (Patterson 1982:13). Turnover of coot numbers was greater on Lake Carl Blackwell, where coots fed infrequently. Timing of counts may also affect perceived migration chronology. If fall counts had been timed at intervals of every 5 days or more, large numbers of migrants would have been missed. Daily counts or counts taken immediately before and immediately after the passage of cold fronts would most accurately reflect the pattern of migration by coots.

Effects of Weather

Increases in numbers of migrant coots in fall always occurred after the passage of cold fronts and subsequent shifting of winds from the north. If winds shifted during the day or night, coots were present on subsequent mornings. If winds shifted to the south or southwest, coots lingered in greater numbers on subsequent days. If northerly winds continued, most coots disappeared within 2 days. Migration behind cold fronts in fall allows birds to increase ground speed, reducing the energy required to fly a given distance, and thus conserving energy reserves (Richardson 1978). In spring, coots arrived and departed when southerly winds prevailed, but did not depart as rapidly as in fall.

Differential Migration

Before the young fledge, male coots probably leave broods to form molting flocks from late June through mid-July (Ward 1953). Flocks of juveniles form by the merging of broods through August. Adult males and females presumably merge with juvenile flocks during the general staging of fall populations (Ward 1953). A similar process of flock formation occurs in post-breeding European coots (Fulica atra) in Siberia, although adults and juveniles stayed segregated at the beginning of migration (Koshelev 1977). We found no evidence for segregation of American coots during autumnal migration in Oklahoma. For most migrant birds, males precede females and adult precede juveniles in spring. (Gauthreaux 1982:141). Male and female coots of the same age migrated synchronously in this study, but adults preceded juveniles in spring. Little is known of the wintering ecology of American coots, but juveniles appear to have lower fat reserves in late winter than adults (Eddleman and Tacha, unpubl. data). Such a difference could result in juveniles requiring more time to prepare for and complete migration in spring. Juvenile female coots arrive on breeding areas later than adults, confirming this pattern of differential spring migration (Alisauskas 1982:19). Because adults occupy suitable habitat and establish territories upon arrival on breeding areas, differential migration of adults and juveniles could explain why yearlings frequently fail to breed or delay breeding (Crawford 1980, Alisauskas 1982:49).

MANAGEMENT IMPLICATIONS

Most waterfowl biologists believe that more coots can be harvested (Fredrickson et al. 1977:137). Because over 80% of coots observed in fall were seen before the waterfowl hunting season (Table 7), coot harvest opportunity is reduced in mid-latitude states such as Oklahoma. Therefore, despite liberal bag limits relative to ducks, coots appear to be underharvested. Adjustment of harvest season opening dates may increase harvest of birds and stimulate interest in coot hunting.

Harvest of coots could be allowed during both teal season and general waterfowl seasons, or a separate coot season could begin earlier than and continue through the waterfowl season. Both options would have to be monitored on an experimental basis, as local overharvest is possible (Bellrose 1944, Kiel and Hawkins 1953, Burton 1959). A special coot season may increase shooting pressure on waterfowl that migrate early (Geis and Crissey 1973). However, coots are easily identified aquatic game birds (Evrard 1970), therefore misidentification should be less of a problem than for other species. Changes in regulations also might necessitate an increased banding effort to monitor harvest mortality and an increased effort to convince hunters in some states that coots are palatable (Fredrickson et al. 1977:143).

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Table 1. Between-year and between-lake comparisons of coot migration chronology, autumn 1979-81 and spring 1980 and 1982.

Lake(s)	Season(s)-Year(s)	n_1/n_2 [a]	Test Statistic [b]	P
All	Fall 1979 vs. 1980	14,147/23,940	0.4472	<0.01
All	Spring 1980 vs. 1982	20,986/ 2,944	0.3311	<0.01
Carl Blackwell	Fall 1979 vs. 1980	3,452/ 3,347	0.2984	<0.01
Carl Blackwell	Spring 1980 vs. 1982	2,666/ 2,815	0.4693	<0.01
Carl Blackwell vs. Sooner	Spring 1980	2,666/18,320	0.3978	<0.01
Carl Blackwell vs. Sooner	Fall 1980	3,347/19,085	0.2483	<0.01

[a] Sample sizes are for first year/second year for comparisons of years, first lake/second lake for comparison of lakes.

[b] Two-sided 2-sample Smirnov test.

Table 2. Tests for differential autumnal migration of American coots between age and sex classes.

Group	Location/Year	n_1/n_2[a]	Test Statistic[b]	P
Age	Lake Carl Blackwell 1979	47/54	0.3459	<0.01
	Lake Carl Blackwell 1980	58/31	0.2036	>0.20
	Sooner Lake 1980	23/22	0.2530	>0.20
Sex	Lake Carl Blackwell 1979	54/47	0.1418	>0.20
	Lake Carl Blackwell 1980	34/55	0.2080	>0.20
	Sooner Lake 1980	20/25	0.3000	>0.20

[a]Sample sizes are numbers of juveniles/adults for age groups and numbers of females/males for sex groups.

[b]Two-sided 2-sample Smirnov test.

Table 3. Chi-square analyses of migration chronology of American coots by age-sex classes for autumn 1979-80 and spring 1980 and 1982.

Lake	d.f.	Season	$\underline{X}^2$	$\underline{P}$
Carl Blackwell	30	Fall 1979	52.412	0.0069
Carl Blackwell	36	Fall 1980	34.141	0.5572
Sooner	18	Fall 1980	21.765	0.2426
Carl Blackwell	36	Spring 1980	64.405	0.0025
Carl Blackwell	24	Spring 1982	38.272	0.0325
Sooner	30	Spring 1980	65.736	0.0002

Table 4. Comparison of migration chronology for all 4 age-sex classes of coots, fall 1979-80 and spring 1980 and 1982 (2-sided 2-sample Smirnov tests).

		Age-sex Classes Compared						
Lake	Season	AM-AF	AM-JM	AM-JF	AF-JM	AF-JF	JM-JF	n_1, n_2, n_3, n_4[a]
Carl Blackwell	Fall 1979	0.1809	0.2337	0.4783[c]	0.2379	0.5217[d]	0.3134	23,31,24,23
Carl Blackwell	Fall 1980	0.4182	0.2000	0.1130	0.5039[c]	0.4269	0.1379	20,11,35,23
Sooner	Fall 1980	0.4167	0.4167	0.1429	0.6667[b]	0.4524	0.4206	16, 6, 9,14
Carl Blackwell	Spring 1980	0.1964	0.4574[d]	0.4478[d]	0.4111[d]	0.3611[d]	0.1552	49,64,29,36
Carl Blackwell	Spring 1982	0.1771	0.3188	0.4375	0.4333	0.5333[c]	0.3000	32,42,10,10
Sooner	Spring 1980	0.1688	0.4788[c]	0.6480[d]	0.5762[d]	0.7692[d]	0.2359	33,14,15,13

[a]Sample sizes are numbers of adult males (n_1), adult females (n_2), juvenile males (n_3), and juvenile females (n_4).

[b]$0.02 \leq P < 0.05$

[c]$0.01 \leq P < 0.02$

[d]$P < 0.01$

Table 5. Tests for synchrony of spring migration of American coots between age and sex classes.

Group	Location/Year	n_1/n_2[a]	Test Statistic[b]	P
Age	Lake Carl Blackwell 1980	65/113	0.4030	<0.01
	Sooner Lake 1980	28/ 47	0.5578	<0.01
	Lake Carl Blackwell 1982	20/ 74	0.4338	<0.01
Sex	Lake Carl Blackwell 1980	100/ 78	0.0703	>0.20
	Sooner Lake 1980	27/ 48	0.1852	>0.20
	Lake Carl Blackwell 1982	52/ 42	0.1355	>0.20

[a]Sample sizes are numbers of juveniles/adults for age groups and numbers of females/males for sex groups.

[b]Two-sided 2-sample Smirnov test.

Table 6. Data on fall migration chronology of coots from other locations.

Location	Date of First Arrival	Dates of Peak Numbers	Use by Coots[a]	Source
South Carolina	-	November-December	M,W	Brisbin 1974
Southern Manitoba	-	early October	B,M	Ward 1953
Wisconsin	-	late October	B,M	Bartelt 1977
Wisconsin	early September	mid-October-early November	B,M	Jahn and Hunt 1964
Colorado	early August (1977) mid-August (1978)	late August-mid-September (1977) mid-October (1978)	B,M	Gorenzel et al. 1981
Southern California	-	late November	W,M	Eley 1975

[a]M - migration area, W - wintering area, B - breeding area

Table 7. Percentage of American coots that migrated through Oklahoma before the opening of the general waterfowl hunting season, 1979-81.

Lake(s)	Year	Opening Date	Number of coots/ Total number observed (%)
All	1979	27 October	9,362/14,147 (66.2)
Carl Blackwell	1979	27 October	3,322/ 3,452 (96.2)
All	1980	25 October	19,035/23,940 (79.5)
Carl Blackwell	1980	25 October	2,870/ 3,347 (85.7)
Sooner	1980	25 October	14,787/19,085 (77.4)
All	1981	31 October	6,112/ 6,285 (97.2)
Carl Blackwell	1981	31 October	3,374/ 3,547 (95.1)
Sooner	1981	31 October	2,398/ 2,738 (87.5)
Total			61,260/76,541 (80.0)

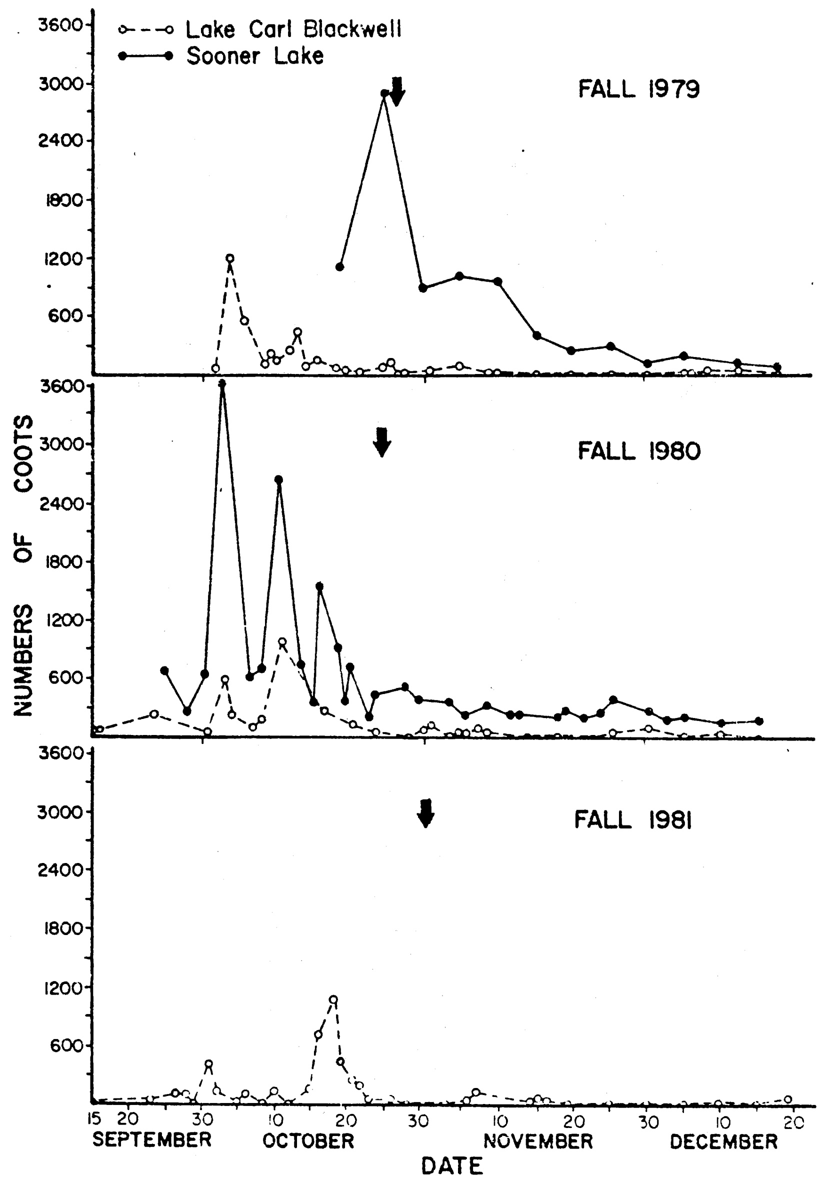

Figure 1. Migration chronology of American coots in fall 1979-81 on Sooner Lake (solid line) and Lake Carl Blackwell (dashed line), Oklahoma. Arrows denote the opening date of the general waterfowl season for each year.

