EXTERNAL ANATOMY, PLUMAGES AND HISTORICAL DISTRIBUTION OF THE ESKIMO CURLEW (*Numenius borealis*)

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Abstract. I sought to distinguish between sexes and age classes of the Eskimo Curlew (*Numenius borealis*), as well as to clarify the historical migration pathways and breeding distribution of the species. Discriminant function analysis revealed that sexes significantly differed in bill and tail length, with bill length the best predictor of sex. I found no significant seasonal discrimination in measurements among individuals, nor did I find any difference between early and later Northeastern fall migrants (i.e., primarily adults vs. primarily juveniles). Breast marking shape and extent of white on throat were uncorrelated with other plumage characteristics, whereas pale abdomens and wide, paler margins of wing covert feathers correlated with low density of breast markings. Individuals with pale abdomens and heavily spotted backs also had wide margins of wing covert feathers. Back spotting was the only significant plumage character related to sex, with heavy spotting predominating among females and light spotting predominating among males. I found few clear seasonal differences in plumage among specimens, although dorsal ground color may have averaged darker on spring specimens. Moreover, more lightly back-spotted individuals tended to occur in later fall, which suggested that these birds were juveniles. The existence of individuals with few Y-shaped breast markings appeared to represent one end of a range of plumage conditions that exhibited no clear relationship to age, sex, or geographic location. Mapping locations of museum specimens clarified details of migration pathway extent, provided evidence of migratory concentration spots, and provided additional evidence that Alaska once possessed a breeding population. Examining dates of last collection indicated that populations collapsed below levels at which birds were regularly located after the first decade of the 20th century.

The obituary of the Eskimo Curlew (*Numenius borealis*) has been written multiple times (Swenk 1915, Banks 1977, Environment Canada 2007) but credible sightings of birds continue to occur with regularity. From 1945 to 1985, Gollup et al. (1986) documented observations of about 80 individuals, with up to 23 sighted at once (Blankenship and King 1984). Recent organized attempts to find birds in historical breeding locations and migratory staging areas have failed (Gill et al. 1998, COSEWIC 2009), but sightings have continued (Waldon 1996, Ellison and Martin 2003, Hoffman 2007). State rare records committees have generally rejected such reports (e.g. Rines 2003), although their exceedingly stringent acceptance standards facilitate rejection of the hypothesis when it should be accepted.

Because of the reasonable possibility of continued persistence by this inconspicuous species of vast and largely inaccessible range, I here investigate aspects of the external anatomy and plumage of preserved specimens. At present, such basic wildlife management needs as the ability to distinguish sexes and age classes are based on minimal sample sizes and poorly substantiated assertions (Gill et al. 1998). Should extant populations be relocated, substantive data on these parameters will be critical to assessing population structure and developing a recovery strategy. In examining specimens, I also uncovered historical data that contribute to our understanding of the species' historical distribution and decline, so I report these findings here as well.

A summary of existing data on morphological measures is reported by Gill et al. (1998). Ridgeway (1919), with a sample size of five, provided the largest, albeit nominal sample of these measures but he

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did not report the season or sex of specimens measured. Most other sources give no data on sample size and do not necessarily refer to consistently made measurements (Gill et al. 1998).

Descriptions of plumage are based on examination of a few to an uncertain number of specimens and do not clearly distinguish plumage states. Hayman et al. (1986), appearing to be in large part a restatement of Ridgeway (1919), did not distinguish between adult alternate and basic plumage and did not distinguish between sexes. Adults were said to have a prominently streaked breast, a cinnamon-buff ventral surface, dark brown back spotted with brown-buff, Y-shaped marks on flanks, and cinnamon-buff axillars and underwing coverts. First basic plumage was characterized as having buff edges on back feathers as well as a more buff ventral surface with strong brown breast streaking. Ridgeway (1919) considered the sexes to be alike except for size and reviewed only the alternate plumage, which he described as having a sooty dark back, with or without buff edging or spotting throughout, a white throat, a buffy ventral surface with narrowly dark-streaked upper breast, nearly unmarked lower breast and abdomen, V-shaped marks on the flanks and axillars, and cinnamon-buff underwing coverts.

No geographic variation in plumage is recognized, although Coues (1861) reported that fall migrants varied greatly in size and colors of the ventral surface, including amount of white on the throat, in manners that appeared unrelated to age or sex. R. MacFarlane, in his 1862–1867 letters to S. Baird (cited in Gollup et al. 1986), further stated that there were actually two species of Eskimo Curlew, although he may have confused the Whimbrel (*N. phaeopus*) and Eskimo Curlew, as there was much uncertainty concerning the identity of these species in the early 19th century (Swenk 1915).

