Hyoid Bone Size and Its Implications for Social Organization and Sexual Selection in *Alouatta pigra* and the Elusive *Alouatta macconnelli*

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The purpose of this research paper is focusing on the hyoid bone in *Alouatta pigra* and *Alouatta macconnelli* and determine its role in affecting the social organization and sexual selection of the individuals in these species. This includes the discussion on the dimensions of the hyoid between the males and females as well as an analysis of observed social behaviour patterns and the sexual selection process. It was found that female *Alouatta pigra* had a larger hyoid than males of the species and that *Alouatta macconnelli* males had a hyoid nearly twice the size of females. The hyoids were measured from the Mammal Biodiversity collection at the Royal Ontario Museum. The bones dimensions were taken using plastic calipers and their circumference measured using a soft tape measure. Based on the sexual selection and social organisation of *Alouatta pigra* which is multi-male/multi-female with the occasional unimale with multiple females, the null hypothesis must be accepted as the larger hyoid is not found in males but in females and the size of the hyoid does not affect the social organization in this species. In *Alouatta macconnelli*, there is little information on this species but the null hypothesis is rejected as males have much larger hyoids than females and the social organization is that of a uni-male with multiple females.

**Keywords:** hyoid bone; howler monkey; sexual selection; alouatta pigra; alouatta macconnelli; social organization

Known for their deafening calls, *Alouatta* spp. is a world famous genus that include platyrrhine monkeys capable of producing a howl that can be heard 500 to 1000 metres away (Van Belle et al., 2013). Their calls, howls, barks and roars are due to a highly specialized bone in the larygical areas called the hyoid (Bergman et al., 2016, p.756; Dunn 2018, p.32). Howler monkeys species have large bloated cup-like hyoid bones that increases their calls vibrancy. The hyoid bone in *Alouatta* spp. ranges from very large to small across the species and among the sexes. This specialized adaptation is unique to the *Alouatta* genus as other genre do not have this feature. This paper will be looking at two species of howler monkeys, *Alouatta pigra* and *Alouatta macconnelli* and their hyoid bones and how their hyoid bone size relates to their social organization and sexual selection.

![Image of hyoid bone](image_url)

**Figure 1.** *Alouatta macconnelli* hyoid bone from the male specimen 31715, from the Royal Ontario Museum Mammal Biodiversity collection.

The hyoid bone is normally small in most species, with *Alouatta* spp. being the exceptions. The bone is connected lateral ventricular to the air sacs in our throats that allows us to make noise. The cup-like feature on a howler hyoid is called a bulla and is absent in anatomically modern humans. All great apes other than *Pongo* and *Homo sapiens* have a bulla, though it is greatly reduced in size (Dunn 2018, p.30). The bulla in howlers is a thin-walled cup shaped features on the anterior part of the hyoid. The hyoid is connected through muscles and ligaments to the mandible, tongue, laryngeal cartilage, pharynx and cranial base. The air sac will actually go into the bulla making a balloon shape (Youlatos et al., 2015). The extreme enlargement forms a resonating chamber for the air sac producing booming calls. The bulla takes up almost all of the hyoid in howlers and is also a sexual dimorphic trait as there is differences in size and shape among different species and sexes (Dunn 2018, p.23). Among the 9 species of howlers, *A. macconnelli* is the least researched yet it has the largest and most bulbous hyoid shape in male individuals. On the other hand, *Alouatta palliata* has the smallest hyoid in male (Dunn 2018).