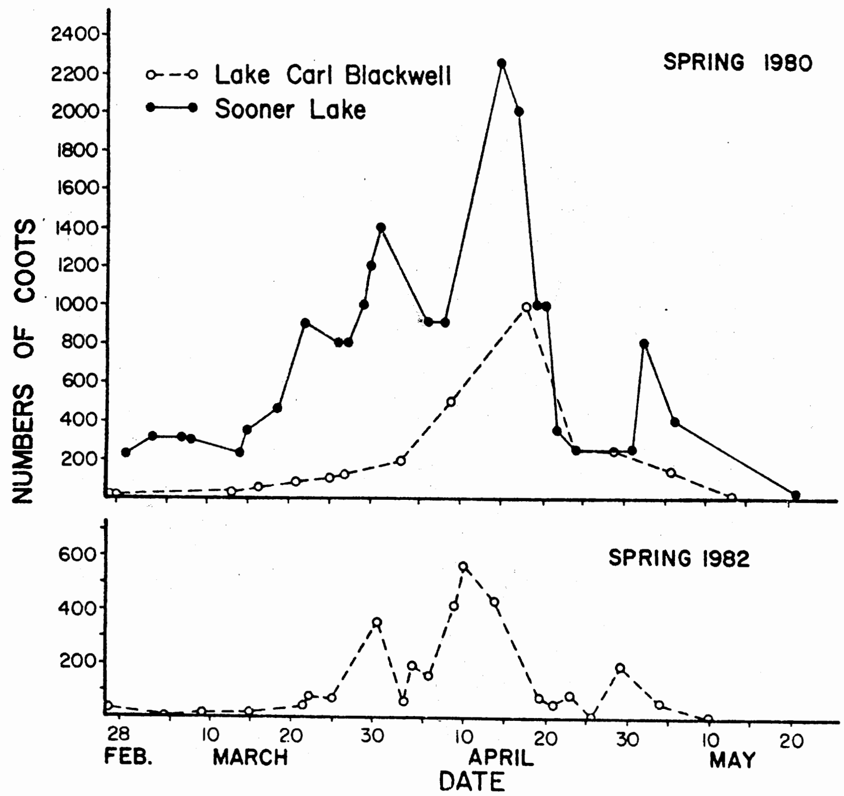

Figure 2. Migration chronology of American coots in spring 1980 and 1982 on Sooner Lake (solid line) and Lake Carl Blackwell (dashed line), Oklahoma.

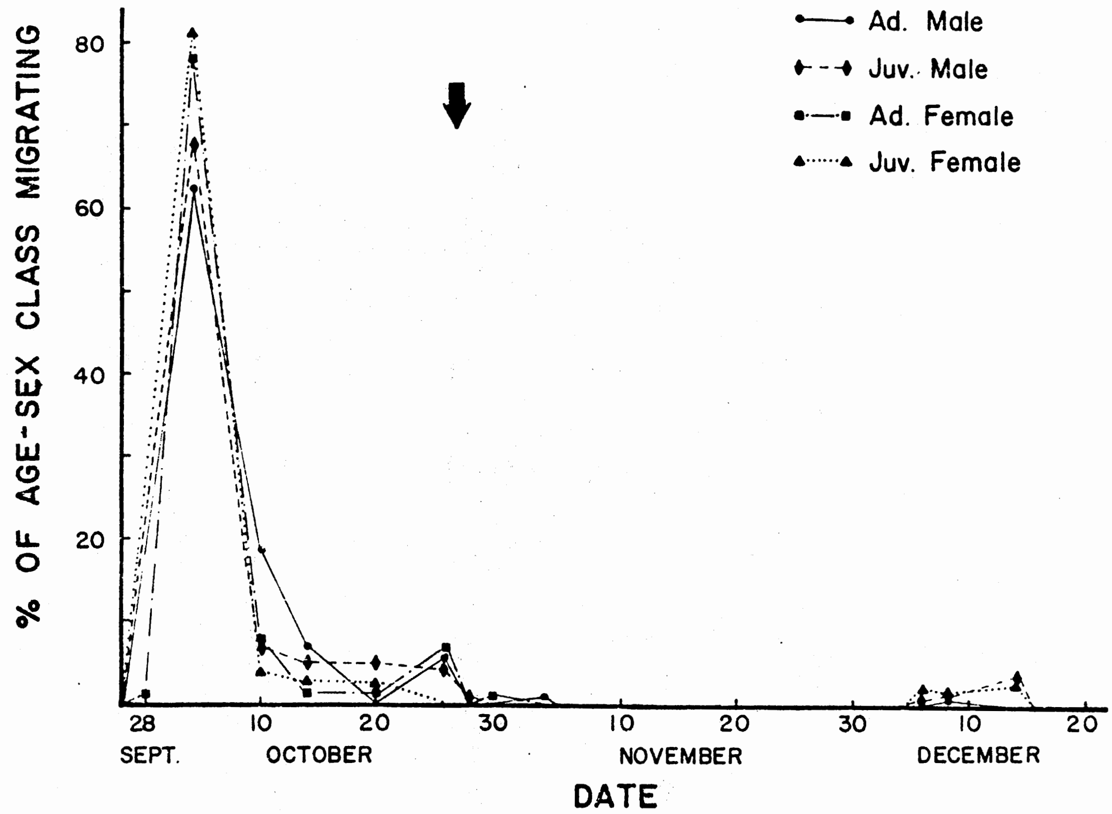

Figure 3. Chronology of migration of American coots in fall 1979 at Lake Carl Blackwell, Oklahoma, based on age and sex ratios of collected birds extrapolated to censuses. Arrow denotes that general waterfowl hunting season opened.

CHAPTER III

HABITAT USE PATTERNS OF AMERICAN COOTS DURING FALL MIGRATION IN OKLAHOMA

BY WILLIAM R. EDDLEMAN AND FRITZ L. KNOPF

Studies of habitats used by birds during migration have been restricted to general habitat descriptions (eg. Parnell 1969). Neither habitat parameters nor use of available habitat types have been quantified. Data are limited for wetland birds especially, although waterfowl may have specific feeding niches on wintering areas (White and James 1978). Because populations of some species are limited by events on migration stopover sites and wintering areas (Fretwell 1972, Morse 1980, Krapu 1981, Heitmeyer and Fredrickson 1981), and because food requirements (and therefore habitats) may change seasonally (Weller 1975), habitat requirements of nonbreeding birds may be even more specific, and more critical for survival, than requirements for breeding.

Habitat studies of postbreeding birds should include not only quantified habitat description, but should also evaluate habitat use in relation to behavioral and physiological needs (Fredrickson and Drobney 1979, Cherry 1982). The habitat requirements breeding American coots (*Fulica americana*) are well described (Weller and Fredrickson 1973, Fredrickson et al. 1977:125, Sugden 1979, Nudds 1982, Bett 1983), whereas habitats used by migrating coots are described only as wetlands with aquatic vegetation and suitable water depth (Jahn and Hunt 1964: 93, Fredrickson et al. 1977:135, Fredrickson and Taylor 1982). Large reservoirs are the primary habitats used by coots during autumnal migration in Oklahoma (M. E. Heitmeyer, unpubl. data), whereas coots migrating in spring often use ponds and small wetlands (Heitmeyer 1980:240). Quantitative data on habitats used by migrating coots are lacking, however. This study (1) describes habitats on large reservoirs in Oklahoma used by American coots during fall migration, (2) quantifies characteristics of these habitats, (3) compares characterisitics of habitats used by coots with characteristics of available habitats, and (4) relates habitat parameters to differences in behavior, migration status, and flocking patterns (coot-only or coot-waterfowl mixed flocks).

STUDY AREAS AND METHODS

Habitat use patterns of American coots were studied in fall 1979-81 on 3 lakes in Oklahoma--Lake Carl Blackwell (Payne-Noble counties), Sooner Lake (Noble-Pawnee counties), and Sequoyah National Wildlife Refuge (Haskell, Muskogee, and Sequoyah counties) on the upper portions of Robert S. Kerr Reservoir on the Arkansas River. General features of these areas have been described (Baumgartner 1942, Eddleman et al., in prep.).

Analysis of General Habitat Use--Habitat types used by coots were determined during censuses of coots and waterfowl in autumn 1979-81. Sites used by flocks of coots during fall migration were classified into 1 of 21 wetland types (Cowardin et al. 1979). For ease of analysis, these 21 types were grouped into vegetated, unvegetated, or covered with dead woody vegetation types; and as shallow water or deepwater types. For each flock of coots, we recorded the wetland type, number of coots and waterfowl, the principal activity of the coots, distance from shore using an optical rangefinder, estimated flock diameter, and estimated mean distance between individual coots. Migration status (arrival; 2, 3, 4, 5, 6, or 7+ days after arrival; and before departure--as determined by subsequent censuses) was determined by frequent observations of flocks on each lake. Because of high turnover rates in numbers of coots on the lakes (Eddleman et al., in prep.), we were able to determine migration status for >90% of flocks. Comparisons of habitat use among coots of different migration status, sites used for different activities (feeding, loafing, maintenance, swimming), and sites used by coot and coot-waterfowl (hereafter referred to as mixed) flocks were made with Chi-square tests for independence (Conover 1980:158). The continuous variables flock size, distance to shore, diameter of flocks, and mean estimated distance between individuals were compared among status groups, the 3 principal activities (feeding, loafing, swimming), and flock types using 1-way analysis of variance with Duncan's Multiple Range Test.

Analysis of Habitat Characteristics--A series of 10 physical and chemical variables were measured at sites used by coots for feeding and for other activities (locomotion, loafing, maintenance) were characterized by sampling a series of 10 physical and chemical variables in autumn 1980-81. Physical variables measured were percentage coverage by emergent vegetation and percentage coverage by floating and submerged vegetation using 10 sightings through a sighting tube (Winkworth and Goodall 1962), mean vegetation height using up to 10 measurements, water depth, and distance to shore using an optical rangefinder. Light penetration was determined with a Secchi disk. Chemical parameters were determined from 200 ml of surface water collected at each site. All chemical parameters were analyzed within 10 hours of collection. Short range (0.2 interval) and long range (1.0 interval) pH papers were used to quantify pH. Alkalinity was determined by titrating 100 ml of the water sample to the phenophthalein and methyl purple endpoints using 0.02 N H_2SO_4. Conductivity was determined on a conductivity bridge using the remaining 100 ml of water.

To sample characteristics of habitats available to coots, 25 random points were selected monthly. Intensive habitat sampling was conducted on Lake Carl Blackwell (September and October 1980, October 1981), Sooner Lake (October 1980), and Robert S. Kerr Reservoir (October 1980). Points were selected by overlaying a numbered grid over maps of each lake and generating coordinates using a random numbers table (White and James 1978). Each physical and chemical variable was measured at these points. Wilcoxon 2-sample tests (with normal approximation) and Kruskal-Wallis tests were used for univariate comparisons of habitat characteristics (Conover 1980:215,229).

Multivariate analysis of variance (MANOVA) was used to determine differences in multivariate space between available and used habitats, sites used by coot-only and mixed flocks, and sites used for feeding and other behaviors. The Hotelling-Lawley trace (F approximation) was used as a test statistic for the MANOVA. Discriminant function analysis with a stepwise, forward selection procedure was performed to determine which habitat variables contributed significantly to separation of habitats in the MANOVA comparisons. The variable with the greatest significance level ($\underline{P} < 0.05$) was entered into the analysis at each step, until no additional variables contributed significantly to discrimination between the classification variable (random or used, flock type, behavior). All analyses were performed using the Statistical Analysis System (SAS Institute, Inc. 1982).

RESULTS

General Habitat Use--Use of the 21 wetland types was not independent of activity ($\underline{X}^2 = 92.361$, d.f. = 60, $\underline{P} = 0.0048$). Habitats of different water depth and vegetative coverage were also used in different frequencies than expected for the 4 activities (Table 1). Feeding occurred in shallow areas and loafing and swimming occurred in deeper water. Vegetated habitats were used more than expected for feeding, while coots in unvegetated habitats mainly loafed or swam. Coots of different migration status also used habitats of different water depth and vegetative coverage (Table 1). For arrival through the 3rd day after arrival, migrants occurred at frequencies higher than expected in unvegetated, deepwater habitat. Flocks of coots present 6 or more days after arrival were found primarily in vegetated habitat in shallow water. Mixed flocks of coots and waterfowl occurred more than expected in vegetated sites with shallow water, while coots in single-species flocks tended to occur in deep, open water (Table 1).

