GEOGRAPHIC VARIATION IN WINTERING GREATER WHITE-FRONTED GEESE

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ABSTRACT: There is relatively little variation in size, expressed mainly in bill dimensions, between or among most wintering populations of the Greater White-fronted Goose (*Anser albifrons*). In the British Isles, slightly larger and darker birds, from the Greenland breeding population, winter in Ireland and Scotland and associated islands, while smaller birds winter in England. Winter birds in continental Europe are the same size as those in England. Asian winter birds average slightly larger than those of Europe; the population is more variable and includes some larger individuals. In western North America, some birds in the Sacramento Valley of northern California, the famed Tule Goose (*A. a. elgasi*), are the largest of the species. There is a great range of variation in smaller birds of the Sacramento Valley and elsewhere in the west coast states. Birds in the midcontinent states, east of the Rocky Mountains, average about the same as smaller California birds but vary widely.

The Greater White-fronted Goose, *Anser albifrons* (Scopoli, 1769), is an abundant and important game bird in much of the Holarctic. It is recognized as being geographically variable; five subspecies (including the nominate) have been named on the basis of wintering birds. Despite this, the nature and extent of geographic variation in nonbreeding birds has not previously been assessed on a world-wide basis. Ely et al. (2005) reviewed variation in the breeding range of the species but did not relate this to the winter distribution. Banks (2011) recently reviewed the taxonomy of the species.

METHODS

The following measurements were made on nearly 1000 specimens: wing chord, culmen length from base of feathering, bill depth at base, bill width at base, and length and width of the bill nail. Measurements were taken of adult birds and immature (first-year) birds collected after 1 January. In only a few instances were first-fall birds measured. Birds presumed to be on the breeding grounds were measured but are not included in this analysis. Measurements were entered into a SYSTAT data base and analysis was done with versions of SYSTAT, finally with SYSTAT 12. Although basic statistics were calculated for wing and nail measurements, these were not used for detailed analysis.

Orthmeyer et al. (1995) used discriminant function analysis to categorize live white-fronted geese from the North American Pacific coast by size. They developed discriminant function models for males and females, using two bill measurements for each. I modified their formulas slightly to account for a probable difference between live birds and museum specimens due to shrinkage in the drying of the skins. I then used these formulas:

$$\text{FEMOV} = 2.479\ \text{bill width} + 0.889\ \text{culmen length} + 1$$
$$\text{MALOV} = 1.692\ \text{bill width} + 0.986\ \text{bill depth} + 2$$

to calculate "Orthmeyer values" (OVs) for each specimen. Because the formulas combined bill measurements in a way useful at least for some populations

(Orthmeyer et al. 1995), I used these values as supplementary characters to help define size classes on a world-wide basis. Because I suspected that some museum specimens may have been wrongly sexed, I applied the OV formulas for both females and males to each specimen, in the hope that I might be able properly to classify mis-sexed or unsexed specimens. That hope was in vain except in suggesting that larger specimens were actually male and smaller ones female, and I excluded unsexed specimens from further analyses.

Because the purpose of this study was to investigate patterns, if any, in geographic variation in migrant and wintering birds and not to distinguish and characterize such populations, I did not perform high-powered statistical analyses, which would have been superfluous if not misleading.

Early attempts to assign specimens to color classes were abandoned because of the great extent of individual variation due to age, the season, degree of wear, etc. Color notes were made for individual specimens where it seemed important, and are discussed as appropriate.

RESULTS

In the species as a whole, variation in any measurement, with the sexes combined, has a normal bell-shaped distribution (Figure 1). In any geographic subsample or population, males are slightly larger than females, but there is generally significant overlap.

British Isles

Wintering Greater White-fronted Geese are abundant in appropriate habitats in the British Isles and have been well sampled. Specimens are available from England, Ireland, Scotland, the Hebrides, and the Orkney Islands. The specimens from Ireland and Scotland and the associated islands are generally

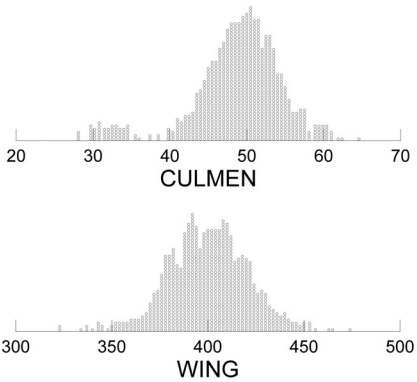

Figure 1. Distribution of measurements (mm) of culmen and wing length in the entire sample of nonbreeding Greater White-fronted Geese worldwide, sexes combined. The grouping at the left in culmen length is a subset of Lesser White-fronted Goose, *Anser erythropus*, entered into the same data base and not separated for this figure. That subset is less noticeable in wing length.

dark and brown and fit the description of *A. a. flavirostris*, known to breed in Greenland (Dalgety and Scott 1948). Indeed, most of those specimens, especially the large series in the British Museum (Natural History), were so labeled previously. I included two migrants from Iceland in my samples, being aware of the presumed origin of these birds,

Scatterplots of OVs and bill measurements of females in the combined British sample reveal a near complete separation into two size classes. One group has a culmen length less than 45 mm, bill depth less than 23 mm, and bill width less than 23.5 mm (Figures 2 and 3). A second group with culmen length greater than 45 mm is more variable in both depth and width of the bill; generally bill depth is greater than 22 mm and width is greater than 23 mm, and both may be more than 24 mm. The first, smaller, group is composed of birds from England, the larger of birds from Ireland, the Hebrides, Orkneys, and Scotland, or *A. a. flavirostris*. The separation is shown well in a plot of the OVs (Figure 4). There are some minor exceptions to this division. Two birds from England (AMNH 730640 from the Severn River; FM 402139 from Bleadon, Somerset) fall into the larger size class. It is possible, or probable, that both are mis-sexed, as they fall within the limits of males from England. One bird from Wells, Norfolk, has a wider than expected bill. One female *flavirostris* from Ireland with small bill depth and width (CAS 66023) is either mis-measured or an unusually small bird.

Males from the British Isles also fall into two size groups, with the same geographic limits, although the distinctions are not as clear. Birds from England (and one from Wales) have culmens shorter than 50 mm, those from elsewhere generally greater than 48 mm, and there is overlap of a few individuals between 48 and 50 mm. Most of the birds from Ireland and Scotland, or *flavirostris,* have both bill width and bill depth 23 mm, or greater.

