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EVIDENCE FROM SALT GLAND ANALYSIS FOR CONVERGENCE OF MIGRATORY ROUTES AND POSSIBLE GEOGRAPHIC VARIATION IN LESSER SCAUP

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INTRODUCTION

Oil pollution resulted in death for thousands of migrating waterfowl in late March and early April, 1963 on the Mississippi River in Minnesota. An account of the effect of this pollution on wildlife has been presented by Peller (1963). A total of 3,333 birds affected by this pollution were picked up. Lesser Scaup (*Aythya affinis*) totaled 65 percent of the sample.

METHODS AND RESULTS

The supraorbital salt glands of Lesser Scaup were dissected and weighed. Supraorbital salt glands, as the name implies, are located above the orbit of the eye and function in the excretion of excess ingested salt. When birds with functional salt glands drink salt water the glands increase in size (Schildmacher, 1932; Schmidt-Nielsen and Kim, 1964). Schmidt-Nielsen and Kim showed that among mallards of approximately the same age, little or no overlap occurs in salt gland weights of birds given fresh water, one percent

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TABLE 1. STATISTICAL ANALYSIS OF SALT GLAND SAMPLES

	MALES					FEMALES			
	Adults			Yearlings		Adults		Yearlings	
	A	B	C	A	B	A	B	A	B
N	470	151	18	125	43	193	42	91	11
$\bar{X}$	508*	426	417	520	410	422	392	462	349
1SD	183	106	115	174	100	144	111	173	112
1SE	8.44	8.62	27.12	15.56	15.24	10.23	17.13	18.13	33.73
CV	36.00	24.90	25.70	33.10	24.40	34.10	28.30	37.40	31.20

A = Birds killed outright
B = Birds that were captive for unknown lengths of time
C = Males captive for a known duration of time
N = sample size, $\bar{X}$ = sample mean, 1SD = one standard deviation of the mean, CV = coefficient of variation expressed as a percentage.

*Means are in milligrams.

NaCl and two or three percent NaCl in their drinking water. Therefore it seemed that the presence of birds from fresh and salt water wintering areas might be indicated by analysis of salt gland weights.

The range of weights for salt gland pairs of adult males is 200 to 1,099 mgms., the coefficient of variation is very large (see Table 1) and the distribution is skewed.

Several hundred birds were not killed outright by the oil and were maintained in captivity for periods ranging from three to 90 days. The precise length of time that each individual bird was maintained in captivity is not known. The salt gland pair weights of these birds range from 200 mgms. to 462 mgms. The mean salt gland pair weight of the captive birds is significantly smaller than the mean of the birds killed outright at the .01 level.

In addition to birds which were in captivity for an unknown time duration, 18 males had been tagged and it was known precisely how long each of these birds had been in captivity before its death. The length of this captive period ranged from 10 to 62 days and averaged 30 days. During the captive period the birds had only fresh water to drink. The mean weight of the salt glands from these birds does not differ significantly from that of adult and yearling males which had been in captivity for an unknown duration.

Within three standard deviations of the mean the smallest captive yearling and adult male salt gland pair would theoretically be minus two mgms. and minus 49 mgms. respectively. This gives an indication of the degree of skewness of the distributions. Among captive birds the smallest theoretical individual salt gland pair would be 108 mgms. among yearlings and 110 mgms. among adults. The smallest salt gland pair actually found in all age-sex classes was 200 mgms. While indications are that the salt gland weight distribution of the captive birds is also skewed it is significantly less so and the distribution does fit a normal curve at the .05 confidence level.

This suggests that the presence of birds from salt and fresh water areas provides explanation for the observed skewness of the distribution of salt gland weights of the birds killed outright. The distinction of two populations along with any area of overlap can be determined if it is assumed that the distribution of salt gland weights from birds which are drinking water with a given salt concentration approximates a normal curve.

