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INFLUENCE OF FACIAL RUFF REFLECTOR FEATHERS ON THE HEARING OF THE BARRED OWL

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Mendez, Madeline

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INFLUENCE OF FACIAL RUFF REFLECTOR FEATHERS ON THE HEARING OF THE BARRED OWL

By

Madeline Maria Mendez

A capstone project submitted for Graduation with University Honors

November 6, 2025

University Honors

University of California, Riverside

APPROVED

Dr. Christopher Clark

Evolution, Ecology, and Organismal Biology

Dr. Begoña Echeverria, Howard H Hays, Jr. Chair

University Honors

Abstract

This research examines the impact of the reflector feathers on the sound perception of the Barred Owl (*Strix varia*). As in most owl species, the Barred Owl has a facial disk, a circular arrangement of fluffy feathers (auricular feathers) forming a concave disk-like shape, surrounded by a dense facial ruff. The facial ruff is composed of thin, stiff, and dark feathers called reflector feathers. The ruff extends behind the owl's ears and preaural flap, a movable skin flap in front of the ear canal. To research this, ten Barred Owl heads were tested with different conditions, manipulating head elevation, ear flap position, and the removal of different feather tracts. A speaker playing white noise was placed in front of the owl specimen, while small microphones placed in the ear canal recorded the sounds received. The collected audio data was analyzed to determine how reflector feathers influence the Barred Owl's hearing. Previous research on a distantly related species of owl, Barn Owl (*Tyto alba*), has shown that facial ruffs composed of reflector feathers acted as a "sound collector", significantly amplifying sounds directly in front of the owl, especially those of higher frequencies (von Campenhausen, 2006). The results showed that although the Barn and Barred Owl were similarly impacted by the removal of reflector feathers, with heads without reflector feathers perceiving sounds at higher frequencies at louder amplitudes than owl heads tested with their reflector feathers removed, their ear asymmetry was shown to be different from one another.

Acknowledgements

I would like to sincerely thank my faculty mentor, Dr. Christopher Clark, for his support throughout this project. I am deeply appreciative of his time, expertise, and help in guiding me through this research. I would also like to thank my friends and family for helping me along the way by teaching me how to code in MATLAB and peer reviewing my work. I would also like to thank University Honors for allowing me the opportunity to complete this capstone project.

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Introduction

This research project allows insight into the hearing of the Barred Owl and its close relatives, highlighting how their facial feathers impact how sound reaches their ears. Most research on owl hearing has been conducted on the Barn owl, a species very distantly related to the Barred Owl. We predict that the Barn Owl and Barred Owl will be found to have similarities in their sound perceptions.

The Barred and Barn Owl have a concave and circular facial region known as the facial disk, as seen in Figure 1. The facial disk is surrounded by a dense arrangement of feathers known as the facial ruff. The facial disk and ruff are composed of two feather types known as auricular and reflector feathers. The auricular feathers are light and fluffy and found in the center regions of the facial disk, as demonstrated in Figure 1. On the other hand, dense and thin feathers known as reflector feathers are found on the edge of the facial disk, forming the facial ruff as shown in Figure 1. The facial ruff extends behind the preaural flap of the owl. Preaural flaps are flaps of skin that cover the ear canal of the Barred Owl. In addition, Barred and Barn Owls have ear asymmetry, meaning that their right and left ears are shaped differently. Figure 3 shows this difference in the ears of the Barred Owl, whose ear asymmetry extends to the preaural flap size as well. Due to the asymmetry found in the Barred and Barn Owls, their ears have directionality, meaning they are capable of determining sound origin in three-dimensional space due to the difference in how sound reaches each ear (von Campenhausen, 2006). In the Barn Owl, it was found that their right ear, when the facial ruff was intact, perceived sounds from above more strongly in the right ear than the left, while the left ear perceived sounds from below to a stronger degree than the right ear (von Campenhausen, 2006).

In Barn Owls, it was found that the removal of the reflector feathers seemed to have a significant impact on the directionality of the ears, decreasing with their removal (van Campenhausen, 2006). Previous research found it likely that in the absence of reflector feathers, Barn Owls will likely find it difficult to pinpoint sounds to their normal abilities (von Campenhausen, 2006). Considering this, we expect there to be interactions between our elevation and ear side (right or left ear) variables in the experiment. If the owls are similar, we would expect the removal of the auricular feathers to have little impact, while the absence of reflector feathers would lead to a decrease in sound amplitude recorded.