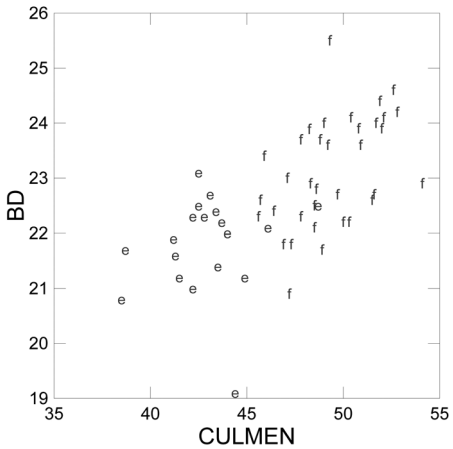

Figure 2. Bill depth (BD) versus culmen length, in mm, of female Greater White-fronted Geese from Britain; e = England, f = Ireland and Scotland. Note the separation at culmen 45 and bill depth 23 mm. Birds marked e with culmen >45 are probably mis-sexed.

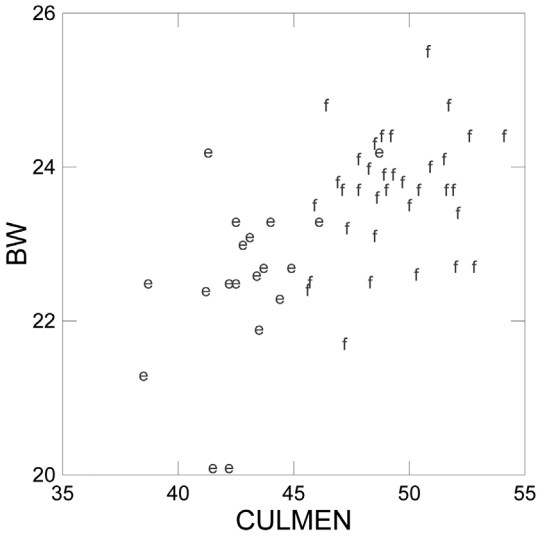

Figure 3. Bill width (BW) versus culmen length, in mm, of female Greater White-fronted Geese from Britain; e = England, f = Ireland and Scotland. Note the separation at culmen 45 and bill width about 23.5 mm. Birds marked e with culmen >45 are probably mis-sexed.

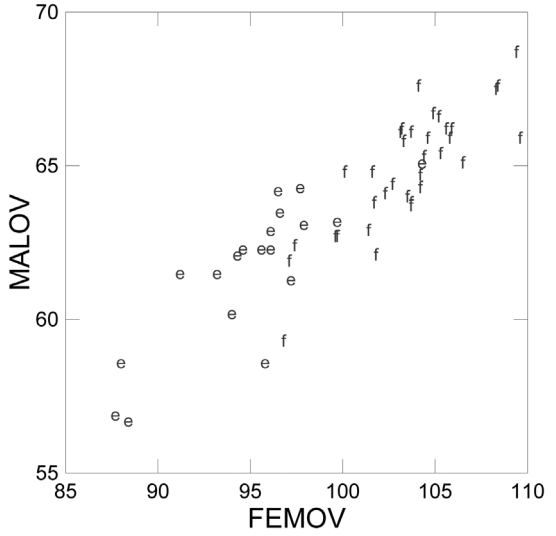

Figure 4. Separation of females from England (e) from those of Ireland at Scotland (f) at FEMOV 100. Specimens marked e at 100 or above are probably mis-sexed. See Methods for derivation of variables FEMOV and MALOV.

The range of variation in males from England is greater than that of females in the latter characters. As in the females, there are a few individuals that do not fit the pattern. One individual with a small bill in all characters (BM 1936-2-18-1) may be mis-sexed. Two large birds I first placed in the sample from England are from the Leadenhall Market in London, taken in 1881 and 1890 (see Collinson 2012). The label on an unsexed bird associated with those indicates that they were actually taken in Scotland, so later I included them in that sample.

With the few exceptions noted above, the available specimen record shows no overlap in winter distribution of the two size classes, although more recent observations (Parkin and Knox 2010:37) indicate at least some winter sympatry of *A. a. flavirostris* and *A. a. albifrons*, which would be the smaller English birds.

Variation in *A. a. flavirostris*.—Birds of the population here considered to be *A. a. flavirostris* are rather uniformly distributed in a narrow range of measurements (Appendix 1), although a few individuals of either sex seem to increase the range of variation in any character; these may be mis-sexed birds. In females, there is a slight suggestion, based on bill depth, of two groups within the sample, with a break at 23 mm. Although these birds can generally be distinguished from neighboring wintering birds on the basis of bill measurements, they are more easily distinguished by their darker brown color and usually much more heavily marked underparts. Bill color, for which the race is named, is not a reliable character in older museum specimens.

Variation in England.—Birds of both sexes in England are distributed over a rather narrow range of bill measurements (Appendix 1), but a few possibly mis-sexed individuals of either sex extend the apparent range of variability. In males there is a slight suggestion of a break into two size classes at a bill depth of about 22 mm.

Continental Europe

The European continental sample consists of 37 males and 15 females, mainly from countries of western Europe but with individuals from Serbia, Palestine, and Egypt. Males average slightly larger than females in every character measured, but overlap is extensive in some (Appendix 1). Some males are smaller in some characters than any females, and some females are larger than any males. Bills are slightly wider than deep, and nails are slightly longer than wide. Males are fairly uniform in culmen length, ranging from 44 to 49 mm. Females are slightly smaller, with most culmens 41–44 mm in length. There is near complete separation of males and females at culmen length 44 mm (Figure 5). In this sample three birds labeled females are more like males in bill dimensions. Three birds labeled as male but with culmens less than 44 mm long may be wrongly sexed. Thus the mean measurements given in Appendix 2 may be slightly low for males and slightly high for females. However, these measurements of culmen length are almost identical to those for bill length given by Cramp and Simmons et al. (1977:409) for birds from Netherlands, although my measurements of wing length (chord) average somewhat less.

England plus Europe

Mean measurements of all characters are virtually identical, in both sexes, in the samples from England and continental Europe, and I combined data into a single sample for further analysis. The combined samples included 63 males and 34 females. Although scatterplots of bill measurements against one another show no patterns, the comparison of OVs yields some interesting suggestions. In males there is an indication of a separation into two classes at MALOV about 62.5 and FEMOV 98. In females, there is a slightly stronger indication of a separation at MALOV 61. In both sexes, about a third of the sample is below the separation, and about two-thirds above it. Birds from both England and the continent are in both groups. It is possible that the total European wintering population represents two slightly different size classes of geese, which may breed in different areas.