The Eskimo Curlew was once a common breeder of the western Canadian Arctic. Nelson (1883) also reported breeding in Alaska, although Gill et al. (1998) considered the breeding range only potentially extending into Alaska. It was a common fall migrant, with much of the population appearing to stage on the coast of Labrador. Smaller numbers are thought to have stopped along the south shore of Hudson and James Bay (Gill et al. 1998), where they have been observed even into more recent years (Hagar and Anderson 1977). South of Labrador, most migrants appeared on Cape Cod, Massachusetts, and its adjacent islands. Some Massachusetts migrants may have traveled to the coast overland from Hudson-James Bay although, based on the long-term observations of MacKay (1929), larger numbers arriving after coastal storms appeared to be south-bound Labrador migrants (MacKay 1892). Spring migrants in the United States were reported first from Texas,

with individuals appearing commonly in the prairie states and prairie provinces of Canada (Gill et al. 1998).

METHODS

Measurements. I made measurements on study skins with a dial caliper of 0.1 mm accuracy. On each skin, I measured the wing chord from the bend in the folded wing feathers (carpometacarpal–radius/ulnar joint) to the distal tip of the feathers. I measured bill length from its distal tip to the proximal end of the nare and bill depth at the distal end of the nare. I chose measuring the bill this way rather than with the traditional measure of exposed culmen as preparation technique and feather loss made such an approach less accurate. I measured length of the ventral tarsometatarsus from the intertarsal joint, generally indicated on specimens by the presence of a groove between bones, to the distal tip at the tarsometatarsal–phalangeal III joint, also often indicated by the presence of a groove between bones. I also measured the phalange III length from the tarsometatarsal–phalangeal III joint to the distal tip of the claw, although in practice tendon shrinkage in specimens sometimes made the phalanges curl, so this measure proved to be of limited accuracy. I measured tail length from the distal tip of the folded tail feathers to the junction of the undertail coverts with the abdomen, although again preparation technique limited the accuracy with which this measurement could be made.

When examining study skins, I recorded data on collection locality, collection date, and age/sex, if noted. In practice, although sex was recorded regularly by collectors, age was recorded infrequently. I also made a dorsal, ventral, and lateral photograph of each specimen to document plumage characteristics. After preliminary examination of plumages and consideration of plumage statements in the literature (Coues 1861, Ridgeway 1919, Hayman et al. 1986), I chose to evaluate 6 characteristics, which I scored as follows: 1) breast marking shape: Y-shaped, line-shaped, mixed; 2) breast marking density: high, low; 3) abdomen color: dark, light (in instances where the vent exhibited staining due to preparation technique, I evaluated color from nearby unstained feathers); 4) extent of white on throat: present only above neck, extending onto neck; 5) pale wing covert feather edging: wide, narrow; and 6) back spotting: heavy, light.

Historical distribution. To attempt to clarify the extent of historical North American migration pathways and breeding sites, I mapped location data from specimens. In instances where multiple specimens existed from the same place, I mapped these as one location. I examined specimens at the American Museum of Natural History (AMNH), U.S. National

Museum (USNM), Harvard Museum of Comparative Zoology (MCZ), Yale Peabody Museum, and Connecticut State Museum of Natural History. I also reviewed data on specimens reported by VertNet (www.vertnet.org) and individual museum web sites from the Australian Museum, Academy of Natural Sciences of Philadelphia (ANSP), Bell Museum of Natural History, Buffalo Society of Natural Sciences, California Academy of Sciences, Chicago Academy of Sciences (CHAS), Carnegie Museum of Natural History, Cornell University Museum of Vertebrates, Delaware Museum of Natural History, Denver Museum of Nature and Science (DMNS), Field Museum of Natural History (FMNH), Illinois State Museum, Louisiana State University Museum of Science, Museum of Southwestern Biology, Museum of Vertebrate Zoology UC Berkeley, Natural History Museum of Los Angeles County, Natural History Museum of the United Kingdom (NHMUK), Natural History Museum, University of Oslo, New York State Museum (NYSM), North Carolina Museum of Natural Sciences, Ohio State University Museum, Queensland Museum, Royal Belgian Institute of Natural Science, Royal Ontario Museum (ROM), San Diego Natural History Museum (SDNHM), Stamford Museum and Nature Center (SMNC), University of California, Los Angeles Museum, University of Colorado Museum of Natural History, University of Florida Museum of Natural History, University of Iowa Museum of Natural History, University of Michigan Museum of Zoology (UMMZ), University Museum of Zoology, Cambridge, University of Kansas Biodiversity Institute, University of Washington Burke Museum, and Western Foundation of Vertebrate Zoology.