Birds of different migration status exhibited differences in behavior (Table 2). At arrival, coots in migrant flocks loafed and rarely fed. If coots lingered 6 days or more, feeding was their principal activity. Coots in mixed flocks usually fed, while coots in single-species flocks loafed and swam more than expected. The statistical relationship between migration status and the occurrence of mixed flocks was not significant, but arriving migrants tended to occur in single-species flocks (Table 2).

Flock size was larger in unvegetated habitat, and unvegetated sites and flooded timber occurred farther from shore than habitats covered by herbaceous aquatic vegetation (Table 3). Flock size, flock diameter, and mean estimated distance between individuals did not differ between sites of different water depth, but shallow water habitats used by coots were closer to shore than deepwater sites (Table 3).

The activities swimming, loafing, and feeding occurred with sufficient frequency to be analyzed for differences in flock size, distance to shore, flock diameter, and mean estimated distance between individual birds (Table 4). Feeding activity occurred nearer to shore than loafing or actively swimming and individuals were closer together in feeding flocks. The only difference in these continuous variables between flocks of different migration status was a significantly larger flock size for coots at arrival through the 2nd day after arrival

(Table 4). No differences were noted in these variables between flock types ($\underline{P} > 0.50$).

Characteristics of Habitats--Before quantitative data on habitat was analyzed, we examined differences for each variable between random plots from different lakes, months, and for the 2 years (Table 5). Because Sooner Lake receives little natural inflow and water is pumped into the lake from the Arkansas River, chemical parameters were significantly higher than for the other lakes. Sooner Lake was also deeper and clearer than the other 2 lakes, as reflected in differences in light penetration and water depth. Robert S. Kerr Reservoir was the largest lake, resulting in greater mean distance to shore for random habitat plots. Differences in light penetration and pH between months were probably caused by a decline in rainfall through the falls of 1980 and 1981. Fewer suspended solids were introduced into the lakes and evaporation and decay of vegetation resulted in lowered pH (Heitmeyer 1980:159). Distance to shore was greater in 1980, reflecting heavy spring rains and, therefore, greater percentage basin coverage in Lake Carl Blackwell in autumn. Greater spring rainfall also resulted in dilution of ions in 1980. Changes in water levels and differences in geological substrates and evaporation rates may all affect chemical composition of wetlands (Hoyer and Reid 1982).

Random sites differed from habitat sites for every variable measured except percentage coverage by emergent vegetation, mean height of vegetation, light penetration and total alkalinity (Table 6). Feeding habitats were characterized by greater vegetative coverage, shallower water, shorter distance to shore, lower pH, higher phenophthalein alkalinity, and higher conductivity than sites used for other behaviors (Table 7). No significant difference occurred between habitat characteristics of sites used by coot-only and mixed flocks (Table 8).

The MANOVA indicated differences between random sites and habitat sites, habitats used by coots and mixed flocks, and habitats used for feeding and those used for other behaviors (Table 9). Variables contributing significantly to the discrimination of random sites and habitat sites were pH, coverage by emergent vegetation, coverage by floating and submerged vegetation, distance to shore, and light penetration. Water depth, coverage by floating and submerged vegetation, pH, coverage by emergent vegetation, and mean height of vegetation were significant contributers to discrimination between feeding habitat and habitats used for other activities. Habitat plots for coot-only and mixed flocks were poorly classified, with pH the only variable contributing significantly to the discrimination (Table 9).

DISCUSSION

Deepwater, unvegetated aquatic sites were most frequently used by coots upon initial arrival during fall migration. These birds loafed or swam in large flocks in the middle of the lakes. Because coots do not migrate during the day (Fredrickson et al. 1977:125), these behaviors would minimize expenditure of stored energy needed for additional migration. Most coots migrated onward within 2-3 days (Eddleman et al., in prep). Coots that lingered more than 3 days fed in shallow, vegetated aquatic habitats sympatrically with several species of waterfowl. Birds collected at deepwater, unvegetated sites had significantly higher lipid reserves than those collected near shore (Eddleman, unpubl. data). Migrating birds lacking adequate lipid reserves may replenish these reserves on migration stopovers (Fredrickson and Drobney 1979, Cherry 1982). Coots feeding in vegetated habitat were probably replenishing lipid reserves in order to continue migration. A few were probably preparing to winter on Sooner Lake, but <150 individuals wintered on that lake in each year.

Habitats used by migrating American coots in autumn did not differ from randomly-chosen sites in coverage by emergent vegetation, mean height of vegetation, light penetration, and total alkalinity. Coverage by emergents was low on the lake relative to preferred nesting habitat for coots (50% coverage by emergents) (Weller and Fredrickson 1973). Coots did not use emergent vegetation for cover during fall migration, and moved to open water if threatened. Habitats used by migrating coots may therefore differ markedly from wetlands used for breeding. Light penetration and total alkalinity were relatively constant within lakes, so these variables were apparently not used by coots selecting habitat.

Habitats and feeding sites used by coots had high coverage of floating and submerged vegetation. Shallow water and proximity to shore probably were selected by coots lingering between waves of migration because of the increased aquatic vegetation in such habitat. Lower pH at used sites was probably caused by increased acidity due to decomposition of vegetation (Heitmeyer 1980:158-159). Greater phenophthalein alkalinity in used habitat was probably a result of higher photosynthetic activity. The mean water depth at feeding sites was greater in our study than on moist soil habitat in Missouri (Fredrickson and Taylor 1982), but was similar to water depths used by feeding coots in a Texas wintering area (White and James 1978). Depth of water used by coots may therefore vary with food types, turbidity, or depth at which aquatic foods occur.

Coots used habitats for feeding during autumnal migration similar to those selected for feeding on wintering areas (White and James 1978). In winter, coots selected sites at with abundant submergent vegetation, sparse emergents, and relatively deep water. Coots and waterfowl apportion wintering habitat on the basis of water depth and coverage by emergent vegetation (White and James 1978). Habitats used for activities other than feeding were not examined on wintering areas, so differences in loafing and feeding habitats may also occur in winter.

In comparison to other aquatic birds, American coots are generalists when selecting aquatic habitats (White and James 1978, Nudds 1982). Coots are night migrants and apparently land on the nearest water at daybreak (Fredrickson et al. 1977:125). Coots did not use small wetland habitats during autumn in Oklahoma, however (M. E. Heitmeyer, Gaylord Laboratory, Puxico, MO 63960, pers. comm.). Because a sufficient number of large reservoirs are available in Oklahoma (Heitmeyer 1980), migrants may respond to the largest nearby lake at daybreak.

Multivariate analysis merely reflected the results of univariate tests on individual habitat variables. Coverage by aquatic vegetation was the principal factor separating habitats and random sites and habitats used for feeding versus other behaviors. Sites used by coot-only flocks and mixed flocks differed little.

Habitats used by migrating coots in fall included both open water and vegetated shallow water for loafing and feeding, respectively. Open water is available on most large reservoirs created for flood control and other purposes (Heitmeyer 1980:27). Shallow, vegetated wetland areas required by some coots for feeding during migration are relatively scarce, and are limited mainly to shorelines of large reservoirs or small, scattered wetlands. Migration stopover areas may serve as extensions of wintering areas (Fredrickson and Drobney 1979). If food supplies are abundant on stopover areas, birds arrive at wintering areas in better physiological condition. Management and preservation of such aquatic habitats appear necessary for at least some coots and other waterbirds to complete migration.

Previous studies of breeding habitats of birds (eg. James 1971, Anderson and Shugart 1974, Whitmore 1977, Stauffer and Best 1980) have considered only song perches and/or nest sites in habitat analysis. Our study illustrates the potential errors of basing habitat studies on sites used for only 1 behavior and of not considering possible differences in habitats used for different behaviors. The potential effects of behavior on habitat use should be considered in analysis of the realized niche of avian species.

SUMMARY

General habitat use, behavior, and characteristics of habitats of fall migrating American coots were investigated on 3 large reservoirs in Oklahoma in fall 1979-1981. Coots exhibited differences in behavior and habitat use relative to migration status. At arrival,

birds loafed in the center of the lakes. Individuals lingering on the lakes 6 days or longer used sites nearer to shore and mainly fed, often in mixed-species flocks with waterfowl. Areas used by coots on the lakes differed from random plots in being closer to shore, in shallower water, having more coverage by aquatic plants, lower pH, and higher phenophthalein alkalinity and conductivity. Habitats used for different activities during fall migration differed markedly. Feeding habitat of coots differed from habitat used for other activities in having greater coverage by submergent vegetation, being closer to shore and having lower pH, higher phenophthalein alkalinity, and higher conductivity. Fall migrating coots switched to a foraging/habitat use pattern similar to that used by birds in winter.

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Table 1. Tests for independence between habitat types used by American coots and coot flocks exhibiting different activities, different flock types, and flocks of different migration status in fall 1979-1981.

Behavioral/	Vegetation class			Water depth		
social variable	X^2	d.f.	*P*	X^2	d.f.	*P*
Activity	282.499	6	0.0001	273.210	3	0.0001
Flock Type	12.676	2	0.0034	6.494	1	0.0189
Migration Status	86.088	14	0.0001	55.879	7	0.0001

Table 2. Tests for independence between coot flocks of different migration status, flock types, and flocks exhibiting different behavioral activities.

Behavioral/ social variable	Migration status		
	X^2	d.f.	*P*
Activity	114.718	14	0.0001
Flock Type	14.859	7	0.0619

Table 3. Comparison of continuous social and habitat variables between coot flocks in habitat types with differing amounts of vegetation and with differing water depths.

Variable	Vegetation class: Flooded timber	Vegetated	Unvegetated	Water depth: Shallow	Deep
Flock size	39.9[a]	56.0[a]	127.6[b]	N. S.	
Distance to shore (m)	133.4[a]	23.5[b]	132.2[a]	23.36[a]	153.4[b]
Flock diameter (m)		N. S.		N. S.	
Mean estimated individual distance (cm.)		N. S.		N. S.	

[a,b] Means having the same letter are not significantly different at 0.05 level of significance

Table 4. Comparison of continuous social and habitat variables for coots exhibiting different activities and of differing migration status (total number of flocks = 396).

	Activity			Migration Status							
Variable	Feeding	Swimming	Loafing	Arrival	2	3	4	5	6	7	Departure
Flock size	62.9^{a}	$110.1^{a,b}$	148.0^{b}	198.7^{a}	255.6^{a}	90.6^{b}	56.5^{b}	11.2^{b}	37.0^{b}	50.1^{b}	45.2^{b}
Distance to shore (m)	22.6^{a}	98.8^{b}	109.4^{b}				N. S.				
Flock diameter (m)	60.2^{a}	60.5^{a}	62.8^{a}				N. S.				
Mean individual distance (cm.)	36.5^{a}	92.3^{b}	96.8^{b}				N. S.				

a,b Means having the same letter are not significantly different at 0.05 level of significance

Table 5. Comparisons of habitat variables between lakes (Lake Carl Blackwell, _n_ = 75; Sooner Lake, _n_ = 25; and Robert S. Kerr Reservoir, _n_ = 25), months (September, _n_ = 25; October, _n_ =100), and years (1980, _n_ = 100; 1981, _n_ = 25) for randomly chosen habitat plots.

	Lakes[a]		Months[b]		Years[b]	
Variable	Test statistic	_P_	Test statistic	_P_	Test statistic	_P_
Emergent vegetation coverage (%)	2.42	0.2981	1,584.5	0.9558	1,548.5	0.872
Mean vegetation height (cm)	3.66	0.1602	1,523.0	0.7511	1,650.0	0.646
Floating and submergent vegetation coverage (%)	0.06	0.9686	1,737.5	0.3193	1,550.0	0.880
Water depth (cm)	9.17	0.0102	1,467.5	0.5102	1,392.5	0.263
Distance to shore (m)	6.76	0.0340	1,408.5	0.3076	1,194.0	0.020
Light penetration (cm)	37.93	0.0001	1,101.0	0.0041	1,341.5	0.152

Table 5. Continued.

	Lakes[a]		Months[b]		Years[b]	
Variable	Test statistic	P	Test statistic	P	Test statistic	P
pH	18.55	0.0001	912.5	0.0001	2,825.0	0.000
Phenophthalein alkalinity (ppm)	2.87	0.2386	1,018.5	0.0008	2,596.0	0.000
Total Alkalinity (ppm)	92.80	0.0001	1,461.0	0.4849	2,138.0	0.000
Conductivity (µmhos)	95.24	0.0001	941.0	0.0002	1,575.0	0.997

[a] Kruskall-Wallis test

[b] Wilcoxon 2-sample test

Table 6. Comparisons of habitat variables at random plots and habitat sites used by migrating American coots in autumn.