Asia

The Asian sample (26 of each sex) is composed primarily of birds from China, Japan, and Korea but includes three birds from Pakistan and two from India. Most are wintering birds, but those in a small series from Manchuria are spring migrants. There are also single October birds from Lake Baikal and Bering Island.

Asian males average slightly larger than European ones in all bill dimensions (Appendices 1, 2). They are also more variable than are European ones, with most culmens ranging from about 45 to about 55 mm in length; the increased variability is toward larger size. The few birds with shorter culmens may be mis-sexed. The birds with the longer and deeper bills are primarily from Korea and Japan, although there are larger and smaller birds in every region.

As is the case with males, females of the Asian sample average slightly larger than their European counterparts and with the exception of bill width have a greater range of variation. Culmen length is generally 44–48 mm, about the range of most males in the European sample. Two birds with culmen greater than 50 may actually be males. Even the small Asian females are slightly larger than the European females in culmen length.

There is some indication that the Asian males can be divided into two size classes on the basis of bill depth (Figure 6); there seems to be a division in bill depth at about 23.5 mm, with eight birds above that mark. Similarly, several birds stand out as having wider bills than most. Six specimens are among the largest in at least two of the bill characters, but 13 others are among the largest in one character. There is also some indication of division

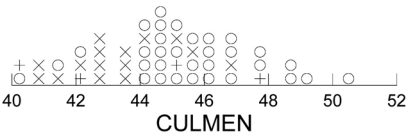

Figure 5. Culmen lengths (mm) of specimens of the Greater White-fronted Goose from continental Europe. Circles represent males, × females, + unsexed. With the exception of some possibly mis-sexed birds, there is near complete separation of the sexes at culmen length about 44 mm.

into two size classes in females, with a break in bill width at about 23 mm; plotting bill depth versus bill width shows that gap and its relationship to bill depth (Figure 7). In both sexes, but especially females (Figure 8), comparison of OVs more strongly suggests a division into two size classes. Given the uncertainty as to where to draw the line in a continuum in most measurements and the fact that some birds may be mis-sexed, division of the sample into two size classes is somewhat subjective and tentative. Nonetheless, I separated subsamples of larger and smaller individuals of both sexes for comparison (Appendix 1). Mean measurements of the two groups do not differ much, and there is considerable overlap in ranges of the two groups. If there are in fact two size classes of birds in Asia, these winter specimens do not reveal it well, and there is no separation by geography. The winter specimens seem to reflect a cline in size of breeding birds across Eurasia (Dement'ev and Gladkov 1967, Ely et al. 2005). In general, the smaller Asian birds are about the same as the European sample.

Western North America

White-fronted Geese migrate south from coastal Alaska west of the Rocky Mountains through British Columbia, Washington, and Oregon to winter primarily in California, some going on to western Mexico. Birds from interior Alaska and western and arctic Canada migrate east of the Rockies through the plains states, wintering primarily in Texas and Louisiana, some traveling on to eastern Mexico. Specimens are available from scattered localities along the migration routes, but most are from winter concentrations. Few specimens are available from Mexico. This analysis concentrates on areas from which large samples are available.

Northern California.—Specimens from northern California are from two general areas, around the head of Suisun Bay and Grizzly Island in Solano

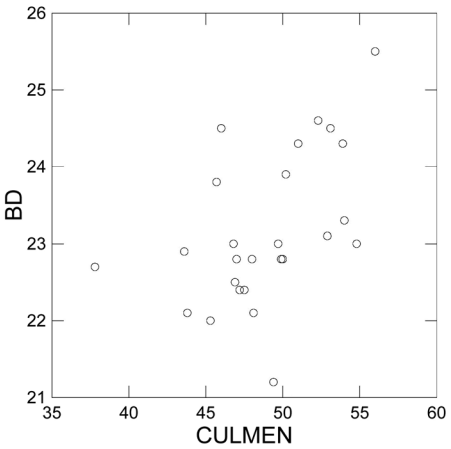

Figure 6. Bill depth (BD) versus culmen length of male Greater White-fronted Geese from Asia, showing possible separation into two size classes at bill depth 23.5. Specimen at far left, culmen <40, is probably mis-sexed.

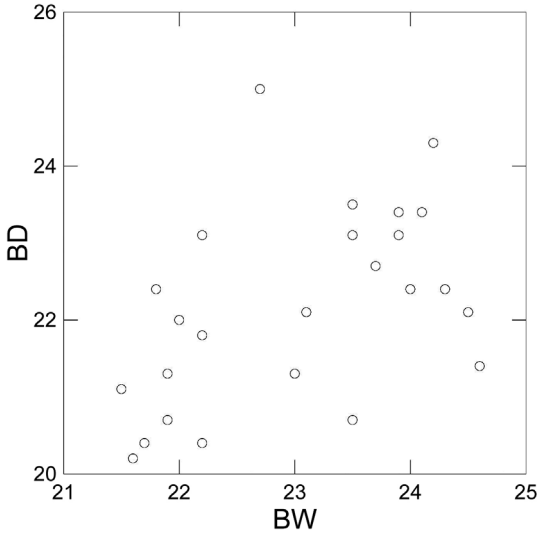

Figure 7. Bill depth (BD) versus bill width (BW) of female Greater White-fronted Geese from Asia, showing a break into two possible size classes at about bill width 23 mm.

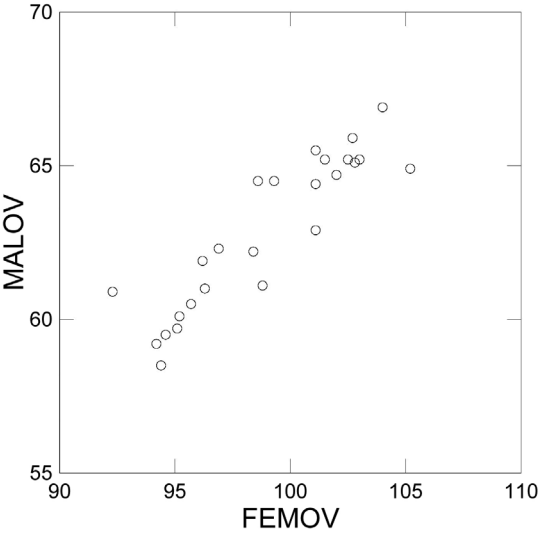

Figure 8. Separation of female Greater White-fronted Geese from Asia into two possible size classes based on a break at MALOV about 64. See Methods for derivation of variables FEMOV and MALOV.