It is important to bear in mind the differences between the Barred and Barn Owls and the years of evolution that divide them. In fact, it has been found that the ear asymmetry found in some owl species likely developed in at least five independent evolutionary lines, with Tyto and Strix, the genera from which the Barn Owl and Barred Owl descend, being two of the five independently evolved lines of ear asymmetry (Norberg, 2002). This means that although both species showcase ear asymmetry, there is a possibility that their asymmetry benefits them in different ways. For instance, there is a likelihood that although the right ear hears sounds from above more clearly than the left ear in the Barn Owl, this may be the opposite in the Barred Owl due to its independent evolution of ear asymmetry. Even so, we expect our findings on the Barred Owl to align with the results found in the Barn Owl and find that the owl heads with reflector feathers will perceive sounds at higher frequencies at louder amplitudes than owl heads tested without their reflector feathers intact.

Design and Methods

Frozen Barred Owl specimens were obtained from the Barred Owl removal experiment. Frozen owls were prepared by thawing them out and having their heads removed. The base of the head was cut into, and the brain was removed using cotton and tweezers. If the facial feathers were wet, cotton balls were placed into the ears of the owl before placing the owl head into a bag of wood dust. This allowed the wood dust to absorb the moisture from the feathers, bringing them back to a more lifelike posture. A blow dryer was set to cold and then used to remove the wood dust from the owl head. Several rounds of wood dust and blow drying were used until the owl feathers were fully dried and in the correct position.

The thawed owl head was pinned to a foam board placed on top of an adjustable stand, as seen in Figure 4. A speaker (JBL Flip 5) sat a foot away from the foam board and played the recording 'Whitenoiseever1', which was created using Audacity 3.4.2 with the white noise generation tool (Mono, 44100 Hz, 32-bit float), which creates sound with all frequencies at an equal volume, creating a static-like noise. The audio has 5 seconds of white noise, followed by 5 seconds of silence, followed by a final 5 seconds of white noise. Small microphones (Polsen PL-5) are placed into each ear of the owl just inside the entrance of the ear canal, as demonstrated in Figure 3. Using a Sound Devices 702 recorder (48 kHz, 24 bits), audio was recorded in stereo for every treatment.

When testing, the head is recorded at 6 different positions for each feather treatment. These positions are as follows: +45 degrees up (the foam platform is angled 45 degrees above level) with the preaural flap pinned fully open, +45 degrees up with the preaural flap fully pinned closed, 0 degrees (level) with the preaural flap fully open, 0 degrees with the preauricular flap fully pinned closed, -45 degrees down (the foam platform is angled 45 degrees below level) with

the preaural flap pinned fully open, and -45 degrees down with the preaural flap pinned fully closed. The preaural flaps were positioned using two thin pins, as shown in Figure 2. Once the audio of the white noise is recorded through the microphones in the owl's ears at the positions listed above, with all feathers intact, the owl head must then undergo feather treatments as seen in Figure 5. The next treatment is to record the data of the owl head without its auricular feathers. The final treatment is then to remove the reflector feathers. This means a total of 18 stereo recordings are taken for a total of 36 individual tracks.

The 18 stereo recordings are each uploaded onto an audio software, Raven Lite 2 (version 2.0.5). Each audio is then divided into two channels, where channel 1 correlates with the left ear and channel 2 correlates with the right ear. A 3-second-long selection spectra is then created with a Bin size of 512, creating a list of data points with each frequency correlating to a different amplitude. This selection spectra is saved and exported, and a different selection spectra is created for with and without white noise playing for each stereo audio. The selection spectras are then opened and put onto an Excel sheet, totaling to a final count of 72 selection spectra columns per owl. The Excel sheets are then uploaded onto MATLAB, where they are used as a reference for the creation of graphs of the data sets. In addition, we also used MATLAB in order to find the average amplitudes of certain frequency ranges of each recording. We found the average amplitudes for the audio from 3000-5000 Hz as well as 7000-8000 Hz. These values were used as every recording had a consistent plateau of amplitude values in these ranges.

