COMPARATIVE OSTEOLOGY OF THE NIGHT HERONS

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This paper is an attempt to evaluate taxonomically the osteological characters of the Black-crowned Night Heron, *Nycticorax nycticorax,* and the Yellow-crowned Night Heron, *Nyctanassa violacea.*

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MATERIALS AND METHODS

Sixty skeletons of the two genera were compared, 41 *Nycticorax* and 19 *Nyctanassa.* Specimens of the Black-crowned Night Heron were from populations currently assigned to the subspecies *N. n. hoactli* (Florida, Kansas, Nevada, Colorado, and California). Specimens of the Yellow-crowned Night Heron were from populations currently assigned to the subspecies *N. v. violacea* (Florida and Kansas). Forty-seven measurements were taken from each of the specimens under consideration. The measurements were similar to those taken by Baumel (Condor, 51, 1953:26–32) and Glatfelter (1950, unpublished thesis, Univ. Fla.). Terminology follows Howard (Univ. Calif. Publ. Zool., 32, 1929:301–394). A total of 18 ratios between the various elements was computed in an effort to magnify the differences between the two species studied. Two statistical methods were used to indicate differences between the two species studied. These were (1) the significance of differences according to t values, and (2) the coefficient of divergence.

DISCUSSION

Measurements of *Nycticorax nycticorax* and *Nyctanassa violacea* are given in tables 1 and 2. These tables include only those measurements whose differences show a t value greater than 3.0 and hence those measurements considered to be of value for the separation of the two genera.

Sexual variation.—Using data from tables 1 and 2, the statistical coefficient of divergence (Klauber, Trans. San Diego Soc. Nat. Hist., 9, 1940:195–214) was used to determine the amount of sexual dimorphism present.

In *Nycticorax nycticorax,* the mean measurements of the male exceed those of the female in all except the maxillary width and the synsacrum width. In these measurements, the mean of the female exceeds the mean of the male by less than 2.0 per cent. There is overlap in the ranges of all measurements taken.

In *Nyctanassa violacea,* the mean measurements of the male exceed the mean measurements of the female in 41 of the measurements taken. In six measurements the mean of the female exceeds the mean of the male. Each of the coefficients of divergence for these six measurements is less than 3.5 per cent. Overlap occurs in all measurements except the preorbital width, and this measurement shows a separation of only 0.1 mm.

Species differences.—The following arbitrary criteria were set up for optimum separation of the two species: (1) measurements separated by three standard deviations of each form; (2) measurements separated by two standard deviations of each form; (3) measurements separated by one standard deviation; (4) measurements separated by one standard deviation only when the same sexes are compared.

In one measurement, the naris length, the mean of *Nycticorax* exceeds the mean of *Nyctanassa* by more than three standard deviations.

In five measurements the means of *Nycticorax* exceed the means of *Nyctanassa* by

two standard deviations. These are the skull length, basal skull length, zygoma length, pterygoid length, and femur length. By the same statistic, the mean length of the tarsus of *Nyctanassa* exceeds the mean length of the tarsus of *Nycticorax* by two standard deviations.