County, and the marshlands of the Sacramento Valley. Although the specimens' dates span a long period, they are concentrated in the first half of the 20th century after the discovery and description of the Tule Goose, now known as *A. a. elgasi*, by Swarth and Bryant (1917) until the beginning of World War II. Most were taken at hunting clubs, many by scientists/sportsmen/collectors from the California Academy of Sciences and Museum of Vertebrate Zoology who were aware of the existence of the larger form.

There is a wide range of variation in all bill measurements in both the 61 males and 47 females in the Sacramento Valley sample. Linear plots of measurements indicate that distribution is essentially continuous but also suggest a division into two or more size classes in both sexes. The best indication of such a division is in the OV ratios. In males (Figure 9), FEMOV breaks at 114–115, and all above that have MALOV of 70 or greater. In this group culmen length is greater than 55 mm and bill depth is 25 mm or greater (Appendix 1). Males with FEMOV less than 114 could be further divided into two groups with a break in MALOV at about 67, and the smaller of these could be even further divided on the basis of MALOV or culmen length. Although such divisions become increasingly arbitrary, they point out that the wintering population is far from uniform. A group of nine individuals with culmens less than 49 mm, plus one bird with the shortest bill depth, make up the "smallest" sample, which emphasizes the difference between the largest birds and the smallest (Appendix 1).

In females, FEMOV breaks between 105.5 and 108.8 (Figure 10), with a single individual (possibly mis-sexed) in that gap. All birds with the higher values of FEMOV have MALOV of 65 or greater. These birds also have a culmen of 52 mm or greater, bill depth 22.9 mm or greater, and bill width 24.2 mm or greater. Smaller females with FEMOV 105.5 or less have a culmen 51.6 mm or less, bill depth 23.9 mm or less (except for one with bill depth 27.4 mm), and bill width 24.4 mm or less. There are four females for which bill width, and therefore either OV, is not available, but all have a culmen less than 52 mm. Data for the small Sacramento Valley females in Appendix 1 include the possibly mis-sexed bird in the FEMOV gap. It might be possible to divide the small Sacramento Valley females into two or more groups, with a break at MALOV 63, but, as with males, such divisions are arbitrary. One group of four individuals (lower left in Figure 10) would constitute a "smallest" female group but are not separated in Appendix 1.

Large Sacramento Valley males have culmens more than 54 mm long, considerably longer than European and all but one of the Asian males. Culmens in large females are more than 52 mm long, much longer than females in Europe or Asia. Width and depth of the bill in both sexes also exceeds those of most or all the European and Asian birds. The sample of smaller Sacramento Valley birds averages slightly larger than their European or Asian counterparts, and there is considerable overlap in the ranges of measurements, although the Sacramento birds are at the high end of the range of the other birds. There is some indication that the smallest Sacramento Valley males average about the same as European or Asian males.

The sample of specimens from Grizzly Island and Solano County is less numerous than that from the Sacramento Valley, but it shows essentially the same range of measurements and the same division into two size classes.

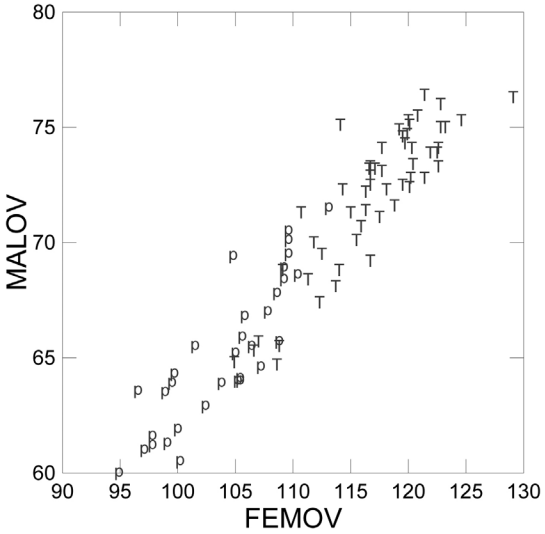

Figure 9. Orthmeyer values of male Greater White-fronted Geese from the Sacramento Valley of California, showing a break at FEMOV 114–115. Smaller birds, labeled p, correspond to what are generally called Pacific white-fronts, whereas larger birds, marked T, would be called Tule Geese. See Methods for derivation of variables FEMOV and MALOV.

Birds of the smaller size class are too few for statistical analysis. In both sexes birds of the larger size classes are nearly identical to the larger Sacramento Valley birds (Appendix 1).

Southern California.—Specimens from the southern half of California are primarily from the San Joaquin Valley in the vicinity of Los Banos, Merced County. There are two large series, one taken 1908–1909 and one taken 1911–1912. In both sexes, bill measurements (Appendix 1) are about the same as in the smaller of the Sacramento Valley size classes. A single male from Los Banos is as large in most measurements as the larger birds in the larger Sacramento Valley sample.

Other West Coast Birds.—Other specimens are migrants or wintering birds from localities scattered throughout the western states and provinces, but there are no localities represented by a series of birds large enough to be analyzed as a sample. From the Northwest, there are seven males and five females ranging from the Queen Charlotte Islands, British Columbia, to the Columbia River. Judged from culmen length alone, all are in the size class of the smaller Sacramento Valley specimens; only one male and one female are near the upper limits of that class. Another set from Tule Lake National Wildlife Refuge in Siskiyou Co., California, with one from nearby Klamath Co., Oregon, has eight males and three females. All these also are of the class of smaller Sacramento Valley specimens. One bird captured at an unspecified locality in Oregon and held in captivity for some time has

