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DETERMINING AGE AND SEX OF AMERICAN COOTS

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Reliable techniques for age and sex determination of migrating and wintering American Coots (*Fulica americana*) have not been available. Breeding coots can be aged through age 3 by tarsal color (birds 4 years and older were placed in a 4+ age class) (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 brown (as opposed to red) eyes to an age of 75 days (Gullion 1954:394). Bill color changes to white by about 120 days. No quantitative data have been available, however, 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 thickness of the wall 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 met with mixed success. Eighty-five percent of 101 fall migrants in Wisconsin could be sexed by the length of the metatarsus-midtoe including claw by using 139.5 mm as a cutoff point (Burton 1959), whereas 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). Two-hundred-thirty-two of 291 coots collected in Iowa, however, were in the zone of overlap between the sexes for this measurement (Fredrickson 1968).

Previous studies attempting to develop aging and sexing techniques for American Coots have been limited to a few study sites or to 1 season or year, often failing to take geographical, annual, and seasonal morphological variation into account (e.g., Visser 1976, Fjeldsa 1977). We designed the present study to refine and quantify 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 Plant (Barnwell County); and in various marshes in South Dakota (Brookings and Lake counties). Collections were made in Oklahoma from September 1979 to May 1982, in Texas from October 1981 to March 1982, in South Carolina from September 1980 to April 1981, and in South Dakota in June 1982 (Table 1). General characteristics of study sites in Oklahoma,

TABLE 1. Numbers of American Coots collected at 6 study sites, 1979–1982.

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

South Carolina, and South Dakota have been described previously (Brisbin 1974, Vaa et al. 1974, Eddleman et al. 1985).

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.); grasses were 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 shot on all 6 sites. 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% coverage (0), 10%–60% coverage (1), or <10% coverage (2). Colors of these soft parts do not fade after freezing and thawing (Burton 1959).

We also measured 19 external structures: 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 (without claw), upper mandible 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 .5 mm except for total length, wing span, wing, and secondary feather measurements, which were measured to the nearest 1 mm. Wing claws were measured to the nearest .1 mm with slide vernier calipers accurate to the nearest .02 mm. All wing and leg measurements were taken on the right side unless the structure was damaged.

Sex was determined by examination of the gonads and age determined by thickness of the wall of the bursa of Fabricius (walls thin and membranous in adults, thick and glandular in juveniles) (Fredrickson 1968), plumage condition (Gullion 1954), 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 (Larson and Taber 1980:157). Breeding coots collected in South Dakota were aged by tarsal color (Crawford 1978). 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 slide vernier calipers, 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 by blotting on a paper towel, and the structure weighed to the nearest 1 mg on a Mettler balance.

Color data were analyzed for each month from September through June; age classes were divided into juveniles (HY = hatching year) and adults (AHY = after hatching year) in September to December; or juveniles (SY = second year) and adults (ASY = after second year) in January to June using characteristics defined above. Birds from all locations were combined for the soft-part color analysis. Chi-square tests for independence were used to test for significant differences between observed and predicted age for each color trait by the criteria in Table 2. The percentage of individuals correctly classified was obtained for each χ^2 analysis. For all analyses, 90% correct classification was considered acceptable. Morphological measurements were subjected to stepwise discriminant function analysis (BMD-07M, Dixon 1968), which eliminated variables that did not contribute significantly to discrimination between the groups. Separate discriminant analyses were performed by 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. Birds from all locations were combined for the discriminant analyses.

Frequency distributions of bursal measurements of birds from all locations were plotted to determine if separation by age class was possible from single characteristics. All analyses except the stepwise discriminant

TABLE 2. Colors of soft parts of juvenile and adult American Coots used in external classification of 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)
Distal 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)
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).

function analysis were performed with 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 from

TABLE 3. Proportion of coots correctly classified into age classes by 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 ranked juvenile.
[b] Numbers in parentheses are percentages of birds classified into the correct age class.

all geographic locations into age classes in September (Table 3). Tarsal color and toe color were also effective for 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 by tarsal color (R. D. Crawford, pers. comm.). 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 color 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 a least 1 of the 4 age criteria (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 >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 soft part and plumage colors 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 still incorrectly aged as juveniles by the combined characteristics.

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

Bursa of Fabricius.—Plotting 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 5 mm and 100 mg as the cutoff points, we correctly classified 20 of 22 adults (90.9%) using bursal width; all adults had bursas weighing <100 mg. These cutoff points (5 mm for width and 100 mg for weight) 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 for width of the bursa in November–December and to 60 mg for weight of the bursa in December.

TABLE 4. Morphological traits of juvenile and adult American Coots.

Measurement	n_1, n_2[a]	Juvenile		Adult		*t*-statistic
		Mean ± SD	Range	Mean ± SD	Range	
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***
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.
** $.001 < P < .01$; *** $P < .001$.

TABLE 5. Percentage of American Coots classified into correct age classes by using discriminant 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.

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 migrating 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 when a bursal weight of 40 mg was used at the cutoff point. Breeding coots aged by tarsal color were not accurately aged internally when characteristics of the bursa were used (Table 6). Similar results in the analysis of bursal width and weight were obtained for coots from all 4 locations. Accurate aging of American Coots, therefore, was possible using bursal width cutoff points of 5 mm during September–October, 4.5 mm during November–December, and 3 mm during January–May. Bursal weight was accurate for aging coots using cutoff values of 100 mg during September–November, 60 mg during December, and 40 mg for January–May.