Variable	Type[a]	Mean ± S.D.	Test statistic[b]	$\underline{P}$
Emergent vegetation coverage (%)	R	5.14 ± 12.97	15,263.0	0.2121
	U	7.89 ± 14.64		
Mean vegetation height (cm)	R	16.63 ± 66.35	15,529.0	0.4250
	U	35.87 ±114.00		
Floating and submergent vegetation coverage (%)	R	1.41 ± 9.51	13,439.5	0.0001
	U	15.93 ± 26.61		
Water depth (cm)	R	403.58 ±318.86	18,623.0	0.0001
	U	263.02 ±313.89		
Distance to shore (m)	R	204.12 ±216.90	20,223.0	0.0001
	U	67.92 ±117.76		
Light penetration (cm)	R	45.74 ± 25.25	16,484.0	0.4123
	U	44.30 ± 32.01		
pH	R	7.71 ± 1.16	11,441.0	0.0001
	U	7.36 ± 1.15		
Phenophthalein alkalinity (ppm)	R	2.26 ± 2.84	14,212.5	0.0027
	U	3.78 ± 4.10		
Total alkalinity (ppm)	R	127.65 ± 15.95	14,422.5	0.0790
	U	136.54 ± 59.85		
Conductivity (μmhos)	R	581.07 ±346.40	13,803.0	0.0002
	U	803.10 ±472.98		

[a] R = random ($\underline{n}$ = 125); U = used ($\underline{n}$ = 130)

[b] Wilcoxon 2-sample test

Table 7. Comparisons of habitat variables at feeding sites of coots and sites used for other activities.

Variable	Type[a]	Mean ± S.D.	Test statistic[b]	P
Emergent vegetation	F	9.56 ± 15.33	3,297.0	0.0989
coverage (%)	L	6.98 ± 14.25		
Mean vegetation height (cm.)	F	61.37 ±167.43	3,335.0	0.0450
	L	21.90 ± 66.65		
Floating and submergent	F	27.96± 29.88	3,789.0	<0.0001
vegetation coverage (%)	L	9.34 ± 22.19		
Water depth (cm.)	F	81.28 ±133.36	2,086.5	<0.0001
	L	362.54 ±339.35		
Distance to shore (m.)	F	11.78 ± 34.68	2,063.5	<0.0001
	L	98.67 ±134.90		
Light penetration (cm.)	F	39.72 ± 32.22	2,722.0	0.1569
	L	46.81 ± 31.81		
pH	F	7.45 ± 1.33	2,299.0	0.0002
	L	8.09 ± 0.97		
Phenophthalein	F	5.41 ± 5.44	3,555.0	0.0066
alkalinity (ppm.)	L	2.88 ± 2.79		
Total alkalinity (ppm.)	F	126.98 ± 26.79	2,725.5	0.1620
	L	141.77 ± 71.41		
Conductivity (μmhos.)	F	923.70 ±501.63	3,635.0	0.0024
	L	737.06 ±445.85		

[a] F = feeding sites (*n* = 46); L = sites used for other activites (*n* = 84)

[b] Wilcoxon 2-sample test

Table 8. Comparisons of habitat variables at sites used by coot-only flocks and sites used by coot-waterfowl mixed flocks.

Variable	Type[a]	Mean ± S.D.	Test statistic[b]	P
Emergent vegetation coverage (%)	C	7.35 ± 14.41	2,307.0	0.3537
	M	9.48 ± 15.40		
Mean vegetation height (cm)	C	40.16 ±126.52	2,216.5	0.7089
	M	23.24 ± 64.40		
Floating and submergent vegetation coverage (%)	C	12.95 ± 23.15	2,355.0	0.2298
	M	24.70 ± 33.77		
Water depth (cm)	C	270.49 ±320.65	2,067.5	0.6168
	M	241.03 ±296.76		
Distance to shore (m)	C	70.84 ±123.50	2,191.5	0.8741
	M	59.36 ±100.23		
Light penetration (cm)	C	46.22 ± 33.36	1,950.0	0.2586
	M	38.67 ± 27.36		
pH	C	7.50 ± 1.06	1,821.0	0.0521
	M	6.97 ± 1.30		
Phenophthalein alkalinity (ppm)	C	3.78 ± 4.23	2,193.5	0.8621
	M	3.76 ± 3.76		
Total alkalinity (ppm)	C	138.80 ± 67.84	2,156.0	0.9786
	M	129.88 ± 23.86		
Conductivity (μmhos)	C	805.93 ±474.14	2,132.5	0.8786
	M	794.79 ±476.76		

[a] C = coot-only flocks (n = 97); M = mixed flocks (n = 33)

[b] Wilcoxon 2-sample test

Table 9. Summary of multivariate analyses for differences between habitat variables.

Grouping Variables	MANOVA: Hotelling-Lawley Trace	MANOVA: Normal Approximation to F[a]	Stepwise Discriminant Analysis: Variables Selected	Stepwise Discriminant Analysis: Number of Sites Correctly Classified (%)
Random/habitat sites	2.433	52.80	pH, coverage by floating and submergent vegetation, coverage by emergent vegetation, distance to shore, light penetration	173/255 (67.8)
Coot-only/mixed flocks	0.092	2.01	pH	58/130 (44.6)
Feeding sites/ sites used for other activities	0.359	7.79	Water depth, coverage by floating and submergent vegetation, pH, coverage by emergent vegetation, mean vegetation height	94/130 (72.3)

[a] Degrees of freedom for all 3 analyses = 10, 217

CHAPTER IV

INTERACTIONS BETWEEN AMERICAN COOTS AND WATERFOWL DURING FALL MIGRATION

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Abstract: Temporal, spatial, and behavioral relationships between migrating American coots (*Fulica americana*) and waterfowl were investigated in fall 1979-81 in Oklahoma. Migration chronology of coots

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differed from chronology of waterfowl for all species, mainly because waterfowl migrated ahead of cold fronts and diurnally, while coots migrated behind cold fronts and nocturnally. Significant positive correlations occurred between numbers of coots and numbers of northern shovelers (*Anas clypeata*), gadwalls (*A. stepera*), American wigeons (*A. americana*), and redheads (*Aytha americana*) on at least some lakes in most years. Waterfowl occurred in mixed flocks with low frequency, but gadwalls and American wigeons were most frequently recorded with coots. Most ducks did not interact with coots in mixed flocks. Cooperative feeding and kleptoparasitism were the most frequently recorded behavioral interactions, especially between coots and gadwall or American wigeon. Interspecific interactions between coots and waterfowl are minimal because of temporal and spatial separation during migration, and behavioral interactions that are mostly neutral or beneficial to ducks.

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Key words: American coot, *Fulica americana*, Oklahoma, migration, interspecific interactions, waterfowl behavior, waterfowl ecology

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Interactions between American coots and waterfowl during the breeding season are well-documented (Ryder 1959, Nudds 1981). Aggressive interactions usually occur when ducks approach nests or broods of coots. Such interactions are most frequent when coots are rearing broods (Ryan and Dinsmore 1979). Coots and ducks compete for nesting, feeding, brooding, and loafing sites in breeding marshes (Munro 1939, Sooter 1945, Ryder 1959). Coots also have been implicated in the destruction of eggs and young of other marsh-nesting birds (Munro 1937, Burger 1973, McNicholl 1975). In Utah, production of duck broods was nearly identical between an area with nesting coots removed and a control area (Ryder 1958, 1961).

Coots, ducks, and swans often feed cooperatively, with coots eating feeds churned up by the waterfowl and vice versa (Ryder 1959, Anderson 1974, Ryan 1981). Waterfowl, particularly American wigeon (Anas americana) and gadwall (A. strepera) kleptoparasitize feeding coots (Knapton and Knudsen 1978, Ryan 1981). Other benefits provided to ducks by coots include creation of potential nest sites, repulsion of predators, and provision of a buffer for predation pressure on ducks (Sooter 1945, Ryder 1958, 1959). The overall relationship between densities of coots and ducks and between brood counts of coots and ducks for a 26-year period in Saskatchewan indicated no significant relationship between coots and waterfowl (Nudds 1981).

Coots and waterfowl from large areas of breeding habitat concentrate on smaller areas during the nonbreeding season (Weller 1975:102). The potential for interspecific interactions between coots and waterfowl may be greatest during this season, when food resources may be limited (Fretwell 1972, Heitmeyer and Fredrickson 1981). This study documented associations between waterfowl and coots during fall migration and examined behavioral interactions between coots and waterfowl in mixed flocks.

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STUDY AREAS

Field work was conducted on lakes in north-central and eastern Oklahoma. Lake Carl Blackwell, Sooner Lake, Perry Lake, and Lake McMurtry (Payne and Nobles counties, Oklahoma) have been described (Baumgartner 1942, Eddleman et al. in prep.). Activities of mixed flocks of coots and ducks were also observed at Sequoyah National Wildlife Refuge (NWR) (Haskell, Muskogee, and Sequoyah counties, Oklahoma) on the upper portion of Robert S. Kerr Reservoir on the Arkansas River. Most of the refuge lies within the bottomland hardwood vegetation type (Duck and Fletcher 1943). Cultivation of wheat and soybeans for migratory waterfowl is the major land-use. Most observations of mixed flocks were made on the upper end of the reservoir and at the mouth of the Canadian River. Cattail (Typha latifolia) marshes, beds of Eurasian watermilfoil (Myriophyllum brasiliense), open water, beds of water primrose (Ludwigia repens), flooded dead timber, and intermittent mud flats are the principal habitats used by coots and ducks.

METHODS

Measurement of temporal overlap of migration among the species was necessary to determine the potential for behavioral interactions. Aerial and ground counts of coots and waterfowl during fall migration were used to determine migration choronology on all lakes but Robert S. Kerr Reservoir. Aerial counts were taken every 5 days in September-December 1979 and 1980. These were supplemented with ground counts on Lake Carl Blackwell and Sooner Lake every 1-5 days in September-December 1979-81. Temporal overlap was then determined by comparison of the chronology of coot migration with the chronology of migration for each waterfowl species encountered. Two-sided, 2-sample Smirnov tests were used to compare the cumulative frequency distributions for numbers of coots and individual waterfowl species (Conover 1980:384). This test uses the maximum difference between 2 cumulative frequency distributions, thus eliminating differences in relative numbers of any 2 species. Because coots differed in migration chronology among lakes in the same year and among years on the same lake, chronology data for each lake and year were analyzed separately (Eddleman et al. in prep.). To determine correlations between numbers of coots and numbers of waterfowl species, we calculated Spearman rank correlation coefficients (Conover 1980:251) which minimized problems of non-normal distribution of count data. Dates of counts were used as sample points and correlation analyses were conducted for all lakes and for Lake Carl Blackwell and Sooner Lake yearly.

If species overlap temporally, then spatial overlap must also occur before the species can interact. Spatial overlap was determined by observation of flocks of coots and waterfowl. During ground counts and some aerial counts (1980), species composition of all waterbird flocks was recorded. Flocks were used as sample points to calculate coefficients of interspecific overlap (Ochiai 1957). Ochiai's coefficient (ro = $\frac{A}{(A + B)(A + C)}$, where A is the number of flocks containing both species, B is the number of flocks containing species 1 but not species 2, and C is the number of flocks containing species 2 but not species 1) was chosen because it satisfies the 6 necessary criteria for such indices (Janson and Vangelius 1981). The coefficient was calculated for each coot-waterfowl species pair for all waterfowl species observed. Ochiai's coefficient ranges from 0 (no overlap in use of space) to 1 (total overlap in use of space). To determine if spatial overlap changed through fall migration, we calculated Ochiai's coefficient for September through December, combining data for all years.

Given spatial and temporal overlap, behavioral associations must occur for 2 species to interact. During ground counts, we observed mixed flocks of coots and waterfowl for at least 5 min to determine the principal behavioral interactions between coots and each waterfowl species in the flock. For species with sufficient numbers of observations, we used chi-square tests for goodness of fit to determine whether behaviors were equally likely to occur in mixed flocks. All statistical analyses were performed using the Statistical Analysis System (SAS Institute, Inc. 1982).