Analysis. I evaluated morphological measures with discriminant function analysis, considering the data's fit to model assumptions with Shapiro-Wilk normality tests, normal Q-Q plots, log determinants, Box's M test, and correlations among independent variables. Exploratory data analysis indicated that only bill and tail length differed between sexes and seasons sufficiently to be meaningful predictors in discriminant function analysis. Indeed, including other measures in analyses had little effect on results, so I included only these two measures in analyses. They were normally distributed, exhibited no collinearity and had nonsignificant covariance matrices. However, they showed some correlation between means and standard deviations, so to stabilize variances I entered square root transformations of these measures into models.

I first attempted discrimination of sexes on specimens of recorded sex, validating this and other models with 30% of specimens withheld from classification. I next similarly analyzed data on spring vs. fall specimens. As is typical for many shorebird spe-

cies (Bent 1929), the Eskimo Curlew appeared to segregate by age classes during fall migration, with adults thought to predominate in August and juveniles migrating in September–October in the Northeast (MacKay 1892, 1929). Hence, I also subdivided specimens of Northeastern migrants into August and September–October classes in order to seek measurement differences between age classes, excluding from analysis specimens collected during the first week of September.

I evaluated plumage characteristics with two-step cluster analysis, which permits consideration of categorical variables and which produces clusters of specimens that can be examined for relationships to sex and age. I evaluated collinearity among independent variables with Kendall's τ and used Schwarz's Bayesian Criterion (BIC), BIC change ratio, and ratio of distance measures to determine the number of significant clusters. As with discriminant function analysis, I first attempted clustering on specimens of recorded sex. I next clustered specimens of recorded season of collection and also sought clusters of early vs. later fall-migrating Northeastern individuals.

RESULTS

Measurements. I measured 86 study skins, of which 49 had sex recorded on their labels. Fourteen specimens had no collection dates and 10 had no locations recorded. Females averaged larger than males in all measures but toe length, which was essentially equal (Table 1).

The function discriminating sex was significant ($n = 49$, Wilk's λ= 0.732, $P = 0.007$, canonical correlation = 0.517, Fig. 1), with 82.9% of selected and 71.4% of unselected original grouped cases correctly classified. Bill length was the best predictor of sex (standardized canonical discriminant function coefficient = 0.721 vs. 0.579 for tail length). I found no significant seasonal discrimination among specimens ($n = 72$, Wilk's λ = 0.938, $P = 0.174$, canonical correlation = 0.248, Fig. 2), with 67.2% of selected and 75.0% of unselected grouped cases correctly classified, with both bill and tail length averaging slightly less in fall. Bill length was again the best predictor for season (standardized canonical discriminant function coefficient = 0.976 vs. 0.357 for tail length). I also found no significant discrimination between early and later fall migrants ($n = 33$, canonical correlation = 0.317, Wilk's λ = 0.899, $P = 0.346$, Fig. 3), with 69.6% of selected and 60.0% of unselected grouped cases correctly classified. Tail length was the best predictor of migration time (standardized canonical discriminant coefficient = 1.104 vs. −0.683 for bill length).

Plumage. Examination of plumage variables demonstrated that breast marking shape and extent of white on throat were correlated with no other plumage characteristics, whereas 72% of specimens with pale abdomens and 71% of specimens with wide margins of wing coverts also had low density of breast markings. Similarly, 81% of individuals with pale abdomens and 82% of individuals with heavily spotted backs also had wide margins of wing covert feathers (Table 2). Hence, I entered only breast marking shape, breast marking density, extent of white on throat, and back spotting into cluster analyses.

Analysis of specimens of recorded sex produced 2 clusters in which back spotting was the only significant contributor to cluster formation ($P > 0.95$), with heavy markings predominating among females and light markings predominating among males (Fig. 4). Although sample sizes were insufficient for statistical testing, males and females exhibited heavy spotting particularly in spring, with no spring females having light spotting. Fall females were equally likely to have light or heavy spotting, whereas fall males were far more likely to be lightly spotted (Fig. 5, 6).

Analysis of specimens with respect to season also produced two clusters, with breast marking shape the only significant contributor to cluster formation ($P > 0.95$). Y markings were present only in cluster one, but plotting frequency of markings vs. season showed no clear distinction in occurrence of breast markings (Fig. 7). Despite my failure to find seasonal differences among specimens, my impression was that dorsal ground color in spring specimens averaged darker than those on fall specimens, although I was unsuccessful in quantifying this trait because of the subtlety of differences I found among specimens.

For early and later fall migrants, clustering identified back spotting as the only significant contributor to clusters ($P > 0.95$). A weak tendency existed for more lightly spotted individuals to occur in later fall (Fig. 8). As noted, a high proportion of fall males and females exhibited light spotting (Fig. 6).