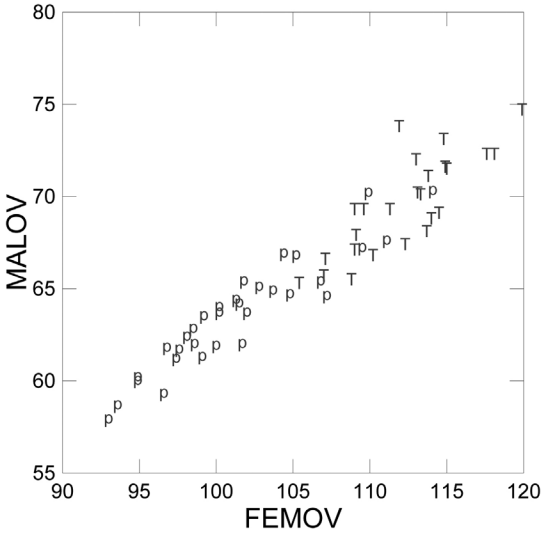

Figure 10. Orthmeyer values of female Greater White-fronted Geese from the Sacramento Valley, showing a break at FEMOV 106–109 and another break at MALOV 63. Smaller birds, labeled p, correspond to what are generally called Pacific white-fronts, whereas larger birds, marked T, would be called Tule Geese. See Methods for derivation of variables FEMOV and MALOV.

a culmen in the range of the larger Sacramento Valley birds. Specimens from scattered localities in California are all of the smaller size class, as are individual vagrants from Nevada and Arizona (Phillips et al. 1964).

Mexico.—I have seen only 7 specimens from Mexico (Jalisco and Sonora), of which two are not sexed. One male and one unsexed bird have culmens of 54.3 and 54.0 mm and thus are at the low end of the range of the large Sacramento Valley birds. Overall, however, they all are in the small size class.

Central Flyway

This large sample consists of both spring and fall migrants and wintering birds from east of the Rocky Mountains and primarily west of the Mississippi River. The largest winter samples are from Texas and Louisiana; there is one group of spring migrants from Saskatchewan. Subdivision by season or geography yields samples that are too small for meaningful statistical comparison.

Of 12 males from Louisiana, five have culmens 54–55 mm, three have culmens 51–53 mm, and two have culmens less than 49 mm. Two birds stand out as the largest in all bill measurements and thus in OVs, equaling some of the large Sacramento Valley birds. These two specimens (CAS 57734, LSU 5609) were taken together, along with several smaller individuals. This small Louisiana sample could break into two or three size classes depending on which character one chooses. A small sample of eight

wintering males from Texas breaks into two size classes. The 14 migrant males from Saskatchewan are fairly uniform, with no apparent division into size classes. Neither spring nor fall migrants from scattered localities in the mid-continent states and provinces show any tendency to break into size classes, although variation is extensive.

Overall, males of the Central Flyway sample seem fairly evenly distributed through a large range of variation in each bill measurement (Appendix 1), although a few individuals stand out in one measurement or another. On average, the Central Flyway birds are about the same size as the smaller Sacramento Valley birds, although there are some larger individuals. Comparison of the OVs suggest that males might be of three size classes, although the largest and smallest are represented by only a few birds each. The breaks are in MALOV, at about 69.5 and 64.5, with eight individuals above or below those arbitrary indicators. There is a considerable difference in the means of all bill measurements between the larger and smaller birds (Appendix 1).

Eleven wintering females from Louisiana break into two size classes based on bill measurements. Three of 10 Texas females lack bill width data, but four individuals stand out as large on the basis of other measurements. Three of 11 spring birds from Saskatchewan stand out as larger than the others in combined bill measurements. Of 24 other spring migrants from mid-continent, two stand out as large in individual or combined bill measurements; the others might arbitrarily be divided into two size classes, but variation is fairly uniform.

Overall, females in the Central Flyway seem to break into only two rather than three size classes, the break being at about 106.5 FEMOV and about 65 MALOV. Culmen length is evenly distributed between 45 and 55 mm, but both bill width and bill depth are more variable. The sample of "large" females (Appendix 1) is probably not strictly analogous to the similar sample of males, and there is no sample of "smallest" females.

In both sexes, there are large individuals in the Central Flyway that equal, or nearly equal, the large Sacramento Valley or Grizzly Island birds. Two males from Louisiana, noted above, are distinguished by their wide bills; their culmens are also long, and one also has a deep bill. One male in the Saskatchewan group has a very long culmen, well within the range of the large Sacramento Valley birds. Four females taken in April 1925 at Whitewater Lake in Manitoba are all large and include the two largest females from the Central Flyway (Table 1).

Eastern North America.—There is no winter concentration of these geese in eastern North America, where the species occurs only as wandering vagrants. There are relatively few available specimens, from eastern Canada (Labrador) to the southern United States (Georgia). Some specimens taken in the birds' first autumn have been reported (e.g., Godfrey 1986) but were not examined for this study. Most of the 18 specimens seen (6 male, 7 females, 5 unsexed) were first-year birds. The origin of these birds is problematic. Culmen length indicates that most could have come from the Central Flyway population or from Greenland. Several specimens have been identified as *A. a. flavirostris*, but most were labeled and cataloged before that subspecies was named, and some may not have been critically examined since. Bill color in old specimens is not a useful character. The culmens of two specimens

(FM 96688, Massachusetts; USNM 419879, North Carolina) are so short as to suggest the birds are from the European population.

Large Specimens

Several times in the previous comments I have noted large individual specimens, out of the normal size range of the wintering populations of which they were a part. These large individuals, about the size of the large Sacramento Valley or Grizzly Island birds, *A. a. elgasi*, are scattered across arctic Canada and through the Central Flyway (Table 1). The more northerly of them were the basis for attributions of the breeding range of the large California birds (when they were known as *A. a. gambelli*) to eastern arctic Canada. Kuroda (1927:176) mentioned the British Museum specimen from "Arctic Coast, E. of Ft Anderson" as proof of the hypothesis of Swarth and Bryant (1917) that *gambelli* (meaning the large California birds, now *A. a. elgasi*) might breed in arctic America east of Alaska. Kortright (1942:124) discussed birds reported as Tule Geese by A. Gavin near the Perry River in 1941; colonies of both large and small geese were found about 6 miles apart, and one of each was shot. Unfortunately, "neither photographs nor specimens were taken" (Gavin

Table 1 Large North American Specimens of *Anser albifrons* Collected Outside the Sacramento Valley, California[a]