Variation in the howls is strong enough for individual males to be identified through their sounds alone. The hyoid bone is responsible for shifts in the frequency and pitch of the noises the monkeys are making (Bergman et al., 2016, p.759). It was found that *Alouatta pigra* average roar has a frequency of $3,319 \pm 17$ Hz (Bergman et al., 2016 p.761). *A. pigra* was also found that a male will have an average roaring bout of $14.8 \pm 0.6$ minutes long, one of the longest sessions among the howler genus (Bergman et al., 2016, p.760; Van Belle et al., 2013, p.1209). There are many reasons why a howler may roar, it’s been observed that at the crack of dawn *A. pigra* will be up howling to let everyone else know that this is his territory (Van Belle et al., 2013, p.1210; Carpenter 1934, p.55). One of the only things known about *Alouatta macconnelli* behaviour is that males are very territorial and will park themselves at the edge of their range and call out to proclaim their control of the area (Van Belle et al., 2013, p.1211). Howlers are known to use
their calls as a way of intra-group communications for infant protection, mate guarding and resource defending (Van Belle et al., 2013, p.1211). Males tend to go on howling bouts alone or sometimes a group of multiple males will howl together (Van Bella et al., 2008, p.1491). In groups with multiple males, the dominate male, who spends the most time around the females, has more howling bouts than the beta or below males. When two neighboring groups of howlers are each at the edge of their territory, they will take turns howling at each other in long sessions (Carpenter 1934, p.82). Alouatta macconnelli are known to furiously defend their territories border and howl at anyone who approaches (Van Belle et al., 2013, p.1211). Females can also howl but not as loud and for as long as the males due to a smaller hyoid bone. Darwin even theorized the difference in the howling between males and females is due to a sexual selective adaptation, which is the hyoid size (Bergman et al., 2016, p.756).

Howler monkeys are known to live in a variety of different group settings. The majority of the troops are multi-male/multi-female groups (Lecompte et al., 2017, p.2; Van Belle et al., 2006, p.131). Some groups are physically separated through physical barriers which mark the boundaries of their territories (Van Belle et al., 2013, p.1210). In a large study of Alouatta pigra in Mexico that included 801 individuals, found that most groups are made of 2 to 12 individuals with a mean of 6.57 ± 1.20 members. In the most common group arrangement for A. pigra there were 2.07 ± 0.41 adult males, 2.26 ± 0.33 adult females, 1.28 ± 0.48 juveniles and 0.96 ± 0.44 infants in a group. In these multi-male/multi-female groups, there can be 1 to 5 males but all mixed-sex groups had a minimum of 2 females, making them polygynous species. (Van Belle et al., 2006, p.126 & 134). A. pigra is also known to have groups of lone males of up to 5 individuals (Van Belle & Estrada 2006, p.130). As mentioned before, A. macconnelli is extremely understudied and very little is known about them. There is some evidence of A. macconnelli being a species with predominantly unmale groups, yet it is unclear how many females there would be in the charge of the single male (Dunn et al., 2015, p.2841).

The highly advertised study on howler monkeys that came out in recent years, shows the connection of the hyoid bone size to the size of the males testicals. It was found that Alouatta males living in a single male group with many females will have smaller testes and a large hyoid. This is because the single male needs to attract many females into his polygynous social group and will be the only male mating with the females. He will not need large testes to outcompete other males. On the reverse, males living in a multi-male/multi-female group will have smaller hyoid bones and larger testicals. This is because the males do not need to attract the females in their group but need to be able to outcompete post-copulation with other males. Large testes produce more sperm and larger ejaculations making their sperm more likely to fertilize the female's ovum (Dunn et al., 2015, p.2839). This study did include a comparison of the hyoid bone size and the testes for A. pigra but not for A. macconnelli. The study shows that A. pigra has an average of 1.7 to 2.4 males per group, a hyoid volume of 60cm³ and testes size of 11 to 13cm³. A. pigra fits with the model of multi-males/multi-females with the need of smaller hyoids and larger testes. By comparison, A. palliata is on the extreme end of the spectrum with many males trying to out do the others through post-copulatory competition (Kelaita et al., 2011, p.179). This study does not include the testes size for A. macconnelli but it does show a group having 1 male and a hyoid volume of 110cm³ (Dunn et al., 2015, p.2841). When following the trend of this theory, A. macconnelli will have very small testes as it has the largest hyoid, a complete opposite to A. palliata.