One striking difference found among specimens was that 12 of the 86 largely lacked the Y markings present on the breast and flanks of most specimens (Fig. 9). Four of these were males, five were females, and three were of unknown sex. Moreover, nine of the specimens were collected in fall and three were collected in spring. The earliest fall migrant was from 1 August and the latest was from October (no date recorded). The only likely breeder was from St. Michael, Alaska (USNM 97571), although four other Alaska specimens did not show this trait nor did four additional summer specimens from Arctic Canada. This plumage state represented the end of a range of variation that included individuals exhibiting strong Y patterning and those with intermediate levels of Y markings.

Historical distribution and last records. Of 257 specimens located, 188 had North American location data sufficient to map (Fig. 10). Spring migrants moved at least in part through central America and Mexico into Texas, where the last specimens were collected 26 March 1902 at Brownsville (NHMUK zoo-1965.M.2960, zoo-1965.M.2961). They then moved through the prairie regions of the United States and Canada, with the last individual collected 22 March 1903 at Fond du Lac, Wisconsin (MMNH 8118). The Arctic breeding grounds appeared to stretch from the vicinity of Great Slave Lake, Northwest Territories, to coastal Arctic Alaska (22 specimens from Arctic Canada, with the last collected 26 May 1900 (ANSP orn-26580), and thirteen 19th century specimens from Arctic Alaska).

In fall, as documented by 21 specimens (with the last taken 29 August 1932 at Battle Harbor; UMMZ 69908), a concentration staged in southern Labrador, whereas others appeared about the shores of the eastern Great Lakes (11 specimens, with the last collected 23 September 1907 at Toronto Harbor, Ontario; ROM 96746). All other fall records were of coastal birds distributed from the Magdalen Islands to New Jersey, with the greatest concentration by far occurring in Massachusetts (45 specimens), where the last individual was collected 5 September 1913 at East Orleans (Lamb 1913; FMNH 403116). In maritime Atlantic Canada, eight specimens exist, with the last taken on Sable Island, likely in fall, 1902 (AMNH 355782). There were also three specimens from Maine, with the last collected 23 September 1901 at Pine Point (MCZ 315225), and seven 19th century specimens from Long Island, New York. Although I found no 20th century individuals from New York, Kobbe (1903) reported a bird shot 29 August 1903 at Quogue, Long Island. Four 19th century specimens came from Connecticut, two from Rhode Island, and two from New Jersey. The only location where spring and fall occurrence overlapped was at the south end of Lake Michigan, where the westernmost fall, 19th century records were from Summit, Illinois (CHAS 9, MCZ 311929). Farther east, all records with data were from fall.

The 13 Arctic specimens collected in Alaska shed light on the probability of a breeding population there. In particular, it is hard to imagine that an individual taken on 21 May 1882 (USNM 88819) at Point Barrow was not a breeder, as this is as far north as birds could migrate. Birds are reported from this location from 20 May to 6 July (Swenk 1915), and Nelson (1883) described summering individuals at Norton Sound as more common than Whimbrels. Other records from St. Paul Island on 26 May 1872

(USNM 62448) and 25 May 1886 at Cape Lisburne (USNM 110184) were also of likely breeders, as a bird from a known breeding population was collected on 27 May at Great Slave Lake, Northwest Territories (USNM 19957). Moreover, a female specimen was taken on 4 July 1877 at St. Michael, Alaska (NHMUK zoo-1888.10.10.2653)—well within the species' breeding season.

Of the four specimens known from Connecticut (Sage et al. 1913), a Connecticut State Museum of Natural History mount with no tag, which I originally located forgotten at Wesleyan University in 1974, is likely to be the one taken in September 1886 at New Haven. An 1840–1844 specimen from New Haven is extant (AMNH 229436; Linsley 1843), a 12 September 1889 New Haven specimen is also extant (SMNC 468756), and Clark's 13 October 1874 Old Saybrook specimen appears to have been lost in a fire with the rest of his collection (W. Burt, pers. comm.).

One specimen, enigmatically labelled as collected near 32° latitude (USNM 6573), has been traced by Hubbard et al. (2001) as being from Doña Ana County, New Mexico, and collected between 1852 and 1856. As such, it is the westernmost spring migrant from the contiguous 48 United States, although a specimen from 8 April 1892 at Lake Palomas, Mexico (USNM 126538), was taken slightly to the west of there, verifying that this region was near the westernmost boundary of spring migration. Hubbard et al. (2001) reported five additional western collections, but I found only 29 April 1882 specimens from Smith's Lake, Colorado (FMNH 406960, SDNHM 20936).

An extralimital specimen exists for Florida with no other data (NYSM zo-9432), although none had previously been reported there (Sprunt 1954). Another specimen, erroneously reported from Florida by VertNet, was instead collected at an unknown location recorded as Lechwallus (AMNH 113696), although written on the specimen tag is a note that this location is in doubt. I found no specimens from South Carolina, despite reports that the species had been taken there (Wayne 1920). A specimen from

TABLE 1. Comparison of male ($n = 23$) and female ($n = 26$) Eskimo Curlew measurements (mm).