To understand the significance of the patterns found in the graphs created on MATLAB, we input the data into JMP (JMP Student Edition 18). On JMP, a chart was created with each recording getting its own row in the table and columns showing each independent variable. The independent variables for this experiment were owl number, flap position, elevation, right or left

ear, and feather treatment. Two more columns were then created in the JMP chart correlating to our dependent variables. Our dependent variables were the average amplitude values found from 3000-5000 Hz and 7000-8000 Hz. Once this was done, we ran a multivariate model with several model effects. These model effects, as listed below in Table 1, included the dependent variables as well as interaction effects. The three tested interaction effects in the multivariate model were interactions between preaural flap position and ear side (right or left ear), feather treatment and ear side, and elevation and ear side. Before the running of the multivariate model, predictions were made regarding the impact of each model effect on the data, as seen in Table 1. Once the data was fully analyzed through the multivariate model, we once again reviewed the graphs generated in MATLAB to determine which relations seen are significant.

Considerations and Requirements

Due to the usage of dead owl specimens, there is some concern that the data will not be fully reflective of what would be expected in a live owl. This is addressed to some degree by massaging the skin after thawing and using wood dust to dry any wet feathers. It should also be mentioned that, unlike previous research done on the Barn Owl (von Campenhausen, 2006), space is not available to move the sound source; thus, the owl head itself will instead be moved. Initial collecting of data showed inconsistencies in results, with changes in the preaural flap position between different feather treatments likely causing the odd results, leading to pinning the preaural flaps into two extreme positions. No special requirements or approvals were needed for this research project.

Results

Using MATLAB, 12 graphs were created summarizing the data collected. There is a graph for every treatment combination, and each graph has an individual line for each owl result. As seen in Figures 6, 7, and 8, each graph shows each individual recording in light blue. Along the bottom of the graphs shown in these figures, one can see a consistent downward-sloping curve; this curve signifies the background noise of the room. In addition, each graph has three bolded and colored lines that show the average dB recorded for each feather treatment. The red line signifies the average dB recorded for treatments with all feathers in place. The green line shows the average dB for treatments with the auricular feathers removed, while the blue line shows the average dB for treatments with the auricular and reflector feathers removed. Although we can see patterns forming in the data shown in these graphs, the graphs do not allow us to determine what factors are significant in this experiment.

To determine the significance of different variables in the experiment, we used JMP to run a multivariate model. Using this model, we tested the following variables: elevation, ear side, preaural flap position, feather treatment, and owl number. In the case of owl number, this was analyzed as a random effect variable due to the possibility of differences between owls. In addition, crosses between preaural flap position and ear side, feather treatment and ear side, and elevation and ear side were also tested.

In a frequency range from 3000-5000 Hz, it was found that elevation, feather treatment, and the cross between elevation and right and left ear were significant, as seen in Table 2. Elevation and feather treatment were found to have a p-value of >0.001, signifying they were significant. The cross between elevation and the right and left ear was also found to be significant, with a p-value of 0.00753. The model effect of ear side was found to have a

significance of 0.04400, meaning it was considered to be statistically insignificant; however, the cross between the ear side and elevation was found to be statistically significant, making it important to review the impact of the right vs left ear as well. Preaural flap position and the cross between preaural flap and ear side, as well as the cross between feather treatment and ear side, were found to be insignificant. Preaural flap position was found to have a p-value of 0.328. The cross between preaural flap and ear side was found to have a p-value of 0.679. A similar finding was also seen with the cross between feather treatment and right or left ear, which was found to be insignificant with a p-value of 0.20111.

In the frequency range from 7000-8000 Hz, the model determined that elevation, right or left ear, feather treatment, the cross between elevation and ear side, and the cross between feather treatment and ear side are significant to the results found. In this range, the model effects of elevation, ear side, and feather treatment, and the cross between elevation and ear side were found to have a p-value of >0.001. This means that all four of these variables have an extremely significant impact on the results found in this experiment. The cross between feather treatment and right or left ear was found to have a p-value of 0.01198, once again showing that this cross was significant to the results found. On the other hand, preaural flap position and the cross between preaural flap and right or left ear were found to be insignificant with p-values of 0.73722 and 0.86616, respectively.