RESULTS

Migration chronology of all waterfowl species differed from migration chronology of coots on both Sooner Lake and Lake Carl Blackwell during 1979-81 (Table 1). Twenty-one species of ducks and geese were present on the lakes, but the single white-winged scoter (Melanitta fusca) was excluded from the analysis. Rank correlations between numbers of coots and numbers of waterfowl indicated several patterns of waterfowl migration relative to coot migration (Table 2). Numbers of geese, wood ducks (Aix sponsa), ring-necked ducks (Aythya collaris), common goldeneyes (Bucephala clangula), and buffleheads (B. albeola) never showed significant correlation with numbers of coots. All of these species except ring-necked ducks occurred in small numbers relative to other waterfowl. Numbers of mallards (Anas platyrhynchos), hooded mergansers (Lophodytes cucullatus), and common mergansers (Mergus merganser) were significantly negatively correlated with number of coots for at least 1 lake or 1 year. Significant positive correlations with numbers of coots were shown for northern shovelers, gadwalls, American wigeons, and redheads. Finally, some significant correlations, both positive and negative, with coot numbers were found with green-winged teal (Anas crecca carolinensis), northern pintails (A. acuta), blue-winged teal (A. discors), canvasbacks (Aythya valisneria), and lesser scaup (A. affinis).

A total of 1,099 coot, waterfowl, and mixed flocks were observed during fall 1979-81 with 14 species of ducks recorded in mixed flocks (Table 3). Gadwall and Americn wigeon were most frequently recorded in mixed flocks, followed by mallard, redhead, and ring-necked duck.

Coefficients of interspecific overlap were low for all waterfowl species, but were highest for American wigeon and gadwall (Table 3). Sufficient data were available to monitor the increase in the coefficient of spatial overlap during September through December (Table 4). Ring-necked ducks and American wigeons showed increases in the coefficient through November, but a decline in December (Table 4). Mallards and gadwall increased their relative occurrence in mixed flocks through December.

Nearly 75% of all waterfowl in 184 mixed flocks showed no interactions with coots (Table 5). Different behaviors were not equally likely to occur for all species combined and for American wigeon and gadwall. Cooperative feeding (ducks feeding on matter churned up by coots and vice versa) occurred between coots and mallards, gadwalls, American wigeons, redheads, and ring-necked ducks. Wigeons and gadwalls were the only species observed kleptoparasitizing coots. We found no evidence that coots kleptoparasitize ducks, although this behavior has been observed with coots and ring-necked ducks on wintering areas (L. D. Vangilder, personal communication, Savannah River Ecology Lab, P. O. Drawer E, Aiken, SC 29801). Aggressive interactions occurred in < 5% of all flocks.

DISCUSSION

Temporal Overlap

Densities of breeding coots showed no significant correlation with densities of breeding dabbling or diving ducks in Saskatchewan parklands (Nudds 1981). Densities of diving ducks were negatively correlated with densities of coots, but none of the relationships were significant.

Migration chronology of most coots and waterfowl in our study differed on both a macro and micro level. Negative correlations among the migration chronology of coots and other species was related to early migration of wood ducks and blue-winged teal, or late migration of mallards and mergansers. For those species with positive correlations with numbers of coots, such as gadwalls, American wigeons and northern shovelers, differences between migration chronology of coots and individual waterfowl species were explained by differences in responses of migrant coots and waterfowl to the passage of cold fronts. Waterfowl characteristically arrive ahead of or just behind fronts and frequently migrate during the day (Richardson 1978). Coots, however, follow cold fronts and are night migrants (Ryder 1963). Therefore, peak numbers of coots often followed peak numbers of waterfowl by 1 day. Potential temporal overlap of coots and waterfowl was thus minimized.

Changes in the magnitude and significance levels of Spearman correlation coefficients between lakes and years (Table 2) for individual waterfowl species indicated flexibility in migration chronology by both coots and waterfowl, especially for species of relatively high abundance. Responses of birds to differences in weather, food resources, habitat, or hunting pressure may affect numbers of birds migrating through or wintering in a given area (Heitmeyer 1980:213-217).

Spatial Overlap

Coefficients of interspecific overlap for all coot-waterfowl pairs were small, but increased as the season progressed. Overlap in the use of resources (including space) by most competing species is reduced during the lean season, when the potential for competition is greatest

(Schoener 1982). Presumably, 2 or more species can use a resource when the resource is abundant, but in times of resource shortages species partition resources. Exceptions occur when a profitable resource is more abundant in the lean season or if all resources of a given type decrease by the same proportion (Schoener 1982). Competing species would then use a wider range of resources and overlap more in their use of these resources.

The increase in spatial overlap of coots and ducks through fall probably indicates a proportional decrease of all aquatic food plants. As foods are depleted in shallow water, dabbling ducks cannot feed on plants available in deeper water (Knapton and Knudsen 1978). Activities of coots make these foods available by kleptoparasitic actions of ducks and by churning of foods to the surface by feeding coots. As a result, ducks associated more with coots and the incidence of mixed flocks (and spatial overlap) increased.

Behavioral Interactions

Interspecific behavioral interactions between breeding coots and ducks peak after hatching of coot broods (Ryder 1959, Ryan and Dinsmore 1979). At that time coots tenaciously defend broods against any species entering the territory. In contrast, we noted little aggression between coots and ducks during fall migration (Table 5); therefore agonism by coots is probably a phenomenon of breeding territoriality and brood defense.

Cooperative feeding and kleptoparasitism allowed dabbling ducks to obtain food in deeper water that was unavailable to them (Knapton and Knudsen 1978, Ryan 1981). Cooperative feeding may also work to benefit coots, which have attended feeding swans (Ryder 1959) and canvasbacks (Anderson 1974). Coots fed on matter churned up by ducks in only 1 instance in Oklahoma. Kleptoparasitism was associated with American wigeon and gadwall, which cannot dive in deep water and consume similar food items (Knapton and Knudsen 1978, Paulus 1982). Because coots and ducks did not interact in mixed flocks in most cases (Table 5), behavioral interactions primarily were of little importance for most coots and waterfowl.

Interactions between coots and waterfowl on nesting areas usually benefit waterfowl or have little effect on waterfowl densities (Ryder 1959, Knapton and Knudsen 1978, Nudds 1981). Similar conclusions are apparent on migration areas, because kleptoparasitic activities of ducks and the churning up of food materials by coots provide foods otherwise unavailable to some dabbling ducks (Knapton and Knudsen 1978). Because many avian species may be limited by events on wintering grounds (Heitmeyer and Fredrickson 1981, Anderson and Batt 1983), future investigations of coots and their associations with waterfowl should concentrate on wintering areas.

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Table 1. Test statistics and sample sizes for comparison of migration chronology of waterfowl species with migration chronology of American coots, fall 1979-81.

	Lake and year				
	1979		1980		1981
Species	Carl Blackwell (3,452 coots)	Sooner (8,548 coots)	Carl Blackwell (3,347 coots)	Sooner (19,085 coots)	Carl Blackwell (3,547 coots)
Greater white fronted goose (*Anser albifrons*)	0.8572(10)[a,b]	-	-	-	0.5870(48)
Snow goose (*Chen caerulescens*)	-	-	-	0.8507(20)	-
Canada goose (*Branta canadensis*)	0.7097(42)	0.9056(323)	-	0.7532(140)	-
Wood duck (*Aix sponsa*)	-	0.9304[c](3)	0.8040(29)	0.9312[d](3)	-
Green-winged teal (*Anas crecca carolinensis*)	0.8943(199)	0.6940[c](4)	0.7287(263)	0.5016(112)	-
Mallard (*Anas platyrhynchos*)	0.9083(601)	0.8516(64,126)	0.7393(1,055)	0.7390(9,024)	0.6279(166)

Table 1. Continued.

	Lake and year				
	1979		1980		1981
Species	Carl Blackwell (3,452 coots)	Sooner (8,548 coots)	Carl Blackwell (3,347 coots)	Sooner (19,085 coots)	Carl Blackwell (3,547 coots)
Northern pintail (*Anas acuta*)	0.8572(7)	-	0.7255(200)	0.3764(157)	0.4314(155)
Blue-winged teal (*Anas discors*)	0.9623(3)	-	0.9659(200)	0.3529(36)	0.7186(54)
Northern shoveler (*Anas clypeata*)	0.9670(10)	-	0.8575(6)	0.6584(28)	0.3048(77)
Gadwall	0.8572(248)	0.2918(302)	0.6153(836)	0.3819(3,994)	0.4332(3,386)
American wigeon	0.8549(432)	0.3181(820)	0.2431(481)	0.2666(2,693)	0.1221(1,091)
Canvasback (*Aythya valisneria*)	0.9626(28)	0.5758(58)	0.8575(58)	0.6467(227)	0.6952(20)
Redhead (*Aythya americana*)	0.8943(118)	0.3850(461)	0.7996(1,466)	0.5917(5,609)	0.6801(4,145)
Ring-necked duck (*Aythya collaris*)	0.7097(36)	-	0.8575(84)	0.4991(735)	0.7197(461)

Table 1. Continued.

Species	1979 Carl Blackwell (3,452 coots)	1979 Sooner (8,548 coots)	1980 Carl Blackwell (3,347 coots)	1980 Sooner (19,085 coots)	1981 Carl Blackwell (3,547 coots)
Lesser scaup (*Aythya affinis*)	0.9384(596)	0.4709(1,362)	0.7881(3,486)	0.7028(2,097)	0.6274(737)
Commmon goldeneye (*Bucephala clangula*)	0.9791(7)	0.8878(47)	0.9020(53)	0.7532(81)	-
Bufflehead (*Bucephala albeola*)	0.9623(40)	0.6940(25)	0.9020(50)	0.7633(89)	-
Hooded merganser (*Lophodytes cucullatus*)	-	-	0.9570(8)	0.8387(133)	0.9501(4)
Common merganser (*Mergus merganser*)	0.9820(125)	0.8765(241)	0.9570(29)	0.7532(203)	-

Table 1. Continued.

	Lake and year				
	1979		1980		1981
Species	Carl Blackwell (3,452 coots)	Sooner (8,548 coots)	Carl Blackwell (3,347 coots)	Sooner (19,085 coots)	Carl Blackwell (3,547 coots)
Ruddy duck (*Oxyura jamaicensis*)	0.3554(56)	0.5291(3)	0.7287(73)	0.6148(97)	0.5105(104)

[a]Two-sided, 2-sample Smirnov test; $P < 0.01$ unless indicated otherwise.

[b]Numbers in parentheses are numbers of the waterfowl species counted on the lake in the indicated year.

[c]$0.01 < P$ 0.02

[d]$0.02 < P$ 0.05

Table 2. Spearman correlation coefficients between numbers of coots and numbers of waterfowl during fall migration in north-central Oklahoma, 1979-81.

	Lake and year						
	1979		1980			1981	
Species	Carl Blackwell	All	Carl Blackwell	Sooner	All	Carl Blackwell	All
Greater White-fronted goose	-	0.0266	-	-	-	-0.0049	0.0961
Snow goose	-	0.1274	-	-0.2600	-0.1403	-	-
Canada goose	0.2672	0.2198	-	-0.1837	-0.0215	-	-
Wood duck	-	-0.0444	0.1427	-0.1793	0.0038	-	-
Green-winged teal	-0.2278	0.1377	-0.1805	0.2093	0.3290[a]	-0.2562	0.1122
Mallard	-0.6924[c]	0.3641[a]	-0.5158[b]	-0.6054[c]	-0.2074	0.0783	0.0622
Northern pintail	-0.1434	0.2279	-0.4239[a]	0.2844	0.1165	0.2104	0.4006[a]
Blue-winged teal	-0.2690	0.1808	0.0619	0.3659[a]	0.1093	0.0307	0.3036
Northern shoveler	0.0108	0.1500	-0.2690	0.1819	0.2477	0.4181[a]	0.5102[b]
Gadwall	-0.0421	0.4256[a]	0.0375	0.2148	0.4338[b]	0.6246[c]	0.6323[c]
American wigeon	0.0629	0.2794	0.1607	0.2823	0.4563[b]	0.5186[b]	0.5779[c]

Table 2. Continued.