Sex	Bill length	Bill depth	Tarsus	Toe	Tail	Wing
Male mean	48	5.3	44.5	26.9	86.8	209
SE	0.8	0.1	0.5	0.5	1	1.3
95% CI	1.6	0.2	1	0.9	2	2.6
Female mean	52.2	5.4	45	26.8	90.2	209.9
SE	0.8	0.1	0.4	0.3	0.9	1.1
95% CI	1.6	0.2	0.8	0.7	1.7	2.2

TABLE 2. Significance probability of Kendall's τ correlations among Eskimo Curlew plumage characters ($n = 86$).

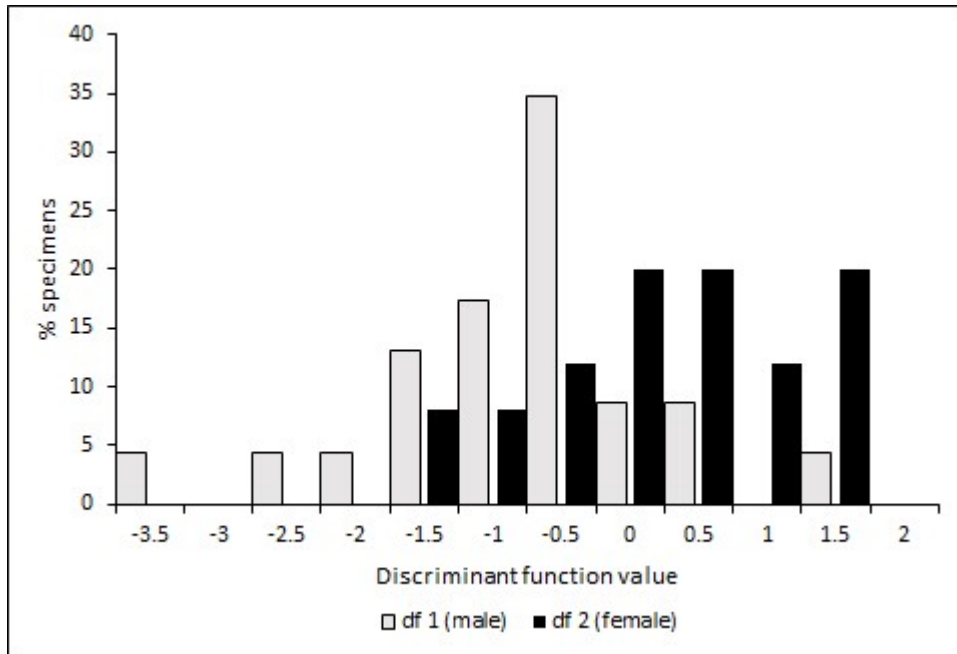|	Breast marking density	Abdomen color	Throat white extent	Wing covert	Back spotting
Breast marking shape	0.782	0.78	0.76	0.099	0.394
Breast marking density		0.001	0.238	0.012	0.482
Abdomen color			0.774	<0.001	0.287
Throat white extent				0.2	0.534
Wing covert					0.002

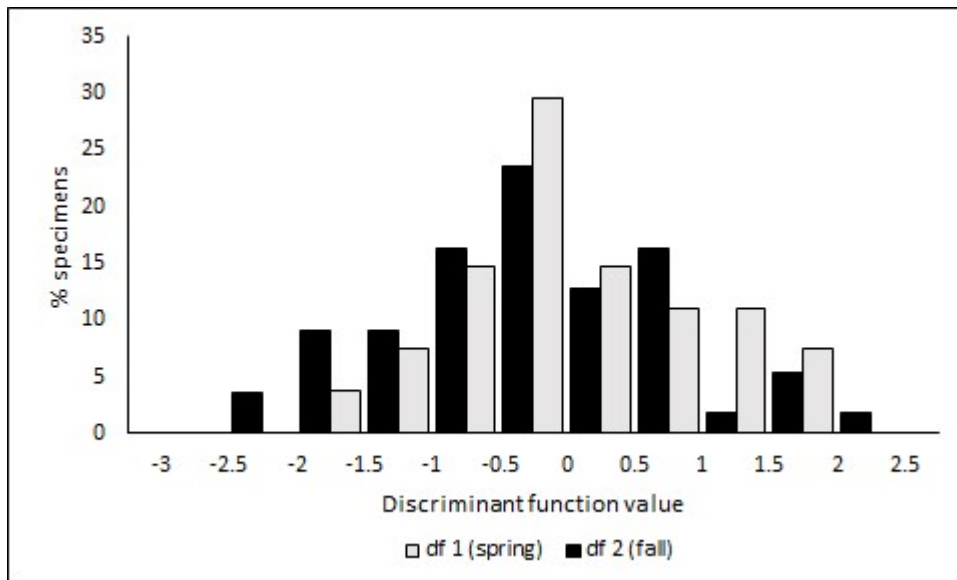FIG. 1. Discriminant function scores for distinguishing males vs. females.