Females in Alouatta pigra groups chose to mate predominantly with the central or dominant male in the group, even if they lived in a multi-male/multi-female group. In groups with many males, the male who spends the most time around the females was more likely to be the dominant male of the group. He maintains much closer proximity to the females even if they were not in a period of estrous. While many females created a monopoly by only mating with the dominant male in the group, others tried to create paternity confusion by mating with a non-dominant male of the same group or with the dominate male of a neighboring group. Females were the majority instigators of sexual interactions as she would present her genitals to the males, establish eye contact and flick her tongue (Van Belle et al., 2009, p.154). The male may occasionally show sexual initiation by grooming the females and sniffing her genitals (Van Belle et al., 2009, p.156). Overall, female Alouatta pigra will choose to mate with the central male an overwhelming majority of the time and only mate with others to create paternity confusion (Van Belle et al., 2009, p.160). There is no record of any sexual behaviour study being conducted on A. macconnelli so any information regarding their sexual behaviour is purely speculative based on the evidence from other species of Alouatta and the data collected from the osteological analysis of the hyoid bones from the ROM collection.

A goal of this paper is to use the results from a osteological study at the Royal Ontario Museum to shed some light on the phantom Alouatta macconnelli based on the size of the hyoid bone. However this is not the focus of the paper as no behavioural study has been conducted on A. macconnelli and therefore I can not prove or disprove any of my hypotheses for it. I can only make interpretations from the data but it still would need to be further tested. The thesis of the paper is the look at the hyoids size in its social organization in its relationship to sexual selection in Alouatta pigra and Alouatta macconnelli. My first hypothesis is that males will have larger hyoid bones than females due to larger body size and this would allow them to produce louder calls. My second hypothesis is that in species with males having a larger hyoid bone, these species are uni-male/multi-female social groupings as females will choose males with large hyoid bones and louder calls.

Methods

This study of the hyoid bone in platyrrhines was conducted at the Royal Ontario Museum (ROM), under the supervision of Dr. Burton Lim. The platyrrhine skeletons in the Mammal Biodiversity Collection were combed through in hopes of finding a hyoid bone among the remains. Unfortunately, almost all the remains were either purley cranial with just the cranium and mandible or were a full skeleton with the hyoid missing. The only non-howler monkey hyoids found were that of Pithecia pithecia, Cebus apella, Ateles paniscus and a fragment from Cebus olivaceus, with only one hyoid per
species listed. *Ateles* is the only other genus used in this study as an outgroup comparison in hyoid bone dimensions. As the hyoid in many species is small, as well as fragile, the bone rarely preserved and is underrepresented in collections.

The Mammal Biodiversity Collection at the ROM was accessed on February 28th, 2019. I was given access by Dr. Burton Lim. As said above, only a few hyoid bones were found. These included one from *Ateles paniscus*, one form *Alouatta belzebul*, 8 from *Alouatta macconnelli* and 6 from *Alouatta pigra*. There are 16 hyoids included in this study with a focus on the ones from *A. macconnelli* and *A. pigra*. Plastic calipers were used to take measurements of the hyoid, including the horns, bulla, the opening mouth of the bulla and the circumference of the body was taken at its widest point using a soft tape measure. The measurements were taken from areas that cover the majority of the shape for the hyoid bone (lateral) and its superior connection the laryngeal area (superior). The key areas include the total body height, body height without the bump after the mouth opening, the lateral width of the bone (taken from a lateral view), the mouth dimensions, the width and length from a superior view and the horn length are all included in Table 1. A reference picture of where the measurement were taken can be found in Figure 2.

The range, mean, median, mode and standard deviation were calculated for the male and female individuals of *A. macconnelli* and *A. pigra*. *Ateles* and *A. belzebul* statistics were not calculated as there is only one hyoid bone of each species found at the ROM. Their measurements are included in Table 1 to be an outgroup comparison size. The median and mode were calculated but are not shown in the result section as there is such a small data set they are almost exactly the same as the mean.