Sex Criteria

Mean measurements of all 19 variables were significantly different between males and females (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 stepwise discriminant function analysis for any season. At least 92% of all individuals could be identified to sex during any season using 13 variables. Higher correct classification was obtained from winter through summer, but only 91% of fall birds were correctly classified into sex classes by using discriminant function analysis (Table 8).

The discrimination of sex involves only 2 levels of the grouping vari-

TABLE 6. Proportion of American Coots correctly classified into age classes by 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 (94.2)	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 ± SD	Range	Mean ± SD	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
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 numbers of females, numbers of males.

[b] All measurements are significantly different between the sexes ($P = .0001$).

TABLE 8. Coefficients and constants for calculation of canonical variables for sexing American Coots at different seasons.

Measurement	All (F = 360, M = 504)[a,b]	Fall (F = 100, M = 155)[c]	Winter (F = 64, M = 122)[d]	Spring (F = 156, M = 179)[e]	Summer (F = 40, M = 48)[f]
Total length	−0.01108	NS[g]	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
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

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

[b] Percentage correctly classified for all locations—92.9%, Oklahoma—92.3%, South Carolina—93.6%, Texas—93.4%.

[c] Percentage correctly classified for all locations—91.0%, Oklahoma—91.7%, South Carolina—91.0%, Texas—90.3%.

[d] Percentage correctly classified for all locations—94.1%, South Carolina—89.4%, Texas—98.1%.

[e] Percentage correctly classified for all locations—95.8%, Oklahoma—95.6%, South Carolina—90.9%, Texas—96.9%.

[f] Percentage correctly classified for all locations—96.6%. (All breeding birds were collected in South Dakota.)

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

able; 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

TABLE 9. Stepdown procedure for classification of American Coots into correct sex classes by using external measurements (n = 1379).

Step no.	Measurement (mm)	Male cutoff	Female cutoff	Range of measurement requiring measurement of next trait	Cumulative number of birds correctly classified
1	Flattened wing	>201.0	<187.0	187–201	630 (45.6)[a]
2	Metatarsus-midtoe with claw	>142.0	<132.0	132–142	918 (66.5)
3	Culmen-shield	>51.0	<42.0	42–51	971 (70.3)
4	Head length	>65.0	<60.0	60–65	1065 (77.1)
5	Bill width	>11.5	<10.5	10.5–11.5	1117 (80.8)
6	Gape	>36.0	<33.0	33–36	1162 (84.1)
7	Bill height	≥11.0	<11.0	None	1248 (90.5)

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

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 8 morphological characteristics (in spring) and numerous calculations, we developed a stepwise key for relative ease of field application (Table 9). The key was developed by making subjective cutoff points on histograms of the frequency distributions of the morphological traits for all birds collected (cf. Cooch and Collins 1982). Variables were chosen on the basis of their ability to discriminate during all or most seasons (Table 8). The key attempts to eliminate or reduce zones of overlap between morphological measurements of the sexes (Fredrickson 1968) by requiring additional measurements for birds in these zones and provided 90.5% accuracy year round. Flattened wing is taken initially (Table 9). Birds with flattened wing >201 mm are classed as male; <187 mm are classed as female. If the wing measurement is 187–201 mm, the metatarsus-midtoe with claw is measured, otherwise no additional measurements are needed. Birds with morphological traits in the zones of overlap between the sexes require 1 to 6 additional measurements until they can be classed as male or female. No additional measurements are needed once a bird is classified. Individual birds, therefore, may require from 1 to 7 measurements to be placed in the correct sex class.

The procedure was >90% 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% (81/88) of those collected in South Dakota, and 92.5% (197/213) of those collected in Texas.

DISCUSSION

Aging techniques.—American Coots from all study sites were accurately aged as adult or juvenile through October by the color of the iris, clarity

of the bill stripe, and head plumage color. Bill color was not accurate for aging coots through October. Color 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 that 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 within 90 min after death, age determination of coots by 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 juvenile trait (color of the iris, bill, head plumage, bill stripe clarity) may be used to classify birds as juvenile (Table 3).

Discriminant function analysis failed to distinguish between adults and juveniles from all study areas 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 measurements) 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).

Both the width and weight of the bursa of Fabricius were 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). 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.

Sexing techniques.—Coots could be sexed with at least 90% accuracy for all seasons and geographic locations sampled. The canonical variable calculation technique, however, is time consuming and is necessary only if accuracy >90% is desired. We recommend the stepdown procedure for the easiest field application on living birds (Table 9). Six of the 7 measurements potentially 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 geographic 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 sampled in this study probably include birds from populations from Alberta eastward (Ryder 1963). The stepdown procedure also reduces 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 are presented for aging and sexing American Coots. Coots may be classed as juveniles or adults through October by colors of the iris and/or head plumage. In November, at least 1 of 4 traits (iris color, head plumage color, bill color, or bill stripe clarity) should be ranked juvenile to class 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 and before breeding when overlap between adults and juveniles is minimal. Coots may be sexed externally with 90.5% accuracy by a stepdown procedure involving 1 to 7 external measurements, including flattened wing, metatarsus-midtoe with claw, culmen-shield, head length, bill width, gape, and bill height. Greater accuracy may be obtained by using canonical variable scores, but the procedure requires more time and lengthy calculations.

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