FIG. 2. Discriminant function scores for distinguishing spring vs. fall individuals.

Laysan Island, Hawaii, taken 1 January 1913 (DMNS 34462) is also previously unreported. A 19th century specimen (NHMUK zoo-1897.11.10.419) with geographic coordinates that placed it at the center of the ice sheet of northern Greenland was far more likely collected at the southern end (and is plotted as such in Fig. 10).

DISCUSSION AND CONCLUSIONS

Anatomy and plumages. As reported by Ridgeway (1919) and repeated by later authors, male Eski-
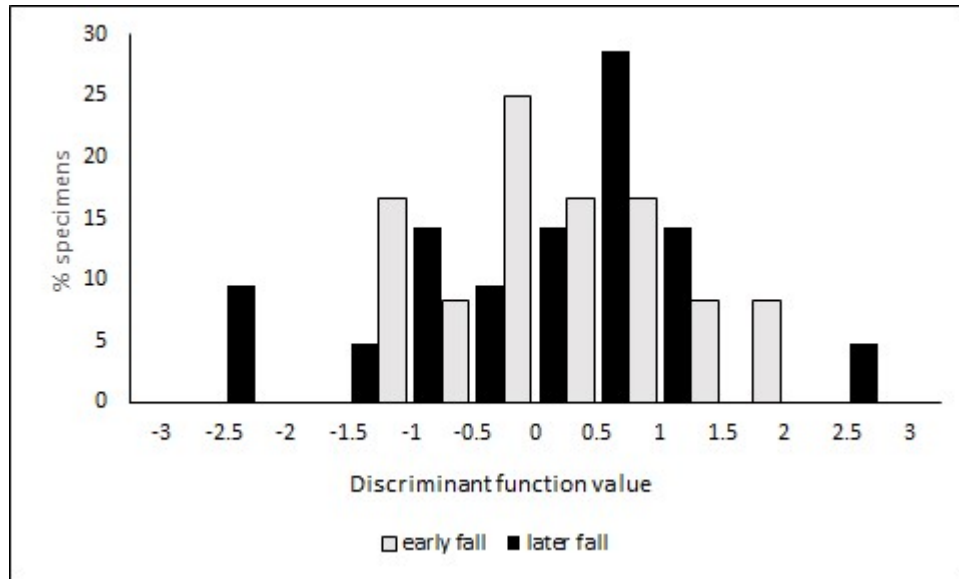
FIG. 3. Discriminant function scores for distinguishing early vs. later fall migrants.
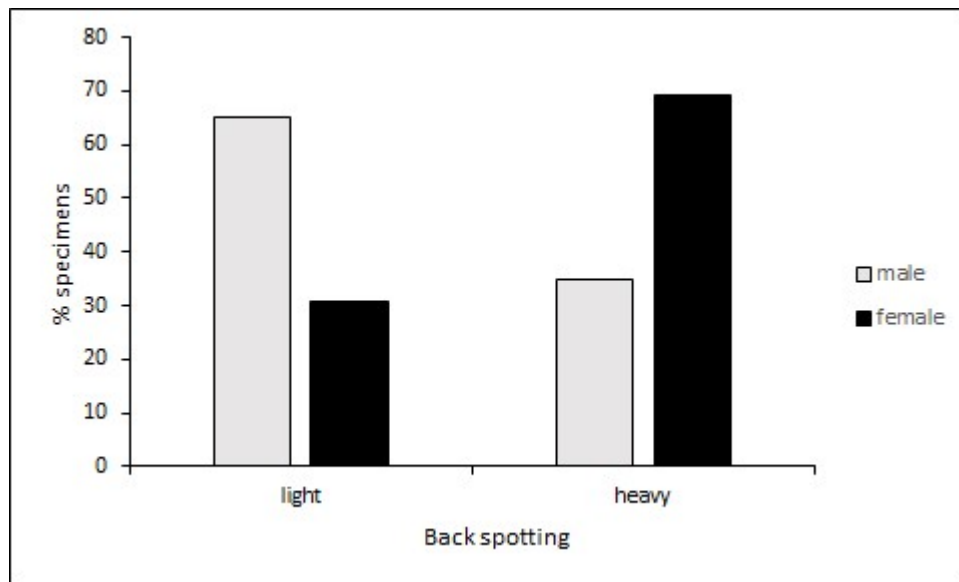
FIG. 4. Comparative back spotting of males vs. females.

mo Curlews averaged smaller than females, although I found significant differences only for the bill and tail. Based on the 95% confidence interval (Table 1), birds with bills <50.6 mm and tails <88.5 mm may be sexed as males and birds with bills ≥50.6 mm and tails >88.8 mm may be sexed as females.