Museum and catalog number	Sex	Locality	Year	Culmen (mm)	FEMOV[b]	MALOV[b]
USNM 607220	—	Washington, DC	1856	57.5	114.8	71.7
USNM 16788	—	Hudson Bay Territory	<1860	55.6	111.2	68.6
USNM 20138	—	Fort Resolution, Great Slave Lake	1860	58.5	116.5	68.7
BM 483112	—	Repulse Bay, NWT	—	61.9	120.7	72.5
BM 922365	F	Arctic coast e of Ft. Anderson	1865	56.0	117.5	75
CAS 13722	M	Merced Co., CA	1909	57.0	115.9	70.7
OTT 19866	F	Whitewater Lake, Manitoba	1925	55.9	114.2	70.7
OTT 19869	F	Whitewater Lake, Manitoba	1925	57.5	115.6	69.7
CAS 57734	M	Abbeville, Vernon Par., LA	1941	54.6	116.2	72.5
LSU 5609	M	Abbeville, Vernon Par., LA	1941	55.0	117.1	73.6
CM 129536	M	Richards Island, Mackenzie Delta	1942	59.4	114.8	67.2
FM 208475	M	Perry River, NWT	1949	56.6	114.5	69.5
FM 208477	F	Perry River, NWT	1949	53.9	108.7	66.0
CM 136366	M	Richards Island, Mackenzie Delta	1955	57.8	116.3	72.0

[a]Other large birds reported: Perry River, by Gavin in 1941; specimens shot, apparently not preserved (Kortright 1942). Adult male captured alive, Buffalo Coulee Lake, Saskatchewan, 23 September 1963; culmen 54 mm, wing 470 mm (Alex Dzubin pers. comm.).

[b]See Methods for derivation of variables FEMOV and MALOV.

1947), although weights of 5 and 9 pounds were estimated. No difference in the birds' taste was noted. Todd (1950) mentioned the 1942 specimens from the Mackenzie Delta in support of Kuroda. Hanson et al. (1956) obtained large specimens from the Perry River area in 1949. In most instances, however, these large birds were taken at the same time and place as smaller individuals, often not mentioned in the reports, suggesting that they are merely large individuals and not representatives of a population of large birds. In some reports, "large" was not quantified, and large birds were found by workers attempting to prove the breeding grounds of the birds wintering in the Sacramento Valley. On the other hand, the possibility that there is (or was) a numerically small population of very large birds widely scattered through the Arctic and sympatric with but ecologically separated from smaller birds cannot be ruled out.

CAVEATS

This is a study of museum specimens and so has several possible pitfalls. Most of the specimens seen, in museums in the United States, eastern Canada, and parts of Europe, were taken many years ago; relatively few specimens of this species have been entered into museum collections since the 1940s. The museum age of the specimens probably has little effect on their measurements, but one must remember that they represent conditions at the time of collecting and not those of the present. The winter distribution of some breeding populations may have changed in the last century or so, as certainly have the numerical sizes of some wintering populations (Banks and Springer 1994, Mooij 2000.). Furthermore, such a study is limited by where past collectors chose, or were able, to work.

ACKNOWLEDGMENTS

Most measurements were made by my wife, Gladys C. Banks, who volunteered as my research assistant for many years of this study. She also entered the data into the SYSTAT data base. I appreciate access to specimens and other courtesies extended by personnel at the following museums and institutions where specimens were measured (abbreviations are given where particular specimens are mentioned): Academy of Natural Sciences of Philadelphia; American Museum of Natural History (AMNH), New York; Bell Museum of Natural History, University of Minnesota, Minneapolis; California Academy of Sciences (CAS), San Francisco; Canadian Museum of Nature (OTT), Ottawa; Carnegie Museum of Natural History (CM), Pittsburgh; Cincinnati Museum of Natural History, Cincinnati; Denver Museum of Natural History, Denver; Field Museum of Natural History (FM), Chicago; Museum of Comparative Zoology, Harvard University, Cambridge, MA; Muséum d'Histoire Naturelle, Paris; Museum of Natural Sciences, Louisiana State University (LSU), Baton Rouge; Museum of Vertebrate Zoology, University of California, Berkeley; Museum of Zoology, University of Michigan, Ann Arbor; [British] Natural History Museum (BM), Tring, England; Natural History Museum, University of Kansas, Lawrence; Naturhistorisches Museum Wien, Vienna, Austria; Peabody Museum, Yale University, New Haven, CT; Royal Ontario Museum, Toronto; San Diego Natural History Museum, San Diego; University of Montana, Missoula; U.S. National Museum of Natural History (USNM), Washington, DC. Daniel D. Gibson provided measurements of specimens in the University of Alaska Museum. Welder Wildlife Foundation sent specimens to LSU for my use. Craig Ely sent me copies of several references and was a cooperative correspondent throughout most of the study. Brian K. Schmidt assisted in preparing the figures.

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Accepted 6 March 2012

Appendix 1. Summary of measurements (mm) of wintering populations of the Greater White-fronted Goose.