Discussion

When running the multivariate model, the different frequency ranges had different factors that were determined to be statistically impactful on the observed results. In the frequency range from 3000-5000 Hz, the most significant variables to the results (Table 2) are elevation, feather treatment, and the cross between elevation and ear side (right or left). Although whether the right

or left ear was recorded was deemed insignificant for the results in this range, due to the interaction between elevation and ear side being found to be statistically significant, it is also important to look at the impact of this variable as well in Figures 6-8. Within this range, it was also determined that preaural flap position, the interaction between preaural flap position and right or left ear, and the interaction between feather treatment and right or left ear are statistically insignificant to the results.

Figures 6-8 display the results for all recordings at each elevation. The light blue lines signify each individual result, while the bolded, colored lines signify the average results from each feather treatment. Since each figure shows the data for a single elevation, the only necessary relationships per figure to check, based on the statistical model, are feather treatment and the interaction between elevation and ear side. When first observing Figure 6, we see a consistent pattern across all four graphs (6a, 6b, 6c, and 6d) over the 3000-5000 Hz frequency range. The green line, the line showing the average result when auricular feathers are removed, is consistently above the two others. The green line is followed by the red line, representing the average data for owl specimens without any feathers removed, and shortly thereafter by the blue line, representing the average data for owl specimens with auricular and reflector feathers removed. Figures 7 and 8 show a very similar pattern as well, almost consistently having the green line lie above the red and blue over the 3000-5000 Hz frequency range. Since the removal of the auricular feathers has consistently increased the volume of sound recorded, this implies that the auricular feathers have a dampening effect over this frequency range. Meanwhile, the removal of the reflector feathers after removing the auricular feathers shows a significant decrease in the audio recorded, implying that the reflector feathers, working antagonistically to the auricular feathers, amplify the sound heard over this range.

In the 3000-5000 Hz frequency range, elevation was also found to have a significant impact on the results seen. In Figure 6, at an elevation of 0°, we see that the green, red, and blue lines signifying the different feather treatments are spaced evenly apart. In comparison, we can see in Figure 7 that at an elevation of +45° the red and blue lines tend to lie closer together than to the green line. This implies that at an elevation of +45°, there is less of a difference found between the average dB recorded in the feather treatment with all feathers in place compared to the feather treatment with the auricular and reflector feathers removed. On the opposite side of the spectrum, in Figure 8, at an elevation of -45°, in three of the four result graphs, the red line is shown to be closer to the green line. Meaning the average dB recorded for the feather treatment with all feathers in place is very similar to the average dB recorded for the feather treatment with the auricular feathers removed. These findings imply that at 0° elevation, the impact of auricular feathers and reflector feathers generally cancel each other out. Meanwhile, at an elevation of +45°, since the removal of auricular and reflector feathers results in similar findings as when all feathers are in place, while the removal of auricular feathers causes an increase in sound removed, the auricular feathers still dampen the sound recorded, but the reflector feathers are no longer amplifying the sound as much as before. At an elevation of -45°, the feather treatment with all feathers in place and the feather treatment with the auricular feathers removed are very similar. This seems to imply that sounds coming from above the head, as in the -45° elevation treatment, seem not to be as impacted by the dampening abilities of the auricular feathers.

The statistical model also found a significant interaction between elevation and ear side in the 3000-5000 Hz frequency range. This means that each ear is impacted differently by the change in elevation. We can see in the graphs found in Figures 6-8 that the right and left ears react differently from one another when elevation is changed. Comparing Figures 6a and 6c to

Figures 7a and 7c, we can see that within this frequency range, the amplitude of the audio recorded for the left ear stays fairly constant at an elevation of +45°. In comparison, we can see when comparing Figures 6b and 6d to Figures 7b and 7d that when going from an elevation of 0° to an elevation of +45°, the right ear shows a decrease in amplitude over this frequency range. When comparing an elevation of 0° to an elevation of -45° for both the left and right ear, the amplitude of the sound recorded stays fairly consistent; however, the change in the impact of the feather treatments is slightly different in the right and left ear. The right ear shows the data for the treatment with all feathers in place, and the data for the treatment with auricular feathers removed are fairly similar at the elevation of -45°, while the left ear maintains clear differences between each feather treatment.

