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CS2621

Midterm Project: Bird Classification

Alhagie Abdoulie Boye

Introduction

Identifying birds by sight can be a very difficult task and frustrating given that there are so many kinds of birds. In this paper, I will be categorizing birds mainly into six categories. Base on this classification I will be investigating the relationship between bone measurements of birds and their ecological niche. This comparison will provide insights into how the adaptation and ecological role of these species suits them for their environment and functions.

Figure 1. Six categories of birds. https://pixnio.com/birds

<u>*Swimming Birds:*</u> These are birds have the ability to swim on water. The water birds have several features that helps them adapt to their environment. They have the following characteristics:

- *Physical appearance*: webbed feet, these help the bird propel itself through the water.
- *Streamline body*: this design helps the bird move efficiently through water with less drag.
- *Waterproof Feathers*: these feathers keep the bird dry and repels water[1].
- *Habitat*: they are found around aquatic habitats.
- *Feeding*: they feed on aquatic plants, fish, and other organisms in the water.

<u>*Wading Birds*</u>*: these* waders can be seen among the wetlands or close to water bodies. They are characterized by their long neck and legs e.g. herons. They have the following characteristics:

- *Physical Appearance:* they are tall and slender, posses long necks and long legs.
- *Habitat*: They live in areas like marshes, swamps, lagoons, and shallow coastal areas.
- *Feeding*: they feed on aquatic plants, fish, and other organisms in the water.

<u>*Terrestrial Birds*</u>*:* these birds spend most of their life on the ground e.g. Sparrow. They have the following characteristics:

- *Physical Appearance*: round and plump bodies with round head. Rounded wings which are incapable of long flights.
- *Feeding*: they feed on insects, grains, fruits etc.
- *Flight*: they do stay close to the ground and flight is short distance[3].
- *Habitat*: they live mostly on the ground e.g. forest, grassland, mountains etc.

<u>*Raptors*</u>: they are predatory birds. They hunt and feed on other animals e.g. Vultures and Eagles[4]. They have these characteristics:

- *Physical Appearance*: powerful sharp talon to grip preys. hooked beaks which is useful in capturing its preys. Also, keen eyesight
- *Habitat*: they can be found in forests, grassland, savannah etc.
- *Feeding*: they primarily feed on other animals i.e. carnivores.

<u>Scansorial Bird</u>: these birds are well adapted for climbing trees e.g. woodpecker. There four toes are arranged in pairs which gives them the efficient power of grasping[5]. They have these characteristics:

- *Physical appearance:* powerful feet and toes. Two pair of toes, with curve clamps for grasping on trees. Sharp beak for pecking into woods.
- *Feeding*: they use their sharp beak to forage for insects, seeds etc.
- *Habitat*: mostly habitats with trees e.g. forests.

<u>Singing Birds</u>: Songbirds are known for their complex and melodic songs, which they use to communicate with each other, attract mates, and defend their territory[6].

- *Physical appearance*: they are mostly small birds with measurements around 4-12 inches.
- *Food*: mainly feed on insects, seeds, fruits, and nectar.
- *Habitat*: they are found in almost every habitat worldwide, except for the polar regions and some oceanic islands[6].

A. Bone measurements: key to bird studies

Bone measurement is really important in studying birds and their ecological research. The measurement (length & diameter) of the humerus, ulna, femur, tibiotarsus, and tarsometatarsus gives valuable insight into how these bones are specifically adapted for their habitat.

<u>Implication to ecological research</u>

Bone size and shape play a crucial role in movement, buoyancy, and flight in their habitat. Therefore, providing relationship between their physical features habitat which provide valuable insight into their ecological roles.

B. Hypotheses

Null Hypothesis (H0): *There is no significant difference in the bone measurements (length and diameter) of the humerus, ulna, femur, tibiotarsus, and tarsometatarsus across the identified ecological categories of birds (swimming, wading, terrestrial, raptors, scansorial, singing).*

Alternate Hypothesis (H1): *At least one of the bone measurements (length and diameter) of the humerus, ulna, femur, tibiotarsus, and tarsometatarsus will differ significantly between the identified ecological categories of bird.*

Analysis

The research question asks which bone measurements, if any, can be used to distinguish between different ecological categories of birds. In order to achieve this, I will analyze the data by categorize the variables as seen in figure2 into their length, diameter, and bone type (see fig3).

id	huml	humw	ulnal	ulnaw	feml	femw	tibl	tibw	tarl	tarw	type
0	80.78	6.68	72.01	4.88	41.81	3.70	5.50	4.03	38.70	3.84	SW
1	88.91	6.63	80.53	5.59	47.04	4.30	80.22	4.51	41.50	4.01	SW
2	79.97	6.37	69.26	5.28	43.07	3.90	75.35	4.04	38.31	3.34	SW
3	77.65	5.70	65.76	4.77	40.04	3.52	69.17	3.40	35.78	3.41	SW
4	62.80	4.84	52.09	3.73	33.95	2.72	56.27	2.96	31.88	3.13	SW