Table 1

Measurements of *Nycticorax nycticorax* in Millimeters

	Males (24)			Females (17)		
Measurements	Mean	Range	SD	Mean	Range	SD
Skull length	136.42	128.0–143.5	3.44	130.53	122.3–139.0	1.45
Basal skull length	135.42	126.5–143.0	3.80	128.88	121.3–134.8	1.41
Cranial length	57.42	54.9–59.5	1.44	55.88	53.3–57.8	1.41
Postorbital width	37.74	34.6–40.0	1.07	36.43	35.3–37.8	.70
Preorbital width	17.83	16.4–18.7	.64	17.89	16.1–19.0	.67
Zygoma length	57.54	55.0–61.2	1.70	56.14	52.4–57.2	.65
Pterygoid length	14.42	12.9–15.2	.54	13.65	12.9–14.3	.38
Ramus length	128.83	120.0–136.2	3.65	123.14	113.9–132.0	5.25
Naris length	18.81	17.4–20.8	.96	17.49	16.1–18.5	.40
Quadrate width	18.03	16.6–19.1	.53	17.25	16.4–18.2	.64
Quadrate length	22.32	20.6–23.2	.64	21.16	19.6–22.0	.57
Pre-ilium width	14.53	13.3–15.7	.77	13.81	12.5–15.2	.70
Pelvic width	20.60	19.2–22.6	1.02	19.83	18.5–21.2	.91
Innominate depth	15.35	14.5–16.6	.58	14.65	13.4–16.0	.70
Acetabular width	6.18	5.6–6.9	.31	5.89	5.3–5.6	.32
Femur length	77.11	73.6–80.4	2.13	73.85	71.2–78.0	1.84
Proximal femur width	13.17	12.3–14.1	.59	12.68	11.8–13.2	.35
Distal femur width	12.43	11.4–13.4	.55	12.13	11.5–12.5	.32
Tibia length	128.50	119.6–136.4	4.03	124.70	115.8–133.0	4.36
Proximal tibia width	10.82	10.2–11.6	.45	10.29	9.6–11.0	.37
Distal tibia width	10.81	9.9–11.3	.48	10.31	9.6–10.9	.31
Tarsus length	83.75	77.0–89.7	3.46	81.07	77.6–87.2	2.62
Coracoid length	55.02	52.0–57.2	1.47	52.43	49.8–55.3	1.45
Scapula length	68.81	63.9–71.8	2.14	64.95	61.5–69.1	2.15
Humerus length	119.67	114.0–128.8	3.28	112.60	106.0–116.2	3.95
Carpometacarpus length	65.36	61.6–70.1	2.17	62.85	59.2–65.3	1.10

In eight measurements the means of *Nycticorax* exceed the means of *Nyctanassa* by one standard deviation. These are cranial length, postorbital width, ramus length, quadrate width, quadrate length, proximal femur width, innominate depth, and carpometacarpus length. In two measurements the means of *Nyctanassa* exceed those of *Nycticorax* by one standard deviation. These are the pre-ilium width and the pelvic width.

Ten measurements show a separation of one standard deviation when the same sex is compared but show overlap between the largest female of one species and the smallest male of the other. These measurements are preorbital width, foramen magnum depth, tibia length, proximal tibia width, distal tibia width, midsternum width, clavicle length, acetabular width, scapula length, and humerus length.

The remaining 20 measurements showed separation of less than one standard deviation, even when compared sex for sex.

Further support of the separation of the two genera is indicated by the significance of differences test by t values. On the basis of the t values, the measurements were divided into three classes: (1) $t = 3.0$ or more; (2) $t = 2.0 - 2.9$; (3) $t =$ less than 2.0.

The differences between the means of the following 26 measurements are of unquestionable statistical significance ($t = 3.0$ or more, $p = .003$ or less): skull length, basal skull length, cranial length, postorbital width, preorbital width, zygoma length, pterygoid length, ramus length, naris length, quadrate length, quadrate width, pre-ilium

Table 2

Measurements of *Nyctanassa violacea* in Millimeters

	Males (8)			Females (11)		
Measurements	Mean	Range	SD	Mean	Range	SD
Skull length	122.25	118.5–124.8	2.11	118.32	111.4–122.5	3.24
Basal skull length	120.50	116.0–123.0	2.60	116.95	110.0–121.8	3.20
Cranial length	53.25	52.1–54.9	.97	52.09	49.9–53.7	1.16
Postorbital width	34.50	33.4–35.9	1.00	33.84	32.4–35.2	.95
Preorbital width	20.50	16.1–23.3	1.80	15.24	14.7–16.0	.48
Zygoma length	49.74	48.4–50.8	.83	49.27	45.8–50.8	1.30
Pterygoid length	11.80	11.5–12.3	.23	11.73	10.6–12.3	.51
Ramus length	112.25	109.6–114.5	1.71	109.64	102.0–112.5	3.47
Naris length	13.39	12.6–14.1	.53	12.70	11.6–13.6	.62
Quadrate width	18.68	15.0–16.9	.52	15.83	14.8–16.6	.51
Quadrate length	19.30	18.4–20.1	.51	18.63	17.9–20.1	.57
Pre-ilium width	16.63	15.7–17.6	.54	16.16	14.7–17.0	.76
Pelvic width	20.60	19.2–22.6	1.02	23.77	20.8–24.4	1.21
Innominate depth	13.38	12.6–14.3	.48	13.35	12.3–14.0	.17
Acetabular width	5.30	4.5–6.2	.59	5.48	5.0–6.0	.26
Femur length	66.00	63.3–69.8	1.68	64.70	62.3–68.3	2.19
Proximal femur width	11.63	10.9–12.4	.50	11.55	10.7–12.0	.44
Distal femur width	11.44	10.5–11.9	.40	11.59	10.6–12.0	.11
Tibia length	140.13	133.6–148.0	4.64	134.27	126.8–143.5	4.45
Proximal tibia width	9.71	9.0–10.3	.51	9.37	8.9–9.8	.29
Distal tibia width	9.90	9.5–10.5	.40	9.53	8.9–10.2	.39
Tarsus length	103.25	95.8–107.4	3.60	98.77	92.9–104.3	3.72
Coracoid length	51.50	48.3–54.7	2.37	49.00	46.8–51.2	1.21
Scapula length	61.38	59.4–62.9	.93	61.95	58.1–66.4	2.27
Humerus length	110.00	106.0–114.7	3.06	107.18	103.5–111.0	2.48
Carpometacarpus length	61.82	59.0–63.5	1.32	59.77	57.2–62.9	1.76