	Male				Female			
	n	Range	Mean	SE	*n*	Range	Mean	SE
Ireland–Scotland								
Wing length	31	390–433	412	2.0	36	377–424	398	2.0
Culmen length	30	46.4–55.3	51.6	0.4	36	45.6–54.1	49.3	0.4
Bill width	32	23.2–26.0	24.5	0.1	36	21.7–25.5	23.6	0.1
Bill depth	32	22.7–25.9	24.2	0.2	36	20.9–25.5	23.1	0.2
Nail length	29	12.3–15.9	14.1	0.2	36	12.2–16.0	14.1	0.2
Nail width	31	10.3–13.1	11.7	0.1	36	9.4–13.2	11.2	0.1
FEMOV	30	103–112	107	0.5	36	97–110	103	0.5
MALOV	32	65–71	67	0.3	36	59–69	65	0.3
England								
Wing length	26	377–431	404	2.7	19	356–409	388	3.4
Culmen length	28	39.8–54.3	46.6	0.7	19	38.5–48.7	43.0	0.2
Bill width	27	20.2–24.7	23.3	0.2	19	20.1–24.2	22.5	0.3
Bill depth	28	20.4–25.2	22.6	0.2	19	19.1–23.1	21.8	0.2
Nail length	27	10.7–15.3	13.1	0.2	18	10.4–15.7	12.8	0.4
Nail width	27	9.7–13.1	11.4	0.2	18	10.1–13.0	11.4	0.2
FEMOV	27	87–109	100	1.0	19	88–104	95	0.9
MALOV	27	56–68	64	0.5	19	57–65	62	0.6
Continental Europe								
Wing length	33	374–438	403	2.6	15	378–404	387	1.9
Culmen length	32	40.1–50.5	45.6	0.4	15	40.7–46.7	43.3	0.4
Bill width	29	21.5–25.1	23.3	0.2	13	20.2–24.8	22.1	0.3
Bill depth	33	20.1–25.0	22.6	0.2	15	20.0–23.9	21.8	0.2
Nail length	32	10.6–14.9	13.1	0.2	15	10.2–15.1	12.6	0.3
Nail width	32	9.7–13.3	11.5	0.2	15	10.1–12.6	11.4	0.2
FEMOV	28	92–106	99	0.7	13	88–100	94	1.1
MALOV	28	59–70	64	0.5	13	57–66	61	0.7
Europe + England								
Wing length	57	374–438	404	2.0	34	356–409	387	2.1
Culmen length	58	39.8–50.5	45.8	0.3	34	38.5–48.7	43.1	0.4
Bill width	54	20.2–25.1	23.2	0.1	32	20.1–24.8	22.4	0.2
Bill depth	59	20.1–25.0	22.6	0.1	34	19.1–23.9	21.8	0.2
Nail length	58	10.6–15.3	13.1	0.1	33	10.2–15.7	12.7	0.2
Nail width	58	9.7–13.3	11.4	0.1	33	10.1–13.0	11.4	0.1
FEMOV	53	87–106	99	0.5	32	88–104	95	0.7
MALOV	54	56–68	64	0.3	32	57–66	61	0.4
Asia								
Wing length	24	364–438	403	2.9	25	360–436	391	3.5
Culmen length	26	37.8–56.0	48.9	0.8	26	41.4–51.7	46.0	0.5
Bill width	24	23.0–26.0	23.9	0.2	25	21.5–24.6	23.0	0.2
Bill depth	26	21.2–25.5	23.2	0.2	26	20.2–25.0	22.2	0.2
Nail length	26	11.4–15.7	13.6	0.3	26	10.7–18.7	13.6	0.3
Nail width	26	10.2–14.0	12.1	0.2	26	9.8–13.5	11.7	0.2
FEMOV	24	93–110	103	1.0	25	92–105	99	0.7
MALOV	23	62–69	65	0.4	25	59–67	63	0.5

(*continued*)

Appendix 1. (*continued*)

	Male				Female			
	n	Range	Mean	SE	*n*	Range	Mean	SE
Asia—large specimens								
Wing length	14	384–438	408	3.5	12	381–436	397	4.5
Culmen length	15	43.6–56.0	50.2	1.0	13	44.2–51.7	47.0	0.7
Bill width	13	23.5–26.0	24.4	0.2	12	22.7–24.6	23.9	0.1
Bill depth	15	22.1–25.5	23.7	0.2	13	21.4–25.0	23.1	0.3
Nail length	15	11.4–15.7	13.8	0.4	13	11.4–18.7	13.7	0.5
Nail width	15	10.2–14.0	12.1	0.3	13	9.8–13.5	12.0	0.3
FEMOV	13	99–110	106	1.1	12	99–105	102	0.5
MALOV	13	65–69	67	0.3	12	64–67	65	0.2
Asia—small specimens								
Wing length	10	364–412	396	4.2	13	360–419	386	5.0
Culmen length	11	37.8–52.9	47.0	1.2	13	41.4–48.2	45.0	0.5
Bill width	11	23.0–23.7	23.3	0.1	13	21.5–23.5	22.2	0.2
Bill depth	11	21.2–23.1	22.5	0.2	13	202–2 3.1	21.3	0.2
Nail length	11	12.0–15.2	13.3	0.4	13	10.7–15.7	13.5	0.4
Nail width	11	10.4–13.8	12.0	0.3	13	9.8–13.2	11.4	0.3
FEMOV	11	93–107	101	1.1	13	92–101	96	0.6
MALOV	11	62–65	64	0.3	13	59–63	61	0.4
Sacramento Valley—large specimens								
Wing length	23	408–474	440	3.1	18	405–440	422	2.7
Culmen length	24	55.4–61.2	58.8	0.4	18	52.2–58.4	55.0	0.4
Bill width	22	25.8–28.1	26.8	0.1	18	24.2–27.2	25.5	0.2
Bill depth	24	25.0–28.4	26.5	0.2	18	22.9–27.4	25.2	0.3
Nail length	24	14.3–18.2	16.1	0.2	18	13.3–17.7	15.4	0.2
Nail width	24	10.3–14.4	12.9	0.2	18	10.2–14.0	12.5	0.3
FEMOV	22	116–125	120	0.6	18	109–120	113	0.8
MALOV	22	70–76	73	0.4	18	66–75	70	0.6
Sacramento Valley—small specimens								
Wing length	36	378–448	419	2.5	29	387–414	402	1.6
Culmen length	37	44.5–55.7	55.7	0.5	29	43.8–53.4	47.5	0.4
Bill width	35	21.5–26.2	24.0	0.2	25	21.1–24.4	22.8	0.2
Bill depth	37	20.7–26.0	23.8	0.2	29	20.6–24.9	22.5	0.2
Nail length	36	12.8–17.0	14.7	0.2	29	12.2–14.6	13.5	0.1
Nail width	36	10.8–13.7	12.3	0.1	29	09.5–12.6	11.6	0.1
FEMOV	34	95–113	106	0.9	25	93–107	100	0.7
MALOV	34	60–72	66	0.5	25	58–67	63	0.4
Sacramento Valley—smallest specimens								
Wing length	10	378–432	407	5.8				
Culmen length	10	44.5–48.5	46.4	0.4				
Bill width	9	21.5–23.9	22.8	0.2				
Bill depth	10	20.7–23.7	22.7	0.3				
Nail length	10	12.8–15.4	14.2	0.3				
Nail width	10	11.0–13.6	12.2	0.3				
FEMOV	10	95–102	98	0.7				
MALOV	9	60–66	63	0.6				

(*continued*)

Appendix 1. (*continued*)