In the frequency range from 7000-8000 Hz, it was found that four variables were significant to the results. These variables included elevation, ear side, feather treatment, and the interaction between elevation and ear side. When looking at the impact of elevation, it is important to compare one ear side at a time to the different elevation treatments. When looking at the impact of elevation on the left ear over this frequency range, we can see a clear change in the results recorded. Figure 6a and 6c show the left ear at an elevation of 0°. At this elevation, we can see that the red line, the average dB recorded with all feathers in place, is very similar to the blue line, the average dB recorded with the auricular and reflector feathers removed. At an elevation of +45°, as seen in Figures 7a and 7c, the dB recorded for the feather treatment without reflector feathers in place is very similar to the dB recorded when the auricular feathers are removed. For the left ear at an elevation of -45°, we can view Figures 8a and 8c to discover that the data is a bit more spread out, with the lines from top to bottom being ordered: green, blue, red. This shows that for the left ear at an elevation of 0°, the auricular feathers dampen the dB

recorded, and the reflector feathers enhance the sound recorded by about the same amount. At an elevation of +45°, the auricular feathers are also seen to help dampen the audio recorded by the microphones; however, unlike at 0° elevation, the reflector feathers do little to help increase the audio recorded. For an elevation of -45°, the auricular feathers are once again seen to dampen the sound, and the reflector feathers help to increase the sound recorded, but to a smaller degree than the auricular feathers decrease the sound. At each elevation, there is a slight variation in dB recorded. In Figures 6a and 6c, the lowest dB recorded from any of the three feather treatments over this frequency range is 90 dB, while the highest is 110 dB. At +45°, the range was found to be 90-100 dB, and for -45°, it was found to be overall louder at 100-110 dB. This means for the left ear, the sound is loudest when the source is level to the ear or when the sound comes from above the ear.

Due to elevation, ear side, feather treatment, and the interaction between ear side and elevation being statistically significant to the results found within the multivariate model, we can now look at the right ear results in different elevations, separate from the left ear results in the 7000-8000 Hz frequency range. In Figures 6b and 6d, we can see the right ear results for an elevation of 0°. We can see that the red line is consistently the lowest, with the blue and green lines lying above. This implies that the auricular feathers dampen the sound to a greater extent than the reflector feathers amplify. Looking at Figures 7b and 7d, we can see fairly similar results with the red line consistently being below the two other lines. In Figures 8b and 8d, we can see once again that the red line lies below the two other lines. Although the order of the lines is fairly similar across all three elevations, we do see a change in the dB recorded. In Figure 6, at an elevation of 0°, the lowest dB recorded for any of the feather treatments was about 90 dB, while the highest was about 100 dB. In comparison, in Figure 7, the right ear had the lowest dB of

about 85 and a high of 95 dB. Finally, Figure 8 shows the dB increasing again to a range of 100 dB to 110 dB. This means that although the feathers were shown to play a similar role at each elevation, the different elevations interacted with the ear differently, resulting in an overall increased dB recorded at -45° elevation and an overall decrease in dB recorded at +45° elevation.

When comparing the differences from the right to the left ear, we can see a few variations. At an elevation of 0°, as seen in Figure 6, the left ear shows that the feather treatment with the lowest amplitude recorded, at about 100 dB, is the treatment with the auricular and reflector feathers removed. On the other hand, the feather treatment with all feathers in place had the lowest amplitude recorded at about 90 dB for the right ear. The highest amplitude treatment in this range on the left ear is the treatment with the auricular feathers removed at 110 dB. Meanwhile, the highest amplitude treatment in this range on the right ear is the treatment with the auricular and reflector feathers removed at 100 dB. This means that at this elevation, the left and right ears have approximately the same amplitude values for the feather treatment with reflector and auricular feathers removed; however, they vary greatly in the values of the two other treatments. It is seen that the amplitudes recorded for the treatment with the auricular feathers removed and with all feathers in place decrease in the right ear.