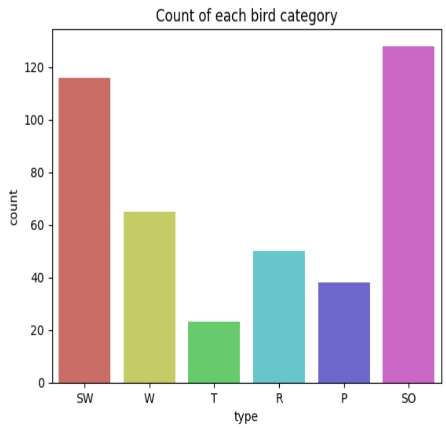
Figure 2. First five rows of my birds dataset

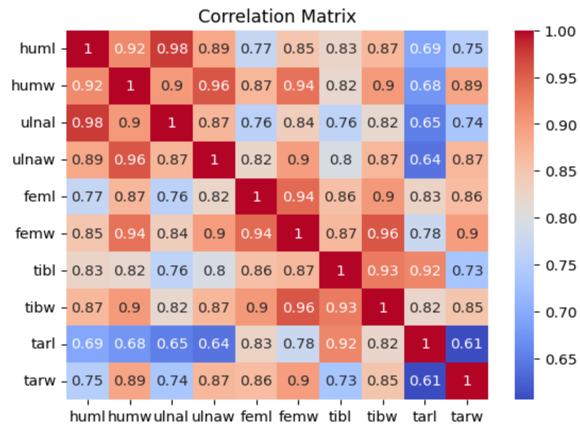
Figure 3 is a table that shows the bone type each variable measures and also the length/diameter of that particular bone type. By analyzing these measurements across the different ecological categories will enable me to see if there are any significant differences in bone size between the bird groups. This will help in answering the research questions.

Variable	Length/Diameter	Bone Type	Category
huml	Length	Humerus	Morphological
humw	Width	Humerus	Morphological
ulnal	Length	Ulna	Morphological
ulnaw	Width	Ulna	Morphological
feml	Length	Femur	Morphological
femw	Width	Femur	Morphological
tibl	Length	Tibia	Morphological
tibw	Width	Tibia	Morphological
tarl	Length	Tarsus	Morphological
tarw	Width	Tarsus	Morphological
type	N/A	N/A	Bird Type

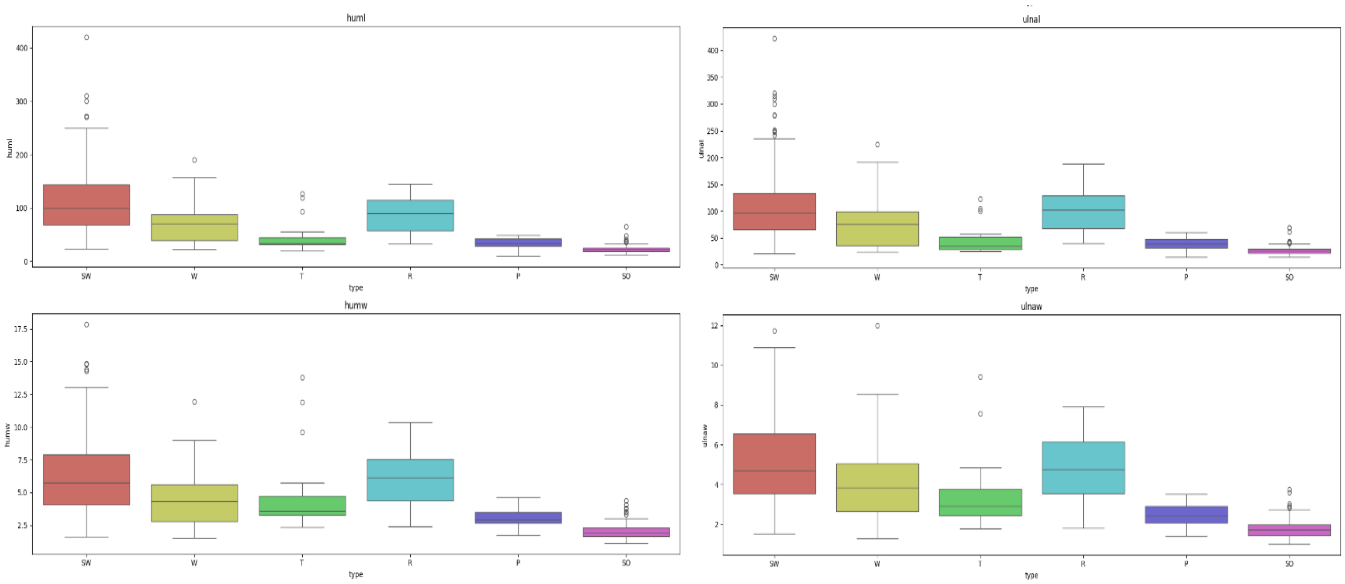
Figure 3. Table categorizing each variable.