	Lake and year						
	1979		1980			1981	
Species	Carl Blackwell	All	Carl Blackwell	Sooner	All	Carl Blackwell	All
Canvasback	-0.1883	0.3672[a]	-0.3428	-0.1278	0.0536	0.2665	0.3590[a]
Redhead	0.0278	0.4097[a]	0.0025	0.2411	0.2992	0.3770[a]	0.2614
Ring-necked duck	-0.0488	0.1772	-0.3556	0.0936	0.2087	0.1610	0.2723
Lesser scaup	-0.0004	0.4005[a]	-0.2386	-0.1963	-0.1592	0.3501	0.2894
Common goldeneye	0.1829	0.0486	-0.3229	-0.2945	-0.1870	-	-
Bufflehead	-0.3278	0.0791	-0.0313	-0.3294	-0.1027	-	-
Hooded merganser	-0.1291	0.1888	-0.1829	-0.5842[c]	-0.3447[a]	-0.1742	-0.2132
Common merganser	-0.4434[a]	0.2512	-0.4052[a]	-0.2405	-0.1260	-	-
Ruddy duck	0.4443[a]	0.3874[a]	-0.5255[a]	0.1656	0.2903	0.2685	0.3719[a]

[a]0.01 < $\underline{P}$ 0.05

[b]0.001 < P 0.01

[c]$\underline{P}$ < 0.001

Table 3. Coefficients for interspecific overlap between American coots and waterfowl species in north-central Oklahoma, fall 1979-81. (Number of flocks = 1,099; number of flocks with coots = 483.)[a,b]

Species	Index of interspecific overlap	Number of flocks with coots	Total number of flocks
Canada goose	0	0	7
Wood duck	0.0186±0.0340[c]	1	6
Green-winged teal	0.0401± 0.0307	6	45
Mallard	0.1021±0.0134	43	367
Northern pintail	0.0433±0.0303	7	54
Blue-winged teal	0.0211±0.0231	3	42
Northern shoveler	0.0235±0.0308	2	15
Gadwall	0.1968±0.0388	70	262
American wigeon	0.2001±0.0398	68	239
Canvasback	0	0	25
Redhead	0.1150±0.0368	30	141
Ring-necked duck	0.0675±0.0328	14	89
Lesser scaup	0.0186±0.0205	3	54
Common goldeneye	0	0	17
Bufflehead	0.0089±0.0172	1	26
Hooded merganser	0.0279±0.199	3	24
Common merganser	0	0	19

Table 3. Continued.

Species	Index of interspecific overlap	Number of flocks with coots	Total number of flocks
Ruddy duck	0.0086 ± 0.0166	1	28

[a]Ochiai's coefficient of interspecific overlap.

[b]Species observed in 5 flocks or less included greater white-fronted goose (5 flocks, 0 with coots) and snow goose (3 flocks, 0 with coots).

[c]95% confidence interval.

Table 4. Changes in spatial overlap between coots and waterfowl species through fall migration, September-December 1979-81.[a]

Species	September		October		November		December	
	Index of overlap	n_1/n_2[c]	Index of overlap	n_1/n_2	Index of overlap	n_1/n_2	Index of overlap	n_1/n_2
Canada goose	–[b]	–	0	0/3	0	0/3	0	0/1
Wood duck	0.0877	1/2	0	0/2	0	0/1	0	0/1
Green-winged teal	0	0/2	0.0529	6/39	0	0/4	–	–
Mallard	0.0555	1/5	0.0728	14/112	0.1710	16/139	0.2278	12/111
Pintail	0.0469	1/7	0.0543	6/37	0	0/9	0	0/1
Blue-winged teal	0.0320	1/15	0.0212	2/27	–	–	–	–
Northern shoveler	0	0/1	0.0318	2/12	0	0/2	–	–
Gadwall	0.0827	2/9	0.2063	50/178	0.2222	14/63	0.2309	4/12
American wigeon	0.1387	5/20	0.1773	42/170	0.3314	16/37	0.2887	5/12
Canvasback	–	–	0	0/13	0	0/9	0	0/3
Redhead	0	0/1	0.1213	23/109	0.1584	7/31	–	–

Table 4. Continued.

Species	September		October		November		December	
	Index of overlap	$\underline{n}_1/\underline{n}_2$[c]	Index of overlap	$\underline{n}_1/\underline{n}_2$	Index of overlap	$\underline{n}_1/\underline{n}_2$	Index of overlap	$\underline{n}_1/\underline{n}_2$
Ring-necked duck	0	0/1	0.0573	8/59	0.1314	5/23	0.0816	1/6
Lesser scaup	-	-	0.0297	3/31	0	0/21	0.0816	0/2
Common goldeneye	-	-	0	0/1	0	0/6	0	0/10
Bufflehead	-	-	0	0/4	0.0325	1/15	0	0/7
Hooded merganser	-	-	0.0389	1/2	0.0630	2/16	0	0/6
Common merganser	-	-	0	0/2	0	0/12	0	0/5
Ruddy duck	-	-	0.0115	1/23	0	0/5	-	-

[a]Ochiai's index for interspecific overlap using flocks as sample points.

[b]Dash indicates no individuals of that species were observed in the indicated month.

[c]Number of flocks containing coots ($\underline{n}_1$)/number of total flocks containing the waterfowl species ($\underline{n}_2$).

Table 5. Behavioral interactions between waterfowl and American coots in 184 mixed flocks, fall 1979-81.

Species	Behavioral interaction					Total
	None	Aggression toward coots	Aggression toward ducks	Cooperative feeding	Kleptoparasitism	flocks
Wood duck	1(100)[a]	0	0	0	0	1
Green-winged teal	5(83.3)	0	1(16.7)	0	0	6
Mallard	19(90.5)	0	0	2(9.5)	0	21
Northern pintail	6(85.7)	0	1(14.3)	0	0	7
Blue-winged teal	3(75.0)	0	1(25.0)	0	0	4
Northern shoveler	2(100)	0	0	0	0	2
Gadwall[b]	33(70.2)	1(2.1)	1(1.2)	7(14.9)	5(10.6)	47
American wigeon[c]	36(70.6)	1(2.0)	1(2.0)	8(15.7)	5(9.8)	51
Redhead	19(67.9)	0	0	9(32.1)	0	28
Ring-necked duck	8(66.7)	0	0	4(33.3)	0	12
Lesser scaup	2(100)	0	0	0	0	2

Table 5. Continued.

	Behavioral interaction					
Species	None	Aggression toward coots	Aggression toward ducks	Cooperative feeding	Kleptoparasitism	Total flocks
Bufflehead	1(100)	0	0	0	0	1
Hooded merganser	1(100)	0	0	0	0	1
Ruddy duck	1(100)	0	0	0	0	1
All species[d]	137(74.5)	2(1.1)	5(2.7)	30(16.3)	10(5.4)	184

[a]Number of interactions in each category (% of interactions for the species).

[b]$\chi^2 = 76.936$, d.f. = 4, $P < 0.001$.

[c]$\chi^2 = 84.980$, d.f. = 4, $P < 0.001$.

[d]$\chi^2 = 353.98$, d.f. = 4, $P < 0.001$.

CHAPTER V

DETERMINING AGE AND SEX OF AMERICAN COOTS

BY WILLIAM R. EDDLEMAN AND FRITZ L. KNOPF

Reliable techniques for age and sex determination of migrating and wintering Americn coots (Fulica americana) are presently not available. Breeding coots can be aged through age 4 by tarsal coloration (Crawford 1978), and males and females have sex-specific behaviors and calls while on breeding territories (Gullion 1950, 1952). Externally, juvenile coots differ from adults in having gray (as opposed to white) bills and brownish (as opposed to red) eyes up to an age of 75 days (Gullion 1954:394). Bill color changes to white by about 120 days. However, no quantitative data are available on the proportion of juveniles retaining these traits through fall and early winter. Nonbreeding coots can be aged as juvenile or adult by internal examination of the conformation of the bursa of Fabricius, although bursal depth does not predictably decline with age (Fredrickson 1968).

Attempts to sex coots by single external measurements or combinations of measurements have been unsuccessful (Fredrickson 1968). Eighty-five percent of 101 fall migrants in Wisconsin could be sexed by the length of the metatarsus-midtoe including claw using 139.5 mm as a cutoff point (Burton 1959), while 88% of 67 coots in California were correctly sexed by the length of the metatarsus-midtoe without claw using 127.5 mm as the cutoff point (Gullion 1952). However, 232 of 291 coots collected in Iowa were in the zone of overlap between the sexes for this measurement (Fredrickson 1968).

All previous studies attempting to develop aging and sexing techniques for American coots have been limited to only a few study sites or to 1 season or year, possibly failing to take geographical, annual, and seasonal morphological variation into account (eg. Visser 1976, Fjeldsa 1977). We designed this study to refine external and internal age and sex criteria for postbreeding coots, with the objective of defining techniques applicable for all seasons over a wide geographical area.

STUDY AREAS

Coots were collected in Oklahoma at Lake Carl Blackwell (Payne-Noble counties), Sooner Lake (Noble-Pawnee counties), and Sequoyah National Wildlife Refuge (Haskell, Muskogee, and Sequoyah counties); in Texas at Laguna Atascosa National Wildlife Refuge (Cameron County); in South Carolina at Par Pond on the Savannah River Project (Barnwell County); and in South Dakota in Brookings and Lake counties (various marshes). Collections were made in Oklahoma from September 1979-May 1982, in Texas from October 1981-March 1982, in South Carolina from September 1980-April 1981, and in South Dakota in June 1982 (Table 1). General characteristics of study sites in Oklahoma, South Carolina, and South Dakota have been described previously (Baumgartner 1942, Brisbin 1974, Vaa et al. 1974, Patterson 1982:4, Eddleman et al. in prep.).

At Laguna Atascosa National Wildlife Refuge, coots were collected in the Cayo, a turbid freshwater channel connecting Laguna Atascosa to the salt water Laguna Madre. Aquatic vegetation in the Cayo at the time of the study was mainly muskgrass (Chara sp.), with grasses being the principal vegetation along the shoreline. Upland vegetation was typical of the desert grassland of the Texas Gulf Coastal Plain (Bailey 1978:35).

METHODS

Coots were collected by shotgun on all 6 sites (Table 1). Immediately after collection, the color of the iris was recorded by comparison with a standard color guide (Smithe 1975, 1981). Birds were then frozen for later analysis. The color of the bill, head plumage, lower tibia, tarsus, and toes were ascertained on thawed birds by comparison with the color guide. The stripe at the distal end of the bill was recorded as absent (0); pigment present, but edges indistinct (1), or pigment present and edges distinct (2). The amount of white on the tips of the feathers on the abdomen was recorded as 60% or more coverage (0), 10%-60% coverage (1), or less than 10% coverage (2). Colors of these soft parts do not fade after freezing and thawing (Burton 1959).

After recording colors of soft parts, we measured 19 external structures. These included total length, wing span, tail, tarsus (Palmer 1962:5), wing chord, flattened and straightened wing (Visser 1976), metatarsus-midtoe with and without claw (Gullion 1952, Burton 1959), culmen-shield (Fredrickson 1968), middle toe and hind toe length (without claw), culmen length along the ventral side from the angle of the mouth to the tip (hereafter referred to as gape), upper mandible height and width at the beginning of feathering at the angle of the mouth, head length from the rear of the skull to the tip of the culmen, head width at the base of the orbits, length of first secondary (plucked), length of wing claw (located at the tip of the alula), and width of the wing claw at the base. Structures were measured with a steel rule to the nearest 0.5 mm except for total length, wing span, wing and secondary measurements, which were measured to the nearest 1 mm. Wing claw measurements were taken to the nearest 0.1 mm with vernier calipers. All wing and leg measurements were taken on the right side unless the structure was damaged.

Birds were then dissected; sex determined by examination of the gonads; and age determined by conformation of the bursa of Fabricius, gonadal development (in fall), and development of the oviduct in females. Juveniles had small underdeveloped gonads in fall and ova were not distinguishable in females. The oviduct was thin and tubular in juveniles through spring, but was more developed in adult females. Birds of uncertain age were eliminated from further analyses. The length of the bursa of Fabricius was measured to the nearest 0.1 mm with vernier caliphers, measuring from the tip to the point of attachment to the cloaca. The width of the bursa at the widest point was also measured to the nearest 0.1 mm. The bursa was then excised, excess moisture removed on a paper towel, and the structure was weighed to the nearest 1 mg on a Mettler balance.

Color data were analyzed for each month from September through June using juveniles (HY) and adults (AHY) as age classes. Chi-square tests for independence were used to test for significant differences between observed and predicted age for each color trait using the criteria in Table 2. The percentage of individuals correctly classified was obtained from the X^2 tables. For all analyses, 90% correct classification was considered acceptable. Morphological measurements were subjected to stepwise discriminate function analysis (BMD-07M; Dixon 1968), which eliminated variables that did not contribute significantly to discrimination between the 2 groups. Separate analyses were performed using sex or age as the grouping variable, for all birds and for each season (fall=September-November, winter=December-February, spring=March-May, summer=June)--a total of 10 analyses.

Frequency distribituions of bursal measurements were plotted to determine if separation by age class was possible using single characteristics. All analyses except the stepwise discriminate function analysis were performed using programs in the Statistical Analysis System (SAS Institute, Inc. 1982).