Since 200 mgms. was the smallest salt gland pair found among 1,142 pairs, it was assumed that 200 mgms. marked a point at minus three standard deviations of the mean, rather than the calculated point at about 110 mgms. or 187 mgms. in those captive for a known duration. (This assumption is made because the distribution of salt gland weights from captive birds is still somewhat skewed and the standard deviation is therefore probably larger than ordinarily might be expected). One standard deviation can then be calculated by subtracting the lightest salt gland pair (200 mgms.) from the mean (426 mgms.) and dividing the result by three. Thus one standard deviation is 75 mgms.

In the sample of birds found dead there are 157 individuals at plus and minus one standard deviation (75 mgms.). At plus and minus 2.1 standard deviations there are 173 and 167 individuals respectively, thus the point of overlap of the fresh water and salt water components is theoretically between 2.0 and 2.1 standard deviations of the mean salt gland weight of birds from fresh water. At 576 mgms. (2.1 SD) the small end of the range of salt glands from birds from salt water begins. The entire range of salt gland weights of birds from fresh water can be estimated by adding three standard deviations to the mean ($225 + 426 = 651$). The entire range of potential overlap includes the area from 576 mgms. to 651 mgms. The area in which the salt glands from birds from fresh water do not overlap in weight with those from salt water is theoretically 652 mgms. to 1,069 mgms. In order to be certain that the entire area of overlap was excluded from morphometric comparisons of the two populations, the range from 500 mgms. to 699 mgms. was omitted from such comparisons.

The salt gland ranges of yearling males and adult and yearling females were treated in an identical manner. The area of overlap of the two populations was found to be the same for yearlings as it was for adults within the respective sex classes. The area of overlap in the distribution of female salt gland weights was considered to be 500 mgms. to 599 mgms., the lower distribution of non-overlap from 200 mgms. to 499 mgms. and the upper range of non-overlap was 600 mgms. and larger.

Schmidt-Nielsen and Kim (1964) have demonstrated that within a species there is a direct body size-salt gland size relationship; the largest salt glands are found in the largest individuals when the experimental birds are all given the same drinking water.

TABLE 2. STATISTICAL ANAYLSIS OF MEASUREMENTS OF ADULT MALE LESSER SCAUP IN SALT GLAND RANGES OF 100 MILLIGRAMS AND ONE LARGE TERMINAL RANGE. (KEY SAME AS FOR TABLE 1.)

Character		Weight of Salt Glands in Millimeters					
		200–299	300–399	400–499	500–599	600–699	700–1069
Sternum	N	15	58	92	52	35	52
	$\bar{X}$	83.42	83.73	83.59	83.14	82.95	83.28
	1SE	.71	.32	.21	.24	.35	.28
Ulna	N	9	38	57	42	26	42
	$\bar{X}$	69.59	69.02	69.79	69.80	70.10	70.10
	1SE	.40	.31	.20	.21	.26	.25
Wing	N	15	49	66	38	30	57
	$\bar{X}$	208.4	207.5	207.9	208.7	207.8	209.3
	1SE	2.56	1.94	.96	1.32	1.98	1.08
Cul. ant. edge of nostril	N	14	58	68	44	26	45
	$\bar{X}$	27.40	27.72	27.84	27.64	27.83	28.06
	1SE	.30	.12	.11	.13	.21	.10
Culmen	N	11	43	52	32	22	41
	$\bar{X}$	41.78	41.10	41.54	41.18	41.65	41.84
	1SE	.45	.21	.19	.31	.24	.17
Toe	N	13	40	51	32	23	27
	$\bar{X}$	55.47	56.20	56.00	55.70	55.87	56.72
	1SE	.56	.25	.24	.28	.33	.37
Tarsus	N	13	45	64	32	23	45
	$\bar{X}$	35.93	35.92	35.80	35.80	36.00	36.22
	1SE	.30	.12	.13	.19	.12	.14

However, their work was with ducklings of different ages. There does not seem to be a body size-salt gland size relationship among adult males in this sample (see Table 2). Sample sizes for the other age-sex classes were too small to make such a detailed analysis. Although there is no apparent body size-salt gland size within the sex classes, the males, which average larger for all measurements than females, also have larger salt glands.