Plumage characteristics proved more problematic in aging and sexing individuals than field guides (e.g., Hayman et al. 1986) would suggest. Only the extent of back spotting appears useful in sexing birds, although this character appears to vary seasonally and also exhibits a strong positive correlation with wide edging on wing covert feathers. When an individual possesses bill and tail measurements as noted above, season of observation and extent of spotting may be used as corroborating evidence of sex, with heavily spotted individuals predominating among females and lightly spotted individuals pre-
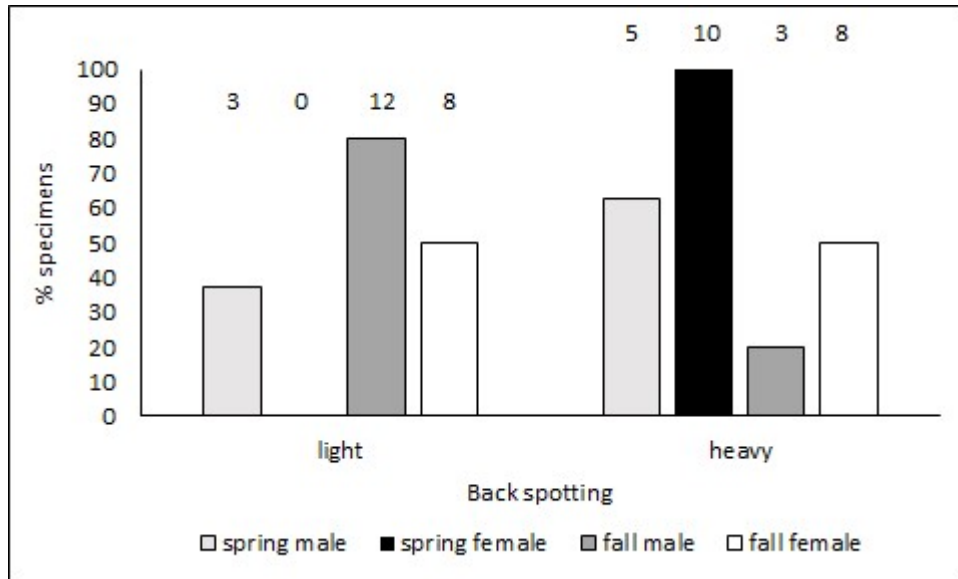
FIG. 5. Comparative back spotting of sexes with respect to seasons. Sample sizes are shown above columns.

FIG. 6. Study skins exhibiting light fall (upper; MCZ 30510) vs. heavy spring back spotting (lower; MCZ 206715) of males.

dominating among males.

I found little evidence to support that adults are characterized by having a prominently streaked breast, a cinnamon-buff ventral surface, a dark brown back spotted with brown-buff, and Y-shaped marks on flanks (Hayman et al. 1986). In contrast, I found that spring specimens as well as early fall migrants, all of which were likely adults, were variable in these traits. I suspect that Ridgeway (1919) was correct in his assessment that the back plumage tended toward
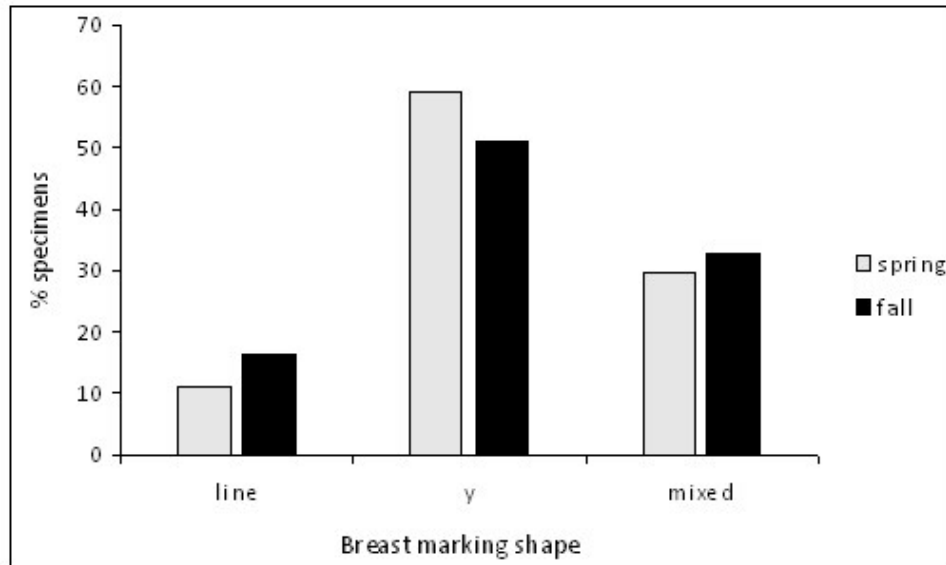
FIG. 7. Comparative breast marking shapes on spring vs. fall individuals.

being more sooty dark in alternate plumage, although further analysis will be necessary to demonstrate this conclusively.