A. Data visualization





Variable	skewness
huml	2.023
humw	1.489
ulnal	2.092
ulnaw	1.234
feml	1.219
femw	1.293
tibl	1.526
tibw	1.249
tarl	1.937
tarw	1.817



From the boxplots (see notebook for more), the distributions of the classes often fall within the same range. Scansorial, singing and terrestrial birds tend to have lower bone lengths and diameters with smaller variance. suggesting that different categories bone sizes. To further investigate the differences in bone sizes across bird types, I will perform a statistical hypothesis tests.

B. Kruskal-Wallis Hypothesis-Test

I will be using Kruskal-Wallis H-Test because it doesn't assume that the data is normally distributed. From the result on the right, all of the p-values are less than 0.05. This means that there is a statistically significant difference in the distributions of these variables across the different bird types. The huml, humw, ulnal, ulnaw and tarw variables show the greatest differences between the groups of bird types. This means that these variables might have a significant influence on the bird type.

Variable	kruskals h_stats	kruskals p_value	stats_sig
huml	282.936664	4.656219e-59	True
humw	242.951201	1.787582e-50	True
ulnal	249.269946	7.884223e-52	True
ulnaw	246.927493	2.507926e-51	True
feml	202.660428	7.660065e-42	True
femw	207.938083	5.685771e-43	True
tibl	215.023086	1.729504e-44	True
tibw	220.765861	1.018374e-45	True
tarl	142.415308	5.485023e-29	True
tarw	233.520919	1.881272e-48	True

C. *Chi-Square χ2 Test of Independence*

To assess whether the numerical variables (binned) are "different" across the categories (bird categories), I will be conducting a chi-square test of independence. In the results, all of the p-values are less than 0.05, which means that for all of the numerical variables, there is a statistically significant relationship with the 'type' variable. In other words, the distribution of categories for each numerical variable is different across the different bird types.

Results from Chi-Square Test

Variable	Chi_stat	p_value	stats_sig
huml	67.734242	1.211635e-10	True
humw	91.856970	2.292257e-15	True
ulnal	48.942991	4.172404e-07	True
ulnaw	135.39444	3.694698e-24	True
feml	136.83431	1.875056e-24	True
femw	137.09222	1.660470e-24	True
tibl	115.41087	4.306484e-20	True
tibw	140.09964	4.020833e-25	True
tarl	74.222537	6.739660e-12	True
tarw	91.972445	2.174308e-15	True

From the two statistical tests I have conducted, the results indicate that all the bone measurements (huml, humw, ulnal, ulnaw, feml, femw, tibl, tibw, tarl, tarw) have a statistically significant relationship with the bird type thus providing strong evidence against our null hypothesis. The wing and the legs of a bird are the main feature that adapt them to their habitat and since all these bones are located at the legs and wings a bird, I think that all of them are traits that can be used to distinguish between birth types. The huml, ulnal, tibl, tarl and tarw can be the most distinguishable feature because the tibl, tarl, tarw are mostly important for the wading/running while the huml and ulnal are symbolic feature for flight.

Discussion & Interpretation

A. Table of Distinguishable traits & their descriptive statistics.

The descriptive statistic of each trait tells us how for e.g. the humerus length and diameter for swimming a bird differs from that of singing bird.

Descriptive statistics for huml:

type	count	mean	std	min	25%	50%	75%	max
P	38	34.4239	9.39971	9.85	28.6975	33.8	42.305	49.12
R	50	86.9344	31.7153	33.12	57.5	89.88	115.025	145
SO	128	22.6915	7.14345	12.69	18.6875	21.605	25.37	64.6505
SW	116	110.251	66.225	22.63	68.4125	100.065	143.5	420
T	23	45.6996	28.0688	20.25	32.065	34.24	44.275	127
W	65	73.1331	37.8423	22.39	38.79	70.93	88.16	190

Descriptive statistics for ulnal:

type	count	mean	std	min	25%	50%	75%	max
P	38	39.1774	11.6389	14.73	31.9625	38.555	47.305	60.95
R	50	99.7179	37.6816	39.85	67.6275	102.37	129.312	188
SO	128	27.0656	8.70821	14.09	22.1225	25.72	29.3975	69.1154
SW	116	111.756	75.8897	20.75	65.6875	96.935	133.75	422
T	23	45.6174	27.2304	25.14	28.635	35.24	51.58	123.27
W	65	78.1014	46.5423	24.16	36.33	75.44	99.31	225