Table 3 shows the statistical analysis of seven measurements of scaup in the 200 to 499 mgm. range, the 500 to 699 mgm. range and the 700 mgm. and larger range of adult males. It is worth repeating that the 500 to 699 mgm. range theoretically represents a mixture of two salt gland populations and should be intermediate for most measurements if two morphometrically different populations are represented. If only one population is represented all groups should have approximately the same mean. The 700 mgm. and larger range has a smaller mean sternum size than that found in the 200 to 499 mgm. range and the difference approaches significance (.1 level). The intermediate range is intermediate in four of seven measurements. The birds of the larger salt gland range also have a significantly longer wing, ulna, culmen, toe and tarsus

TABLE 3. STATISTICAL ANALYSIS OF MEASUREMENTS OF ADULT MALE LESSER SCAUP IN THREE SALT GLAND RANGES. (KEY SAME AS FOR TABLE 1.)

Character		Salt Gland Ranges (Mgms.) 200–499	500–699	700–1069
Sternum	N	165	87	52
	$\bar{X}$	83.63	83.03	83.28
	1SD	2.18	1.86	2.00
	1SE	.17	.20	.28
	Range	77.4–90.8	79.2–86.8	78.0–87.4
Ulna	N	104	68	42
	$\bar{X}$	69.49	69.99	70.10
	1SD	1.67	1.27	1.61
	1SE	.16	.15	.50
	Range	65.2–73.0	66.2–72.4	66.4–73.2
Wing	N	130	68	57
	$\bar{X}$	207.9	208.2	209.3
	1SD	4.40	4.20	4.10
	1SE	.38	.50	.55
	Range	191–216	198–217	201–218
Culmen from the anterior edge of the nostril	N	140	60	45
	$\bar{X}$	27.86	27.73	28.06
	1SD	.71	.94	.70
	1SE	.06	.11	.10
	Range	38.1–43.7	38.4–45.2	39.7–44.7
Culmen	N	106	54	41
	$\bar{X}$	41.28	41.43	41.84
	1SD	1.43	1.52	1.09
	1SE	.14	.21	.17
	Range	38.1–43.7	38.4–45.2	39.7–44.7
Tarsus	N	122	55	45
	$\bar{X}$	35.88	36.90	36.22
	1SD	.92	.91	.96
	1SE	.08	.12	.14
	Range	33.0–37.7	33.7–38.4	34.3–38.4
Toe	N	104	55	27
	$\bar{X}$	56.03	55.78	56.72
	1SD	1.70	1.57	1.92
	1SE	.17	.21	.37
	Range	51.5–60.4	52.6–59.2	52.6–60.6

than the birds of the smaller salt gland range. Yearling males in the larger range possess a significantly longer wing and toe than those in the smaller range of salt gland weights. Adult females of the larger salt gland range possess a significantly smaller mean sternum and yearling females of the large salt gland range also have a significantly smaller sternum as well as a significantly longer wing and toe (see Tables 3-6).

TABLE 4. STATISTICAL ANALYSIS OF MEASUREMENTS OF YEARLING MALE LESSER SCAUP IN THREE SALT GLAND RANGES. (KEY SAME AS FOR TABLE 1.)

Character		Salt Gland Ranges (Mgms.)		
		200–499	500–699	700–1069
Sternum	N	51	31	15
	$\bar{X}$	82.80	82.90	83.18
	1SD	2.13	2.13	1.71
	1SE	.30	.38	.44
	Range	74.1–87.8	79.4–86.8	80.6–85.6
Ulna	N	49	26	9
	$\bar{X}$	69.30	69.68	70.76
	1SD	1.62	1.79	—
	1SE	.23	.35	—
	Range	63.8–73.4	65.8–72.5	69.5–71.6
Wing	N	51	20	10
	$\bar{X}$	204.78	204.96	206.40
	1SD	4.11	4.05	3.69
	1SE	.58	.91	1.79
	Range	190–217	196–213	201-212
Culmen from the anterior edge of the nostril	N	44	21	10
	$\bar{X}$	27.66	27.55	28.05
	1SD	.95	.99	.96
	1SE	.14	.22	.30
	Range	24.7–29.0	26.0–29.3	26.5–29.6
Culmen	N	40	19	8
	$\bar{X}$	41.37	41.50	42.14
	1SD	1.47	1.39	—
	1SE	.23	.32	—
	Range	37.5–44.4	39.3–43.9	40.6–43.6
Tarsus	N	45	21	10
	$\bar{X}$	35.65	35.65	35.73
	1SE	1.11	1.12	1.06
	Range	32.8–37.9	33.3–37.4	33.3–37.0
Toe	N	36	22	9
	$\bar{X}$	55.06	55.08	56.49
	1SD	1.81	1.65	—
	1SE	.30	.35	—
	Range	49.3–58.6	51.2–59.5	52.3–59.4