width, pelvic width, innominate depth, acetabular width, femur length, proximal femur width, distal femur width, tibia length, proximal tibia width, distal tibia width, tarsus length, coracoid length, scapula length, humerus length, and carpometacarpus length. The *t* values for these measurements range from 25.2 for the naris length of the females to 3.3 for the proximal humerus width of the males.

The following four measurements show a *t* value greater than 3.0 for the males, but less than 3.0 for the females. These are external lamina length, sternum width, clavicle length and proximal humerus width. Four measurements show a *t* value greater than 3.0 for the females, but less than 3.0 for the males. These are maxillary width, postacetabular width, distal humerus width, and humerus shaft diameter.

The differences between the means of the synsacrum length has a *t* value of 2.5 and is therefore considered statistically significant.

Measurements showing *t* values of 2.0–2.9 for the males only are as follows: coracoid width, humerus shaft diameter, ulna length, and radius length. Measurements showing similar values for females only are ischium length, ilio-ischiatic fenestra, femur shaft diameter, sternum width, and proximal humerus width.

Other measurements are not considered statistically significant and for this reason are not listed here.

To indicate further the differences between *Nycticorax* and *Nyctanassa,* the coefficient of divergence was calculated for each measurement. *Nycticorax* exceeds *Nyctanassa* in 33 and 35 measurements, for the males and females, respectively, while *Nyctanassa* exceeds *Nycticorax* in 14 and 12 measurements for the males and females, respectively.

Ratios.—The purpose of ratios in comparisons of skeletal elements is to magnify the differences in proportions existing between *Nycticorax* and *Nyctanassa*. The ratios were computed on the basis of the measurements of individual specimens in order to eliminate any inherent error that might occur. These ratios, expressed in per cent, are given in table 3.