**Table 1.** Key measurements taken of the hyoid bone in millimeters taken from the right lateral side and a superior view.

| Species | Specimen | Sex | Total Height (mm) | Lateral View (mm) | Superior View (mm) |
|---------|----------|-----|------------------|------------------|------------------|
| *Ateles paniscus* | 139625 | Male | 21 | 12 | 17 | 5 |
| *Alouatta belzebul* | 612259 | Male | 32 | 15 | 11 | 15 |
| *Alouatta macconnelli* | 29467 | Male | 30 | 16 | 14 | 12 |
| *Alouatta pigra* | 29460 | Female | 18 | 13 | 17 | 11 |
| *Alouatta pigra* | 29460 | Female | 21 | 17 | 20 | 16 |
| *Alouatta pigra* | 29460 | Female | 27 | 22 | 25 | 20 |
| *Alouatta pigra* | 29460 | Female | 30 | 27 | 30 | 22 |
| *Alouatta pigra* | 29460 | Female | 33 | 32 | 33 | 25 |

Included in Table 1 are some of the key measurements that were taken *Ateles paniscus*, *Alouatta belzebul*, *Alouatta pigra* and *Alouatta macconnelli* hyoid bones from the Royal Ontario Museum Mammal Biodiversity collection. A reference of where the measurements were taken on the hyoid bone can be found in Figure 2. Figure 3-5 are graphs depicting the ranges for *A. macconnelli* and *A. pigra* in total body height, body width and circumference measurements.

**Figure 2.** Diagram of where measurements were taken on the hyoid bone. Image of *Alouatta macconnelli* hyoid bone from specimens 31715.

*Alouatta macconnelli* males have a range of total height from 53 to 70mm and mean of 61 ± 7.31mm (n=5). Females range is 33 to 34mm and mean of 33.33 ± 0.57mm (n=3). Males have a body width range of 40 to 52mm and mean of 47.4 ± 4.67mm (n=5). Females have range of 19 to 23mm and mean of 21.67 ± 2.31mm (n=3). Males have a body circumference range of 162 to 187mm and mean of 174.8 ± 10.71mm (n=5) and females range of 86 to 99 mm and a mean of 94.33 ± 7.23mm (n=3).

*Alouatta Pigra* males have a range in total body height of 17 to 19mm and mean of 18 ± 1.41mm(n=2). Females range is 21 to 23mm and mean of 21.75 ± 0.96mm (n=5). Males have a range of body width of 11 to 12 and means of 11.5 ± 0.71mm (n=2). Females range is 11 to 15 mm with a mean of 13 ± 2.31mm (n=4). Males have a body circumference range of 63 ± 4.24mm (n=2) and females’ range is 75.75 ± 0.96mm (n=4).

**Figure 3.** Total body height range for male and female *A. pigra* and *A. macconnelli* hyoid bones.
larger the hyoid the louder the call and smaller testes due to less competition between males. The male with a large hyoid and powerful call attracts the females and is more likely to be in a uni-male polygynous social group (Van Belle et al., 2008; Dunn 2018, p.32; Dunn et al., 2015). This fits with the small evidence about the social organization of male Alouatta macconnelli living in groups consisting of one male and undetermined number of females (Dunn et al., 2016, p.2841).

I am able to accept my second hypothesis as A. macconnelli would be able to produce a dominating call that would attract females led to living in a single male-multi female group. However, there are some problems with the rejection of my second null hypothesis. The first being there is no other information of the behaviour and social organization of A. macconnelli beyond Dunn et al., 2015. A. macconnelli is an extremely understudied species, yet they have the largest hyoid bone of all Alouatta (Dunn 2018). There is no information on the number of females in a social grouping. This means there is a possibility that A. macconnelli could be monogamous with only one male and one female per group. Overall, there is a lack of information to fully confirm my hypothesis, I can only make inferences based on the osteological data collected, the limited information available for this species and connections to other Alouatta species.