DISCUSSION

Explanation of the observed range of salt gland weights in this sample could involve any combination of several factors. For example, it was not possible to distinguish birds that might have shuffled back and forth between fresh and salt water. Perhaps, some of the birds in the intermediate range of salt gland weights would fit this category. It is also entirely possible that some of the birds from salt water wintering sites reached fresh water earlier than other populations from salt water. This could result in smaller salt gland weights in birds of the former category by the time they

TABLE 5. STATISTICAL ANALYSIS OF MEASUREMENTS OF ADULT FEMALE LESSER SCAUP IN THREE SALT GLAND RANGES. (KEY SAME AS FOR TABLE 1.)

Character		Salt Gland Ranges (Mgms.) 200–499	500–599	600–999
Sternum	N	103	16	17
	X̄	80.46	80.69	79.28
	1SD	2.28	3.06	2.26
	1SE	.22	.76	.55
	Range	75.1–87.1	74.9–87.9	77.1–85.1
Ulna	N	63	11	11
	X̄	68.56	68.94	68.70
	1SD	1.61	1.05	1.12
	1SE	.20	.32	.34
	Range	62.8–71.4	66.4–70.4	66.4–69.8
Wing	N	91	12	16
	X̄	202.70	200.58	201.10
	1SD	3.66	3.14	3.99
	1SE	.38	.91	.99
	Range	192–213	196–205	193–209
Culmen from the anterior edge of the nostril	N	75	11	14
	X̄	26.63	26.84	26.75
	1SD	.95	.74	1.03
	1SE	.10	.21	.24
	Range	24.4–28.5	26.0–28.1	25.2–28.3
Culmen	N	75	11	14
	X̄	40.36	40.60	40.97
	1SD	1.35	1.14	1.83
	1SE	.16	.34	.49
	Range	36.1–42.9	38.3–42.4	38.9–43.6
Tarsus	N	72	9	13
	X̄	34.92	35.07	34.73
	1SD	.84	—	.80
	1SE	.10	—	.22
	Range	33.1–36.9	34.1–35.9	32.7–35.6
Toe	N	57	10	13
	X̄	54.52	54.65	54.04
	1SD	1.35	1.52	1.61
	1SE	.18	.48	.45
	Range	51.4–59.9	52.6–56.8	52.2–57.7

reached Minnesota. The presence of winter banded birds in the sample sheds some light on potential sites of origin of these birds.

Three Lesser Scaup in this sample were banded the winter before death, in mid-February at Grand Lake, Louisiana. Grand Lake is a fresh water lake (.05 percent concentration of salt) and is an annual wintering locality of Lesser Scaup (pers. comm. R. H. Chabreck, Research Leader, Louisiana Wildlife and Fisheries Commission). The other bird was banded at Titusville, Florida in a salt water habitat. Probably many of the birds comprising this sample originated from these two sites. There was no way of

TABLE 6. STATISTICAL ANALYSIS OF MEASUREMENTS OF YEARLING FEMALE LESSER SCAUP IN THREE SALT GLAND RANGES. (KEY SAME AS FOR TABLE 1.)