Table 3

Mean, Minimum, and Maximum Ratios in Per Cent

	Nycticorax nycticorax				*Nyctanassa violacea*			
	Male		Female		Male		Female	
Ratio	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Lamina: zygoma	61.6–70.5	65.04	61.1–68.4	64.15	68.1–75.8	71.31	69.2–78.7	73.91
Ramus: skull	91.3–96.2	94.44	92.8–96.2	94.14	90.7–92.6	91.68	91.3–94.0	92.32
Postorbital: cranium	59.9–68.2	65.92	62.3–68.5	65.68	63.7–67.1	65.25	61.1–69.1	65.02
Pterygoid: quadrate length	59.8–68.1	64.42	60.2–68.8	64.35	59.2–64.7	61.64	55.8–65.4	62.28
Pterygoid: quadrate width	73.3–83.9	80.01	72.2–84.8	78.72	72.3–78.7	74.70	67.1–79.1	73.72
Foramen magnum width: depth	82.4–103.4	90.45	76.9–96.6	87.38	83.6–96.9	91.47	82.3–95.2	89.06
Interorbital: skull	11.7–15.9	14.34	12.5–16.4	14.34	14.1–17.3	15.10	12.5–16.9	15.17
Preorbital: skull	11.9–13.9	13.06	12.3–13.8	13.15	13.5–18.8	16.86	12.3–13.5	12.91
Postorbital: skull	25.2–29.1	27.65	26.6–29.6	28.01	27.5–29.2	28.37	27.8–31.0	28.67
Tarsus: ulna	61.9–67.9	64.35	61.4–68.6	64.88	75.6–82.3	80.22	76.9–81.0	79.11
Femur: tibia	58.1–62.3	59.83	57.7–61.5	59.24	44.1–49.2	47.31	47.6–49.7	48.52
Tarsus: tibia	62.6–66.7	64.96	62.3–67.8	65.04	69.7–76.8	73.81	71.5–76.2	73.42
Femur: humerus	58.8–66.5	64.16	64.4–67.4	65.70	59.6–60.9	60.07	58.9–62.1	60.67
Tibia: ulna	95.5–101.7	98.69	98.5–102.9	100.75	105.5–115.2	109.33	103.7–110.6	107.34
Carpometacarpus: tarsus	75.6–82.1	78.06	74.1–80.2	77.26	56.5–61.6	59.69	58.7–62.7	60.48
Sternum width: length	41.1–51.0	47.83	42.4–51.5	46.98	40.1–45.2	43.52	39.3–49.4	43.64
Innominate: synsacrum width	47.7–53.9	50.21	41.4–52.8	48.77	37.3–43.4	40.65	37.9–44.6	41.93
Synsacrum width: length	49.3–57.3	53.48	51.7–61.0	55.24	54.9–69.0	60.77	54.4–67.3	59.89

The mean ratios of the various measurements are of the same magnitude in both sexes of a given genus, indicating no sexual dimorphism. The variation is less than three per cent with overlap in all cases.

The ratios of the skull elements of *Nyctanassa* are of the same magnitude as those of *Nycticorax*. The overlap in the ranges is such that no significant difference is indicated in the skull ratios under consideration.

Much the same condition exists in the body ratios of the two genera. Of the 14 ratios computed on the skeletal elements of the body, only five are considered worthy of mention:

(1) Carpometacarpus: tarsus. The difference between the ranges of this ratio indicates excellent separation, the lower limit of the range of *Nycticorax* being 12 per cent larger than the upper limit of the range of *Nyctanassa*. This difference is attributed to the greater length of the carpometacarpus of *Nycticorax* and the greater length of the tarsus of *Nyctanassa*.

(2) Femur: tibia. The lower limit of the range of *Nycticorax* is eight per cent greater than the upper limit of the range of *Nyctanassa* for this ratio. This is attributed to the greater length of the femur of *Nycticorax*, and the greater length of the tibia of *Nyctanassa*.

(3) Tarsus: ulna. This ratio is greater in *Nyctanassa* than in *Nycticorax*, the lower limit of the range of *Nyctanassa* being seven per cent greater than the upper limit of the range of *Nycticorax*. This, again, is attributed to the greater length of the tarsus of *Nyctanassa* and the greater length of the ulna of *Nycticorax*.

(4) Tarsus: tibia. The lower limit of the range of this ratio for *Nyctanassa* is two per cent greater than the upper limit of the range for *Nycticorax*. The tarsus and the tibia are both significantly larger in *Nyctanassa* than in *Nycticorax*.

(5) Tibia: ulna. This ratio is shown to be greater in *Nyctanassa* than in *Nycticorax*, the lower limit of the range of the former exceeding the upper limit of the latter by one per cent. This difference is attributed to the greater length of the tibia in *Nyctanassa* and the greater length of the ulna in *Nycticorax*.

Other perceptible differences.—Characters such as contour and conformation of the elements under consideration were impractical to measure but deserve comment. These characters were examined by comparison with specimens of other species of American herons. Variations are noted below:

(1) Nasal septum. According to Shufeldt (Ann. Carnegie Mus., 1, 1901:158–249), the osseous nasal septum is either incomplete or entirely missing in the subfamily Ardeinae. The septum exists in *Nyctanassa* only as a very small, partially ossified sliver along the median dorsal line of the nares, so reduced as to be almost missing.

In *Nycticorax* the nasal septum, partially ossified, extends anteriorly along the dorso-median line of the nares for two-thirds of their length. The septum runs diagonally from the anterodorsal angle of the external nares to the posteroventral angle.