RESULTS

Age Criteria

Soft Part Colors--Iris color, head plumage color, bill color, and bill stripe class could be used to correctly classify at least 95% of coots in age classes in September (Table 3). Tarsal color and toe color were also effective in age classification of more than 90% of 40 coots in September [16 of 17 juveniles (94.1%) and 20 of 23 adults (87.0%) for tarsal color; 16 of 17 juveniles (94.1%) and 21 of 23 adults (91.3%) for toe color], but were capable of correct age classification of 85% or less of birds collected in later months. Twenty-three of 24 yearlings (95.8%) and 63 of 64 older coots (98.4%) from the sample of breeding birds were correctly aged using tarsal color. Colors of the tibial spot and abdominal plumage were not effective (< 90% of all birds were correctly classified) for aging coots at any time.

Juveniles began to acquire adult bill coloration in October, when only 74% of juveniles retained juvenile bill color (Table 3). Color of the irides and head plumage remained effective for aging coots through October for 94% of the birds examined. By the end of November 20% of all juveniles had attained adult appearance in at least 1 of the traits iris color, bill color, head plumage color, and bill stripe class (Table 3). The characteristics of the bill stripe could still be used to effectively age 87.5% of juveniles and all adults in November. By early December over 40% of juveniles retained at least 1 juvenile trait, but no single criterion was effective for aging coots. All juveniles we examined had attained adult appearance externally by 1 January. At least 95% of juveniles were correctly aged through November, when the 4 soft part color traits were combined and birds were assigned to the juvenile age class if at least 1 trait was juvenile (Table 3). At least 14% of adults were incorrectly aged by the combined characteristics, however.

External Morphology--Mean measurements for all variables except metatarsus-midtoe without claw and hindtoe length were significantly different between age classes (Table 4). Use of stepwise discriminant function analysis was not successsful in separation of age classes of coots in any season but fall, when 91.8% were correctly aged using 8 variables (Table 5). From 1 December until the breeding season, aging of coots by external measurements was not possible.

Bursa of Fabricius --Plotting of the frequency distribution of bursal measurements indicated extensive overlap in bursal depth between juvenile and adult coots, as noted by other workers (Gullion 1952, Fredrickson 1968). Width and weight of the bursa did not overlap to the same degree as depth, however (Table 6). In September all juveniles had bursas 5 mm wide, weighing at least 100 mg. Using these cutoff points, 20 of 22 adults (90.9%) were correctly classified using bursal width and all adults had bursas weighing < 100 mg. These characteristics were not as accurate for October migrants as for September migrants (Table 6). Because size and weight of the bursa declined through December, cutoff values were reduced to 4.5 mm or more for width of the bursas of juveniles in November-December and to 60 mg or more for weight of the bursas of juveniles in December.

From 1 January through May a bursal width of 3.0 mm was effective in aging 186 of 191 juveniles (97.4%) and 559 of 579 adults (96.5%) (Table 6). Bursal weight was also accurate for aging migrant and wintering coots from 1 January through May, when 167 of 176 juveniles (94.9%) and 462 of 478 adults (96.6%) were correctly aged using 40 mg or more as the criterion for juveniles. Breeding coots were not accurately aged internally using characteristics of the bursa (Table 6). Similar results in the analysis of bursal width and weight were obtained for coots from all 4 locations.

Sex Criteria

Mean measurements were significantly different between males and females for all 19 variables (Table 7). Sixteen of the 19 variables were useful in discriminating sex for at least 1 season or for the entire year (Table 8). Wing span, metatarsus-midtoe without claw, and middle toe lengths were not selected in the discriminant function analysis for any season. At least 92% of all individuals could be be identified to sex during any season using 13 variables. Higher correct classification was obtained in winter through summer, but only 91% of fall birds were correctly classified into sex classes using 8 variables (Table 8). Discriminant function analysis allowed a sexing of > 89% of coots at each geographic location (Table 8).

The discrimination of sex involves only 2 levels of the grouping variable; therefore the canonical variable score for an individual bird can be obtained by the equation

$$(W_i x_i) + C$$

where W_i = Canonical variable coefficient for morphological characteristic i

x_i = Measured value of morphological characteristic i

C = Constant

The values for constants and the canonical variable coefficients are given in Table 8. If the canonical variable score is < 0, the bird is classified as a male and if the score is > 0, the bird is classified as a female. The probability of correct classification for the entire year and for each season is given in Table 8.

Because this process involves the measurement of up to 9 morphological characteristics (in spring) and numerous calculations, we developed a stepwise key for relative ease of field application (Table 8). The key was developed by making subjective cutoff points on histograms of the frequency distributions of the morphological traits (Cooch and Collins 1982). Variables were chosen on the basis of their ability to discriminate during all or most seasons (Table 7). The key attempts to eliminate or minimize zones of overlap between morphological measurements of the sexes (Fredrickson 1968) and provided 90.5% accuracy the year-around. One measurement is taken initially, with up to 6 additional measurements necessary for birds in zones of overlap (Table 8). The procedure was accurate for all 4 locations; 90.1% (764/848) of Oklahoma birds were correctly classified as were 90.4% (199/220) of the coots collected in South Carolina, 92.0(81/88) of those collected in South Dakota and 92.5% (197/213) of those collected in Texas.

DISCUSSION

Aging Techniques--American coots were accurately aged through October by the color of the iris, clarity of the bill stripe, and and head plumage color. Bill color was not accurate for aging coots in fall. Coloration of the bill could be confounded not only by the attainment of white color by juveniles, but also by fading of bill color in post-breeding adults (Gullion 1953). Because observations of bill stripe clarity may be subjective, we recommend the bill and bill stripe characteristics be used for aging only if confirmed by at least 1 other soft part color. Because iris color fades to ferruginous in adults after 1 1/2 hours, age determination of coots using iris color should be made immediately after collection (Table 2). Observations of plumage color should be made only on dry birds, as wetting of the feathers darkens the perceived color. In November presence of at least 1 of the traits may be used to age coots (Table 3).

Discriminant function analysis failed to distinquish between birds of different age in every season except fall, when colors of soft parts are more accurate and easier to use for external aging. Presumably, structures depending on size of bones (tarsal measurements, toes, bill measurements, and head mesurements) have not reached asymptotic growth until after fall migration, allowing the greater discrimination between age classes in fall. The wing claw of juveniles was usually shorter and thinner in fall juveniles than in spring juveniles. In years of poor food availability, nutrients necessary for feather growth may not be available and feather structures may be shorter in juveniles fledged in such years (Fjeldsa 1977).

The width and weight of the bursa of Fabricius were both effective in aging coots internally during the nonreproductive portion of the year. We recommend use of the width of the bursa as the simplest, most accurate aging technique for coots collected after 1 December, when colors of soft parts are inaccurate. The structure should not be used to confirm the age of breeding coots, however, as the bursa enlarges considerably in many adults during breeding (Table 6; Eddleman, unpubl. data). This enlargement may persist in early fall, as the accuracy of bursal measurements for aging coots is lower in early fall than in winter and spring.

<u>Sexing Techniques</u>--Coots could be sexed with at least 90% accuracy throughout the year for all locations sampled. The canonical variable calculation technique, however, is time consuming and is necessary only if accuracy > 90% is desired. For the easiest field application on living birds, we recommend the stepdown procedure (Table 8). Six of the 7 measurements used in the procedure are traits based on bone structure. Wing and tail measurements depend on feather length, which is subject to wear and therefore annual variations unrelated to sexual differences. Because individuals for all 4 geographical areas were pooled in the formulation of this technique, structural variations were taken into account in formulating the procedure. Birds taken from the migration

and wintering areas probably encompass breeding populations from Alberta eastward (Ryder 1963). The stepdown procedure also minimizes the problem of overlap between morphological measurements of the sexes (Fredrickson 1968) by considering additional measurements for those birds in the overlap zones.

SUMMARY

Techniques for aging and sexing American coots are presented. Coots may be aged as juvenile or adult through October by colors of the iris or head plumage. In November, at least 1 of the traits--iris color, head plumage color, bill color, or bill stripe class--should be juvenile to classify a bird as juvenile. Fresh, dry birds are necessary to age coots externally in fall. Nonbreeding coots may be aged internally by width or weight of the bursa of Fabricius, especially after October when overlap between adults and juveniles is minimal. Coots may be sexed externally with 90.5% accuracy by a stepdown procedure involving up to 7 external measurements, including flattened wing, metatarsus-midtoe with nail, culmen-shield, head length, bill width, gape, and bill height. Greater accuracy may be obtained using canonical variable scores, but the procedure requires more time and lengthy calculations.

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Table 1. Numbers of American coots collected at 6 study sites, 1979-82.

Location	Age-sex class: Adult males	Adult females	Juvenile males	Juvenile females	Total
Oklahoma (3 sites)	291	301	188	179	959
Laguna Atascosa National Wildlife Refuge (Texas)	81	39	56	37	213
Savannah River Project (South Carolina)	94	58	40	16	208
Brookings-Lake counties (South Dakota)	33	31	15	9	88
Total	499	429	299	241	1468

Table 2. Colors of soft parts of juvenile and adult American coots used in external classification of American coot age classes.

Soft part	Juvenile trait(s)[a]	Adult trait(s)[a]
Iris	Shades of brown, ferruginous (41), or browns with flecks of scarlet (14) or flame scarlet (15)	Entire iris geranium (12), scarlet (14), flame scarlet (15), chrome orange (16), or intermediate red colors
Bill	Pearl gray (81), olive gray (42), light neutral gray (85), pale neutral gray (86), smoke gray (44), plumbeous (78), glaucous (79), grayish horn color (91), or combinations of these colors	White, white with tip pale neutral gray (86) or pearl gray (81)
Head plumage	Blackish neutral gray (82), dark neutral gray (83), medium neutral gray (84), light neutral gray (85), plumbeous (78), or intermediate colors, often with white feathers intermixed	Jet black (89)
Distil end of tibia	Greens, grays, or other colors not regarded as adult	At least partially spectrum yellow (55), sulfur yellow (57), orange-yellow (18), spectrum orange (17), chrome orange (16), or flame scarlet (15)

Table 2. Continued.

Soft part	Juvenile trait(s)[a]	Adult trait(s)[a]
Tarsus	Dominant color grays, olive greens darker than yellowish olive green (50), olive grays, lime green (59)	Dominant color flame scarlet (15), chrome orange (16), spectrum orange (17), orange-yellow (18), spectrum yellow (55), sulfur yellow (57), olive-yellow (52), yellowish olive-green (50), or yellow-green (58)
Toes	Dominant color smoke gray (44,45), glaucous (80), medium neutral gray (84) or darker	Dominant color pearl gray (81), light neutral gray (85), pale neutral gray (86), or containing spectrum yellow (55), yellow-green (58), or olive-yellow (52)

[a]Numbers in parentheses refer to Smithe (1975, 1981).

Table 3. Proportion of coots correctly classified into age classes using colors of soft parts.

Month	Age class	Iris color	Head plumage color	Bill color	Bill stripe	Combined[a]
September	All	29/ 29(100)[b]	36/ 37(97.3)	39/ 41(95.1)	37/ 39(94.9)	36/ 41(87.8)
	Juvenile	16/ 16(100)	17/ 17(100)	17/ 17(100)	16/ 17(94.1)	17/ 17(100)
	Adult	13/ 13(100)	19/ 20(95.0)	22/ 24(91.7)	21/ 22(95.4)	19/ 24(79.2)
October	All	108/115(93.0)	352/371(94.9)	330/385(85.7)	346/380(91.0)	353/385(91.7)
	Juvenile	79/ 83(95.2)	190/199(95.5)	148/200(74.0)	171/197(86.8)	194/200(97.0)
	Adult	69/ 72(95.8)	162/172(94.2)	182/185(98.4)	175/183(95.6)	159/185(85.9)
November	All	41/ 49(83.7)	66/ 74(89.2)	64/ 83(77.1)	78/ 83(94.0)	78/ 83(94.0)
	Juvenile	17/ 24(70.8)	27/ 35(77.1)	23/ 40(57.5)	35/ 40(87.5)	36/ 38(94.7)
	Adult	24/ 25(96.0)	37/ 37(100)	41/ 43(95.4)	43/ 43(100)	40/ 43(93.0)
December	All	41/ 71(57.8)	56/103(54.4)	64/103(62.1)	66/101(65.4)	74/103(71.8)
	Juvenile	18/ 47(38.3)	22/ 58(37.9)	19/ 58(32.8)	22/ 56(39.3)	31/ 58(53.4)
	Adult	23/ 24(95.8)	44/ 45(97.8)	45/ 45(100)	44/ 45(97.8)	43/ 45(95.6)
January		All red	All jet black	All white	All class 2	-

[a]Birds were considered juvenile if at least 1 of the 4 traits was juvenile.