	Male				Female			
	n	Range	Mean	SE	*n*	Range	Mean	SE
Grizzly Island, California								
Wing length	17	422–463	440	2.9	8	414–430	423	2.3
Culmen length	17	53.0–64.6	58.3	0.7	8	52.8–59.2	54.9	0.8
Bill width	17	25.1–28.5	26.7	0.2	8	23.6–26.2	25.1	0.3
Bill depth	17	25.1–28.5	25.6	0.2	8	23.4–28.6	25.4	0.6
Nail length	17	14.6–19.1	16.4	0.3	8	14.6–17.0	15.6	0.3
Nail width	17	11.7–14.2	13.0	0.2	8	11.7–13.3	12.2	0.2
FEMOV	17	114–129	119	0.9	8	107–118	112	1.2
MALOV	17	69–76	73	0.4	8	66–74	69	1.0
Merced Co., California								
Wing length	43	381–431	408	2.1	37	363–410	390	1.6
Culmen length	46	41.8–57.0	49.3	0.4	38	41.4–53.8	47.1	0.5
Bill width	46	22.4–25.9	24.0	0.1	37	19.2–24.5	23.0	0.2
Bill depth	46	21.5–25.2	23.3	0.1	38	20.0–23.8	22.1	0.1
Nail length	46	12.3–16.4	14.2	0.1	38	11.4–15.8	13.5	0.2
Nail width	46	10.7–13.1	12.0	0.1	38	10.1–13.8	11.7	0.1
FEMOV	46	98–116	104	0.6	37	86–110	100	0.8
MALOV	46	61–71	65	0.3	37	54–66	63	0.4
Central Flyway								
Wing length	63	377–438	408	1.8	59	362–422	397	1.8
Culmen length	64	46.6–57.3	52.3	0.3	61	43.2–57.5	50.4	0.4
Bill width	64	22.0–27.1	24.3	0.1	58	21.2–25.6	23.5	0.2
Bill depth	64	2.1–26.2	24.3	0.1	61	20.2–25.8	23.3	0.1
Nail length	63	12.0–18.0	14.8	0.1	61	12.1–16.6	14.3	0.1
Nail width	64	9.7–14.2	12.2	0.1	61	9.8–13.5	11.8	0.1
FEMOV	64	99–117	108	0.5	58	95–116	104	0.7
MALOV	64	62–74	67	0.3	59	59–71	65	0.4
Central Flyway—large specimens								
Wing length	8	409–435	421	3.1	20	375–422	404	3.0
Culmen length	8	52.2–55.2	54.2	0.3	21	48.1–57.5	53.3	0.5
Bill width	8	25.1–27.1	26.0	0.2	21	23.5–25.6	24.7	0.1
Bill depth	8	24.7–26.2	25.5	0.2	21	22.8–25.8	24.3	0.2
Nail length	7	14.5–16.3	15.5	0.3	21	12.9–16.0	14.8	0.2
Nail width	8	10.7–14.2	12.0	0.4	21	10.4–13.5	11.8	0.2
FEMOV	8	112–117	114	0.7	21	107–116	110	0.5
MALOV	8	70–74	71	0.5	21	65–71	68	0.3
Central Flyway—small specimens								
Wing length	8	377–425	394	6.0				
Culmen length	8	46.6–51.8	49.4	0.6				
Bill width	8	22.0–23.2	22.7	0.2				
Bill depth	8	21.1–23.9	22.0	0.3				
Nail length	8	12.0–15.0	14.0	0.3				
Nail width	8	9.7–13.0	12.0	0.4				
FEMOV	8	99–103	101	0.4				
MALOV	8	62–64	63	0.2				

Appendix 2. Means of measurements (mm) of populations of the Greater White-fronted Goose, mainly from Appendix 1 but with some subsamples added.

Sex and population	Wing	Culmen	Bill width	Bill depth	Nail width	Nail length	FEMOV	MALOV
Males								
Ireland–Scotland	412	51.6	24.5	24.2	11.7	14.1	107	67
England	404	46.6	23.3	22.6	11.4	13.1	100	64
Continental Europe	403	45.6	23.3	22.6	11.5	13.1	99	64
Europe + England	404	45.8	23.2	22.6	11.4	13.1	99	64
Asia—all specimens	403	48.9	23.9	23.2	12.1	13.6	103	65
Asia—large specimens	408	50.2	24.4	23.7	12.1	13.8	106	67
Asia—small specimens	396	47.0	23.3	22.5	12.0	13.3	101	64
Sacramento Valley—large specimens	440	58.6	26.8	26.5	12.9	16.1	119	73
Sacramento Valley—small specimens	418	50.4	24.0	23.7	12.3	14.7	105	66
Sacramento Valley—smallest specimens	407	46.4	22.8	22.7	12.2	14.2	98	63
Grizzly Island	440	58.3	26.7	25.6	13.0	16.4	119	73
Merced Co.	408	49.3	24.0	23.3	12.0	14.2	104	65
Central Flyway	408	52.3	24.3	24.3	12.2	14.8	108	67
Central Flyway—large specimens	420	54.2	25.5	25.5	15.5	12.0	114	71
Central Flyway—small specimens	394	49.4	22.7	23.0	14.0	12.0	101	63
Louisiana	408	52.5	25.2	24.8	12.2	15.0		
Texas	413	54.0	24.8	24.3	12.2	15.1		
Saskatchewan	413	53.0	24.0	24.8	12.7	15.1		
Central Flyway—fall specimens	412	52.1	24.2	24.3	12.0	14.7		
Central Flyway—spring specimens	403	51.3	23.9	23.6	11.9	14.4		
Females								
Ireland–Scotland	398	49.3	23.6	23.1	11.2	14.1	103	65
England	388	43.0	22.5	21.8	11.4	12.8	95	62
Continental Europe	387	43.3	22.1	21.8	11.4	12.6	94	61
Europe + England	387	43.1	22.4	21.8	11.4	12.7	95	61
Asia—all specimens	391	46.0	23.0	22.2	11.7	13.6	99	63
Asia—large specimens	397	47.0	23.9	23.1	12.0	13.7	102	65
Asia—small specimens	386	45.0	22.2	21.3	11.4	13.5	96	61
Sacramento Valley—large specimens	422	55.0	25.5	25.2	12.5	15.4	113	70
Sacramento Valley—smallest specimens	402	47.5	22.8	22.5	11.6	13.5	100	63
Grizzly Island	423	54.9	25.1	25.4	12.2	15.6	112	69
Merced Co.	390	47.1	23.0	22.1	11.7	13.5	100	63
Central Flyway	397	50.4	23.5	23.3	11.8	14.3	104	65
Central Flyway—large specimens	404	53.3	24.7	24.3	11.8	14.8	110	68
Louisiana	396	51.5	23.8	24.0	11.9	14.2		
Texas	397	50.1	23.7	23.0	11.7	14.5		
Saskatchewan	401	50.3	22.4	23.0	12.3	14.7		
Central Flyway—spring specimens	398	50.4	23.7	23.3	11.6	14.1		