An examination of the other American members of the subfamily Ardeinae shows them to be divided into two well defined groups with respect to the nasal septum. *Florida caerulea* is the only form found to possess the enlarged nasal septum as in *Nycticorax nycticorax*. The remainder of the American species are found to have only a very small, partially ossified nasal septum and would therefore be placed in the same general group as *Nyctanassa violacea*.

(2) Nasal grooves. In *Nycticorax nycticorax* a slit runs forward fully two-thirds the length of the culmen, from the anterior angle of the external nares. This appears to be an extension of the nasal opening, and it may be the remnant of once greatly enlarged external nares. This groove does not occur in *Nyctanassa violacea*.

In the day herons at my disposal the external nares end rather abruptly, with only a slight indentation appearing on the culmen. The genus *Hydranassa* most nearly approaches the condition found in *Nycticorax*.

(3) Ectethmoid. In *Nycticorax* the ectethmoid consists of two parts. The larger part extends out almost at right angles to the interorbital septum, to make a flat, plate-like projection anterior to the eye. The second part joins the first by means of a narrow bridge in the upper anterior region of the interorbital septum. This then extends forward and lateral to the lacrymal, just below the frontal bone. This condition of the

ectethmoid bone in *Nycticorax* may be correlated with the nocturnal habits of the form, serving as an extra support for the greatly enlarged orbit.

In *Nyctanassa* the frontal portion of the ectethmoid is reduced in comparison with that of *Nycticorax*. The anterior and posterior portions of the ectethmoid bone are separate, there being no osseous connection between the two parts.

The day herons may be separated into three groups on the basis of the conformation of the ectethmoid bone. In the genera *Ardea* and *Casmerodius* the ectethmoid is similar to that of *Nycticorax*, while the genera *Leucophoyx* and *Florida* resemble *Nyctanassa*. Two genera, *Butorides* and *Dichromanassa*, are intermediate, having the enlarged frontal portion as in *Nycticorax*, but with the median connecting portion missing as in *Nyctanassa*.

(4) Supraorbital foramen. In each orbit of *Nycticorax*, above and anterior to the optic foramen, there is an additional opening into the braincase, which Shufeldt termed the optic vacuity. This is here referred to as the supraorbital foramen.

In *Nyctanassa* the supraorbital foramen is absent. The single foramen occurring at the median posteroventral angle of the interorbital septum appears much the same as in *Nycticorax*, being very nearly of the same magnitude.

Further examination shows a striking similarity between *Nycticorax* and the day herons, the only variation being in the relative size of the paired foramina. The largest paired openings occur in *Hydranassa tricolor*.

SUMMARY

Measurements from skeletal elements of two night herons, *Nycticorax nycticorax* and *Nyctanassa violacea*, are compared. Two statistical methods used to examine the differences between the two forms were the test of significance of difference by *t* values and the coefficient of divergence. The latter statistic was used to indicate the degree of sexual dimorphism.

Mean measurements of the male of *Nycticorax* exceed those of the female in all except the symsacrum width. In no case did the measurements of one sex exceed those of the other sex by more than 2.0 per cent. Mean measurements of the male of *Nyctanassa* exceed those of the female in 42 of the measurements taken. Each of the coefficients of divergence of the six measurements in which the female exceeds the male are less than 3.5 per cent.

The two genera differ significantly in 17 of the 47 measurements taken, irrespective of the sex. For comparisons of thirty-two measurements the *t* values are 3.0 or more, for six the *t* values are 2.0–2.9; remaining measurements do not differ significantly.

Nycticorax exceeds *Nyctanassa* in 33 and 35 measurements, for the males and females, respectively, while *Nyctanassa* exceeds *Nycticorax* in 8 and 10 measurements, for the males and females, respectively.

Of 18 ratios computed for various combinations of skeletal elements, only five are considered to be significant. These reflect throughout the differences in lengths of the leg bones of the two forms. There is no sexual dimorphism exhibited in the ratios.

Differences in structural form, those not easily expressed by measurements, also indicate distinctions between skeletal elements of the two genera. Four such differences are noted and are compared between night herons and other herons.

A great variation in the conformation of skeletal elements is found in the subfamily Ardeinae. It would be desirable to investigate the degree of correlation of the skeletal differences with differences in ecology and to compare other members of the family. In the meantime, the available evidence favors maintaining *Nycticorax* and *Nyctanassa* as separate genera.

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