Descriptive statistics for tibl:

type	count	mean	std	min	25%	50%	75%	max
P	38	41.8813	17.1465	20.89	31.97	36.65	49.235	85.88
R	50	89.8774	26.4892	38.99	66.585	96.36	113.207	126.54
SO	128	36.7688	10.3038	22.13	28.825	35.535	41.3975	64.97
SW	116	85.3171	39.8409	5.5	57.5875	75.275	106.03	237
T	23	66.0909	41.866	27.67	49.035	53.77	56.435	189
W	65	76.15	41.0739	30.31	46.24	70.39	89.93	240

Descriptive statistics for tarl:

type	count	mean	std	min	25%	50%	75%	max
P	38	25.7874	14.8366	7.77	15.8225	21.895	30.54	63.91
R	50	58.7676	19.1081	19.1	45.085	60.045	72.7925	99.72
SO	128	25.8427	7.52548	15.19	19.845	24.31	29.6475	48.35
SW	116	45.1562	20.8967	18.42	30.125	39.695	56.1375	128.35
T	23	40.0865	30.7081	15.68	26.78	31	34.82	134
W	65	47.5434	31.3781	15.8	24.64	37.17	60.81	175

Descriptive statistics for tarw:

type	count	mean	std	min	25%	50%	75%	max
P	38	1.90263	0.573452	1.16	1.5325	1.74	2.0575	3.6
R	50	5.031	2.0239	2.22	3.1275	4.835	6.6375	9.64
SO	128	1.34937	0.423478	0.66	1.0475	1.265	1.6025	2.57
SW	116	4.14991	2.67706	0.83	2.245	3.225	5.63	14.09
T	23	3.18391	1.74685	1.55	2.34	2.49	2.945	8.19
W	65	2.76031	1.33056	0.83	1.71	2.53	3.57	7

B. Avian Trait Diversity

Birds like any order organisms needs their body to be well adapted for their environment. The tests and visualizations show that different bird types require a specific bone or bones to be well equipped for the habitat and lifestyle. From my research I have found features that distinguishes each bird category. Here is six main types of birds groups and their biological difference.

The songbird (SO) generally has a small body with small bones(e.g. humerus, ulna). Their feet are well structures with three pointing forward and 1 pointing backward for easy grip on tiny branches.

The woodpecker (P) has a strong and chisel like beak for pecking on wood. Their feet(tarsus) are well structured to grip on trees.

Bald eagles (R) have wide wing (ulna, humerus) for flight. They possess sharp talons, hooked beaks, and excellent vision for hunting.

Sparrow (T) has traits such as overall body size (related to various bone lengths) and wing morphology (e.g., ulna length) could vary depending on factors such as flight capabilities, foraging strategies, and habitat preferences.

Herons (w) they forage for aquatic prey. Longer legs (e.g., tibiotarsus length) possibly longer bills might be beneficial for reaching prey in water or probing into the mud.

Penguins (SW) have traits such as longer and strong legs (e.g., tarsometatarsal length) and possibly wider wings (e.g., ulna width) use for propulsion in water thus may be advantageous for swimming birds.

B. Advantages of Morphological Traits Over Contextual Traits in Ecological Studies.

The morphological traits are inherent to the species i.e. they are permanent traits of each bird throughout their life. They are directly link to the species adaption and ecology. This study aims to evaluate the predictive potential of morphological data in determining the primary lifestyle of birds using a tree-based machine learning algorithm. The researchers used the AVONET project's supplementary dataset 1, including 11 morphological predictors and classifications based on primary lifestyle for over 95% of bird species. Univariate analysis revealed statistically significant differences in all morphological traits across primary lifestyles. Machine learning models achieved high accuracy rates (>78%), surpassing traditional approaches. These findings support the prediction of bird primary lifestyle based on morphological traits and highlight the importance of morphological traits in ecological modeling[7].

Contextual traits are influence by external factors such as location. These traits are temporal and may vary. Contextual traits can also be more challenging to quantify and standardize across diverse bird species. Morphological traits, being more objective and measurable, lend themselves well to predictive modeling.

Conclusion

To address the research questions, my research examined if specific bone measurements can be used to differentiate between bird groups. I found that morphological traits like bone length and thickness tend to separate the bird categories. These physical qualities probably mirror how each bird type is specially adapted to its normal habitat and life-style. This suggest that there is enough evidence to reject my null hypothesis which states that There is no significant difference in the bone measurements across the identified ecological categories of birds. Thus, confirming that at least one of the bone measurements will differ significantly between the identified ecological categories of bird.

These suggestions might be useful for any researcher who wants to continue or expand on this work:

- Validating finding across different geographical regions.
- Explore whether environmental shifts (e.g., climate change) influence bone morphology.
- Explore how variations in bone length and thickness impact flight capabilities, foraging behavior.

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