My examination and measurementing of the Alouatta pigra hyoid collection at the ROM revealed unexpected results. As seen in Table 1 and Figures 3-5, female A. pigra have a larger hyoid bone than the males of this species. The female circumference range is 75.75 ± 0.96mm (n=4) while the males is 63 ± 4.24mm (n=2). This is the opposite of my first hypothesis saying that males had larger hyoids than female. Therefore I must reject my first hypothesis and accept by null hypothesis for this species. The collection at the ROM has limited my reference data to only 6 individuals of A. pigra, which is an extremely small data set. As my data set is so limited, I can not fully show that all female A. pigra have a larger hyoid than the males, I can only show that this is the case for my data. As seen in Dunn’s pictogram (Figure 6), the male hyoid is very large but there is no female hyoid for A. pigra. The female A. macconnelli hyoid shown in the figure is smaller than that of the male A. pigra (Dunn 2018). According to my data, the female A. macconnelli is larger than male A. Pigra hyoids. This calls into question the scale of these hyoid depictions and that the male hyoids in my data set may be from the smaller end of the spectrum for male hyoid size and that a much larger data set may reveal that male A. pigra hyoids are bigger than both female A. pigra and A. macconnelli hyoids. Another piece of evidence that my data set for male A. pigra hyoid size is of the lower end outliers is how body size affects the hyoid dimensions. A. pigra males have a body weight range of 11,113 to 11,590g and females have a range of 6,577 to 6290g (Ford & David 1992, p.16; Kelaita et al., 2011, p.182). Males are substantially heavier and therefore have a larger body size than females. As large bodied individuals would have a larger hyoid (Bergman et al., 2016, p.762), this shows that the males in the ROM collection may be subadult or on the smaller side of the weight range.

I must also reject my second hypothesis and accept the null hypothesis for A. pigra. As in this hypothesis I state that males have a larger hyoid bone than females and this leads to one-male polygynous social groups. This is not the case for A. pigra as my data shows females having larger hyoids and A.
pigra social groups are majority multi-male/multi-female (Lecompte et al., 2017, p. 2; Van Belle et al., 2013, p.1212; Van Belle & Estrada 2006, p.126). The average of adult males in a A. pigra group is 2.07 ± 0.41 and 2.26 ± 0.33adult females in the group, which is not what I hypothesized (Van Belle & Estrada 2006, p.126). Based on my data and the reversal of my first hypothesis (i.e. females have larger hyoids) it would make more sense if A. pigra was a monogamous species with very little sexual dimorphism or they are polyandry with one female and multiple males in a group. Upon first examination of the A. pigra hyoid bone, I had theorized that this was a polyandry species.

Figure 6. Picture of male Alouatta macconnelli hyoid, cranium and mandible along with a taxonomic cladistic of the Alouatta genus from the paper Sexual Selection and the Loss of Laryngeal Air Sacs During the Evolution of Speech by Jacob Dunn.

Conclusion

My hypothesis for A. pigra and A. macconnelli was that males would have a larger hyoid bone than females, and that due to the larger hyoid size, are able to attract more females through their calls and be living in a single-male/multi-female polygynous social group. However the data from my ROM osteological study and the lack of behaviour studies has lead to my rejection of some of my hypotheses. A. pigra has a smaller hyoid bone than the females of this species. This means I must reject my first hypothesis. As well, A. pigra lives in a social group of multi-males/multi-females and the males must post-copulatory compete rather than attract females in being apart of a polygynous social group (Lecompte et al., 2017, p.2; Dunn et al., 2015). Therefore I must accept both null hypotheses in the case of A. pigra. For A. macconnelli, there is extremely limited evidence for behaviour of this species which makes my acceptance of my second hypothesis challenging. I accept my first hypothesis for this species as a male A. macconnelli nearly has twice the size of a female hyoid bone. I am accepting my second hypothesis but am cautious as there is little evidence supporting the social organization of this species as a polygynous unimale social group and there is no evidence on how many females there are in each group (Dunn et al., 2015, p.2841). The study of A. macconnelli should be continued as there is much to learn about the sexual dimorphism, sexual selection and social organization of the species. As well, larger datasets are needed to further the analysis of A. pigra in its hyoid size and sexual dimorphism.

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