[b]Numbers in parentheses are percentages of birds classified into the correct age class.

Table 4. Morphological traits of juvenile and adult American coots.

Measurement	n_1, n_2[a]	Juvenile Mean ± S. D.	Juvenile Range	Adult Mean ± S. D.	Adult Range	t-statistic
Total length	538, 922	368.0 ± 18.2	301.0 - 437.0	371.3 ± 18.4	318.0 - 434.0	- 3.307***
Wing chord	540, 928	180.6 ± 9.0	156.0 - 202.0	184.7 ± 8.2	161.0 - 210.0	- 8.470***
Flattened wing	499, 868	193.2 ± 9.3	167.0 - 214.0	197.2 ± 8.8	173.0 - 219.0	- 7.906***
Wing span	536, 925	646.1 ± 40.0	491.0 - 719.0	656.6 ± 29.5	581.0 - 742.0	- 5.323***
Tail	539, 923	50.6 ± 2.9	42.0 - 59.5	52.5 ± 3.0	43.5 - 65.5	-12.312***
Tarsus	540, 935	55.1 ± 3.1	46.5 - 68.0	56.1 ± 3.5	47.5 - 69.0	- 5.539***
Metatarsus-midtoe with claw	540, 938	136.6 ± 7.5	116.0 - 157.0	138.4 ± 7.8	117.0 - 160.0	- 4.333***
Metatarsus-midtoe without claw	540, 928	124.5 ± 6.7	105.0 - 142.0	124.8 ± 6.9	106.0 - 150.5	- 1.628
Middle toe	539, 928	73.7 ± 5.1	61.5 - 85.0	74.6 ± 4.2	61.0 - 86.0	- 3.146***
Hind toe	539, 927	23.0 ± 1.5	19.0 - 29.0	22.9 ± 1.5	19.0 - 28.0	0.719
Culmen-shield	540, 933	44.1 ± 3.6	35.5 - 54.5	46.6 ± 3.3	39.0 - 57.5	-13.015***
Gape	537, 919	35.0 ± 1.9	29.0 - 41.0	35.3 ± 2.0	30.0 - 46.0	- 2.362**
Bill height	537, 922	10.3 ± 0.7	8.5 - 13.0	10.9 ± 0.8	9.0 - 13.0	-12.997***

Table 4. Continued.

Measurement	n_1, n_2[a]	Juvenile Mean ± S. D.	Juvenile Range	Adult Mean ± S. D.	Adult Range	t-statistic
Bill width	537, 921	10.8 ± 0.8	9.0 - 13.0	11.3 ± 0.8	9.5 - 13.0	-11.432***
Head length	536, 917	62.8 ± 3.0	54.5 - 71.5	63.8 ± 3.1	54.0 - 72.0	- 6.069***
Head width	536, 917	15.0 ± 0.9	13.0 - 20.0	15.2 ± 0.9	13.0 - 21.0	- 4.430***
Wing claw length	507, 856	3.6 ± 0.4	2.2 - 5.1	4.5 ± 0.8	2.5 - 9.4	-24.676***
Wing claw width	391, 735	1.0 ± 0.1	0.8 - 1.5	1.1 ± 0.1	0.8 - 1.5	-14.762***
First secondary length	271, 607	111.1 ± 5.4	93.0 - 124.0	115.1 ± 5.9	102.0 - 132.0	- 9.909***

[a]Sample sizes are numbers of juveniles, numbers of adults

**0.001 < P < 0.01

*** P < 0.001

Table 5. Percentage of American coots classified into correct age classes using discriminate function analysis on external morphological measurements.

Season	Percentage correctly classified	n_1, n_2[a]	Measurements selected
All	80.2	267, 597	Total length, flattened wing, tail, hind toe, culmen-shield, gape, bill height, wing claw, wing claw width, first secondary
Fall	91.8	137, 118	Total length, wing span, tail, culmen-shield, bill height, head length, wing claw, wing claw width
Spring	76.1	51, 284	Total length, tail, gape, bill height, head length, wing claw, wing claw width
Summer	61.4	24, 64	Wing span, hind toe, wing claw, first secondary
Winter	81.2	55, 131	Wing span, hind toe, wing claw, first secondary

[a]Sample sizes are numbers of juveniles, numbers of adults.

Table 6. Proportion of American coots correctly classified into age classes using width and weight of the bursa of Fabricius.

Month	Cutoff value (mm)[a]	Bursal width			Cutoff value (mg)	Bursal weight		
		All	Juveniles	Adults		All	Juveniles	Adults
September	5.0	35/ 37(94.6)[b]	15/ 15(100)	20/ 22(90.9)	100	26/ 26(100)	13/ 13(100)	13/ 13(100)
October	5.0	296/322/(91.9)	149/168(88.7)	147/154(95.5)	100	275/305(90.2)	144/168(85.7)	131/137(95.6)
November	4.5	75/ 78(96.2)	39/ 40(97.5)	26/ 28(92.9)	100	49/ 50(96.1)	25/ 26(96.2)	24/ 25(96.0)
December	4.5	97/103/(4.2)	58/ 61(95.1)	39/ 42(92.9)	60	70/ 73(95.9)	47/ 48(97.9)	23/ 25(92.0)
January	3.0	60/ 61(98.4)	21/ 21(100)	39/ 40(97.5)	40	33/ 33(100)	15/ 15(100)	18/ 18(100)
February	3.0	69/ 70(98.6)	11/ 11(100)	58/ 59(98.3)	40	39/ 39(100)	7/ 7(100)	32/ 32(100)
March	3.0	218/228(95.6)	27/ 27(100)	191/201(95.0)	40	187/197(94.9)	19/ 21(90.5)	168/176(95.5)
April	3.0	338/349(96.8)	83/ 87(95.4)	255/262(97.3)	40	308/322(95.6)	81/ 87(93.1)	227/235(96.6)
May	3.0	60/ 62(96.8)	44/ 45(97.8)	16/ 17(94.1)	40	62/ 63(98.4)	45/ 46(97.8)	17/ 17(100)
June	3.0	62/ 88(70.4)	16/ 24(66.7)	46/ 64(71.9)	40	55/ 85(64.7)	18/ 24(75.0)	37/ 61(60.7)

[a]Birds with bursal widths and weights greater than the cutoff values were classed as juveniles.

[b]Numbers in parentheses are percentages of birds correctly classified.

Table 7. Morphological traits of male and female American coots.

Measurement	n_1, n_2[a]	Female		Male		t-statistic[b]
		Mean ± S. D.	Range	Mean ± S. D.	Range	
Total length	665, 795	357.6 ± 13.0	317.0 - 395.0	380.5 ± 15.4	301.0 - 437.0	-30.725
Wing chord	670, 798	176.6 ± 6.6	156.0 - 210.0	188.6 ± 6.2	162.0 - 206.0	-39.491
Flattened wing	622, 745	188.4 ± 6.3	167.0 - 216.0	201.9 ± 6.3	180.0 - 219.0	-35.726
Wing span	666, 795	630.1 ± 30.8	572.0 - 691.0	671.8 ± 23.4	583.0 - 742.0	-28.658
Tail	667, 795	50.7 ± 2.7	42.0 - 59.0	52.7 ± 3.1	42.5 - 65.5	-13.092
Tarsus	675, 800	53.5 ± 2.6	37.0 - 63.5	57.6 ± 2.8	49.5 - 69.0	-28.962
Metatarsus-midtoe with claw	676, 802	131.8 ± 5.1	116.0 - 150.0	142.8 ± 5.8	118.5 - 160.0	-38.928
Metatarsus-midtoe without claw	670, 798	119.7 ± 4.7	105.0 - 150.5	129.2 ± 5.2	108.5 - 145.0	-36.555
Middle toe	669, 798	71.0 ± 3.7	61.0 - 79.0	77.0 ± 3.2	65.5 - 88.0	-33.222
Hind toe	668, 798	22.0 ± 1.2	19.0 - 28.0	23.7 ± 1.2	20.5 - 29.0	-25.784
Culmen-shield	672, 801	43.8 ± 3.2	35.5 - 56.0	47.3 ± 3.2	22.5 - 57.5	-21.523
Gape	660, 796	33.9 ± 1.5	29.0 - 44.0	36.2 ± 1.6	32.0 - 46.0	-28.620
Bill height	663, 796	10.2 ± 0.6	8.5 - 13.0	11.1 ± 0.7	9.0 - 13.0	-27.651

Table 7. Continued.

Measurement	n_1, n_2[a]	Female		Male		t-statistic[b]
		Mean ± S. D.	Range	Mean ± S. D.	Range	
Bill width	662, 796	10.6 ± 0.6	9.0 - 12.0	11.6 ± 0.7	9.0 - 13.0	-29.138
Head length	658, 795	61.5 ± 2.4	54.0 - 69.0	65.1 ± 2.6	56.0 - 72.0	-27.698
Head width	658, 795	14.8 ± 1.0	13.0 - 20.0	15.4 ± 0.8	13.5 - 21.0	-12.952
Wing claw length	617, 746	4.0 ± 0.8	2.2 - 9.4	4.3 ± 0.8	2.4 - 7.7	- 5.942
Wing claw width	487, 639	1.0 ± 0.1	0.8 - 1.3	1.1 ± 0.1	0.8 - 1.5	-11.719
First secondary length	366, 512	108.9 ± 4.1	97.0 - 127.0	117.4 ± 4.4	103.0 - 132.0	-28.678

[a]Sample sizes are number of females, number of males.

[b]All measurements are significantly different between the sexes (P = 0.0001).

Table 8. Coefficients and constants for calculation of canonical variables for sexing American coots at different seasons.

Measurement	All (F=360, M=504)[a]	Fall (F=100, M=155)	Winter (F=64, M=122)	Spring (F=156, M=179)	Summer (F=40, M=48)
Total length	-0.01108	NS[b]	NS	NS	NS
Wing chord	-0.03175	NS	NS	-0.05146	NS
Flattened wing	-0.04584	-0.06452	-0.07015	NS	NS
Tail	0.06632	0.14376	NS	0.07482	NS
Tarsus	NS	NS	-0.18240	NS	NS
Metatarsus-midtoe with claw	-0.03737	NS	NS	-0.07598	-0.10492
Hind toe	-0.11294	-0.16646	NS	NS	NS
Culmen-shield	NS	NS	-0.11406	NS	-0.40581
Gape	-0.10430	-0.17987	NS	NS	0.25988
Bill height	-0.34207	-0.43306	NS	-0.44267	NS
Bill width	-0.18471	NS	NS	-0.50068	NS
Head length	-0.09591	-0.15018	-0.15521	-0.12026	NS

Table 8. Continued.

Measurement	All (F=360, M=504)[a]	Fall (F=100, M=155)	Winter (F=64, M=122)	Spring (F=156, M=179)	Summer (F=40, M=48)
Head width	NS	NS	-0.68945	NS	NS
Wing claw	0.32984	0.37842	0.38849	0.19309	0.59242
Wing claw width	1.01621	NS	NS	NS	NS
First secondary	-0.04344	-0.09393	NS	-0.08967	-0.15450
Constant	41.26365	38.44011	48.16290	43.79063	40.03836
Percentage correctly classified	92.9%	91.0%	94.1%	95.8%	96.6%
Oklahoma	92.3	91.7	-	95.6	-
South Carolina	93.6	91.0	89.4	90.9	-
South Dakota	-	-	-	-	96.6
Texas	93.4	90.3	98.1	96.9	-

[a]F = number of females used in the analysis; M = number of males.

[b]NS = not selected by the stepwise discriminant function procedure for the indicated season.

Table 9. Stepdown procedure for classification of American coots into correct sex classes using external measurements ($\underline{n}$ = 1,379).

Measurement (mm)	Male cutoff	Female cutoff	Number of birds correctly classified (all locations)
Flattened wing	$>$ 201.0	$<$ 187.0	630 (45.6)[a]
Metatarsus-midtoe with claw	$>$ 142.0	$<$ 132.0	918 (66.5)
Culmen-shield	$>$ 51.0	$<$ 42.0	971 (70.3)
Head length	$>$ 65.0	$<$ 60.0	1065 (77.1)
Bill width	$>$ 11.5	$<$ 10.5	1117 (80.8)
Gape	$>$ 36.0	$<$ 33.0	1162 (84.1)
Bill height	$\geq$ 11.0	$<$ 11.0	1248 (90.5)

[a]Numbers in parentheses are percentages of total birds.

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