I found some evidence that the first basic plumage, which should have predominated among later fall migrants, was characterized by a tendency toward having lighter back spotting. This difference with adult plumage is unreported. However, because of strong correlations among lighter back spotting, high density of breast markings, narrow feather edging of wing coverts, and darker abdomens, all these characters may be associated with first basic plumage. Hayman et al. (1986) concur that a more buff abdomen and strong breast streaking are characteristic of this plumage. My findings contrast, however, with their assertion that buff edges on back feathers are traits of first basic plumage.

The notable occurrence of birds with few Y-shaped breast markings appeared, echoing Coues (1861), among male, female, and spring and fall individuals. Moreover, I found no substantive evidence that the trait was geographically based. Hence, I conclude that this characteristic is an uncommon plumage state at the end of a range of plumage variation.

Distributional and historical notes. Plotting locations clarified details of migratory pathways, provided evidence of migratory concentration, and provided support for the presence of an Alaskan breeding population. Moreover, examining dates of last collection indicated that populations collapsed below levels at which birds were regularly located after the first decade of the 20th century. Afterwards, collection became rare. Indeed, even the detailed and long-term observations of MacKay (1929) yielded only two Massachusetts individuals by 1898 (MacKay 1899)—the last birds he reported.

The concentration of fall migrants in Labrador and the coastal Northeast is confirmed, although the comparative frequency with which birds appeared about the eastern Great Lakes provides strong evidence for the existence of an inland migratory pathway that previous writers have deemed uncertain (Gill et al. 1998). Great Lakes migrants perhaps came from staging areas about Hudson and James Bay although, curiously, I found no specimens to document the existence of such areas. Only a single specimen taken in August 1886 at Ungava Bay, Quebec (NHMUK zoo-1979.10.1), provided evidence for other possible staging areas. Whether the Labrador and Great Lakes pathways represented migrants from separate populations might be clarified through DNA analysis of specimens. Further examination could also clarify whether Northeastern migrants comprised a convergence of these two pathways.
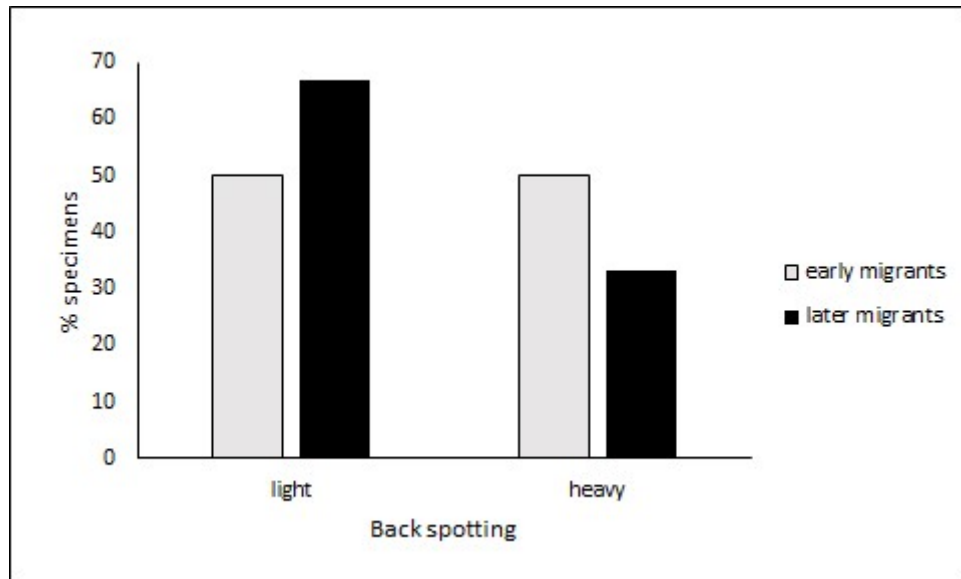
ACKNOWLEDGEMENTS

FIG. 8. Comparative back spotting on early vs. later northeastern fall migrants.

FIG. 9. Study skins exhibiting prominent Y-shaped breast markings (upper; USNM 18193) and primarily line-shaped markings (lower; USNM 88819).

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FIG. 10. Geographic locations of spring/ summer (gray) vs. fall specimens (black).