Character		Salt Gland Ranges (Mgms.) 200–499	500–592	600–999
Sternum	N	57	11	20
	X̄	79.78	78.89	79.71
	1SD	1.88	2.58	2.39
	1SE	.25	.78	.53
	Range	74.0–84.9	75.6–82.1	75.6–84.4
Ulna	N	27	11	17
	X̄	68.25	68.65	68.49
	1SD	1.67	1.59	1.59
	1SE	.32	.48	.38
	Range	63.8–71.7	66.3–71.5	64.7–70.5
Wing	N	38	11	14
	X̄	198.3	199.6	200.1
	1SD	4.02	2.74	4.38
	1SE	.65	.83	1.17
	Range	190–209	196–204	194–209
Culmen from the anterior edge of the nostril	N	33	10	17
	X̄	26.43	26.35	26.49
	1SD	.95	1.03	.87
	1SE	.17	.33	.21
	Range	24.7–28.6	23.6–27.8	23.6–29.2
Culmen	N	28	8	14
	X̄	40.28	40.95	40.88
	1SD	1.06	—	1.96
	1SE	.20	—	.37
	Range	34.0–42.4	39.0–42.6	38.9–44.3
Tarsus	N	38	9	13
	X̄	34.71	34.82	34.85
	1SD	.90	—	.48
	1SE	.15	—	.19
	Range	32.5–36.9	33.8–36.1	34.0–35.966
Toe	N	35	8	12
	X̄	53.06	54.18	54.06
	1SD	1.98	—	1.82
	1SE	.33	—	.53
	Range	49.3–58.2	51.1–56.5	51.2–57.5

determining other areas from which birds in the sample might have originated. While not providing all of the answers, band returns in combination with salt gland sizes seem to suggest that Lesser Scaup killed in Minnesota in late March and early April, 1963 are from at least two different wintering localities and that they converged in Minnesota or had converged enroute to Minnesota on return to their respective breeding grounds.

Of 871 birds which died soon after contact with the oil, 109 (12.5 percent) possessed salt glands indicating salt water wintering habitats. A minimum of 612 (70.3 percent) had salt gland sizes suggesting fresh water wintering areas. Birds classified intermediate as to salt gland weights may have originated from salt water or fresh water areas. The intermediate group contained 17.2 percent of the sample.

Observation that the birds within the range of birds with the heaviest salt glands have, on the average, longer appendages and shorter sternums suggests the possibility of geographic variation among populations of this species. Currently no geographic variation has been reported for Lesser Scaup.

Low homing rates to the breeding grounds, high pioneering rates, and mixing of different populations on the wintering areas with pair formation taking place there will all tend to increase genetic mixing thus reducing geographic variation between populations. (For a discussion of geographic variation see, for example, Mayr, 1963.)

Weller (1965) presents data showing that some pairing in Lesser Scaup occurs during late migration. If pairing occurs in Minnesota or any other places where different wintering populations converge in migration and if these populations mix, the chance of genetic variation among populations would be reduced. Mendall (1958) and Weller (1965) also state that considerable pair formation in North American *Aythya* occurs on the breeding grounds. Chabreck (pers. comm.) has data suggesting that Lesser Scaup home to Grand Lake, Louisiana. If pairing occurred primarily on the breeding grounds and if Lesser Scaup home to both the wintering and breeding grounds the chance of geographic variation developing, as a result of different selection among different populations, would be greatly enhanced.

The degree to which geographic variation has developed in Lesser Scaup can be determined through examination of a series of breeding birds. As Mayr (1963:302) has pointed out, the absence of geographic variation in a species is due often to insufficient study. The explanations for the morphological diversity or lack of it, between scaup populations can be explained partly through further research concerning the amount of genetic mixing which occurs, that is, the 1) degree of homing by the age-sex classes to both the wintering and breeding grounds, 2) amount of pioneering, 3) chronology of pair formation, and 4) degree of mixing of populations on the wintering grounds, especially with regard to one and three.

SUMMARY

The supraorbital salt glands of 1,142 Lesser Scaup were dissected and weighed. The distribution of the weights indicates that birds from salt water and fresh water habitats were present in the sample. Winter banded birds were from salt water and fresh water localities, thus lending support to the thesis that birds from at least two different wintering localities had converged in or enroute to Minnesota during spring migration, 1963. We found that those birds with

large salt glands (those presumably wintering in salt water habitats) had slightly smaller sternums and slightly longer appendages, on the average, than those birds with smaller salt glands, (those presumably wintering in fresh water habitats) perhaps suggesting geographic variation among populations of Lesser Scaup.

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