The comparison between the left and right ear for an elevation of +45° can be clearly seen in Figure 7. Changing from the left to the right ear does not impact the order of the feather treatment lines. We see that, fairly consistently in either ear, the average amplitude recorded with auricular feathers removed is greater than the amplitude recorded for the feather treatment with the auricular and reflector feathers removed, and the treatment with the least amplitude recorded is the treatment with all feathers in place. It can be seen that generally the left ear resulted in higher decibels recorded than the right ear at this elevational treatment. We see the amplitude

recorded from the left ear ranges from 95-100 dB, while the right ear ranges from 85-95 dB. The results for the feather treatment with the auricular feathers removed and the feather treatment with the auricular feathers and reflector feathers removed show little to no difference between the right and left ear, as seen when comparing Figures 7a and 7c to Figures 7b and 7d. However, the same graphs also seem to show a slight decrease in amplitude recorded for the feather treatment with all feathers intact in the right ear compared to the left ear.

Comparing the right and left ear at an elevation of -45°, as seen in Figure 8, we can see that the order of the feather treatments from highest dB recorded to lowest dB recorded is about the same. The feather treatment that results in the highest dB is the treatment with auricular feathers removed, followed by the treatment with auricular feathers and reflector feathers removed, and finally the treatment with all feathers in place. Comparing the amplitudes recorded, both ears have about the same results, except for the recordings for the treatment with auricular feathers removed. In the left ear, the treatment with auricular feathers removed is found to have an average amplitude of a little over 110 dB, while the same treatment on the right ear is found to have an average amplitude of a little below 110 dB.

When looking back upon the predicted experimental results, it is clear that several predictions were found to be statistically unlikely. Unlike what was predicted, preaural flap position, the interaction between preaural flap position and ear side, and the interaction between feather treatment and ear side had little to no impact on the recorded results. We were partially correct on the impact of ear side on the data recorded, although there was not a significant impact of ear side on the data in the frequency range of 3000-5000 Hz; a significant effect was found over the 7000-8000 Hz frequency range. Our predictions on elevation and the interaction between elevation and ear side were found to be correct, and both had a significant impact on the

data results. We were partially correct in the prediction for the impact of the feather treatments on the data recorded. We predicted that the removal of the auricular feathers would have no impact on the data recorded, while the removal of reflector feathers would significantly diminish the amplitude of the audio recorded. Instead, it was found that the auricular feathers impacted the data by dampening the sound recorded, while reflector feathers, just as we predicted, helped to amplify the sounds recorded.

A possibility of similarities between the Barred and Barn Owls was also previously discussed. The data shows that, similar to the results found in the Barn Owl, there seems to be a difference in how the right and left ears react to changes in elevation. However, it seems that the right ear in the Barred Owl, opposite to the Barn Owl, is responsible for amplifying sounds heard from below. The same pattern was found for the Barred Owl's left ear, which was found to amplify sounds from above, unlike the Barn Owl, whose left ear amplifies sounds from below. Similar to the research previously completed on the Barn Owl, it was found that the removal of the reflector feathers caused the right and left ears to have very similar recorded results. As was expected, due to the separate evolution of the Barred and Barn Owls' ear asymmetry, although they may share some similarities, such as in the impact of the reflector feathers, the structures of their right and left ears are significantly different from one another.

Figures and Tables

Model Effect	**Prediction**
Elevation	We predict amplitude recorded would vary due to previous research findings.
Right/Left ear	Due to the difference in shape, we predict one ear to be more sensitive to sound than the other.
Preaural Flap Position	We predict the amplitude recorded to be significantly quieter when the preaural flaps are in the closed position.
Feather Treatment	We predict the removal of the auricular feathers to have no impact on the audio recorded. We predict that the removal of the reflector feathers will significantly diminish the amplitude of the audio recorded.
Owl Number	Random effect variable
Interaction Effects:	
Preaural Flap Position x Right or Left ear	We predict that the preaural flap position will impact the right and left ear differently due to variation in flap shape in either ear.
Feather Treatment x Right or Left ear	We predict the feather treatment will impact the left and right ears differently due to the difference in ear shape.
Elevation x Right or Left ear	We predict elevation changes will impact the results differently in the right and left ears due to ear asymmetry and previous research findings.

Table 1: Independent variables and their respective predicted impact on the results.

Table of Results		
Model Effect	**P-Values**	
	3000-5000 Hz	**7000-8000 Hz**
Elevation	>0.0001	>0.0001
Right/Left Ear	0.04400	>0.0001
Preaural Flap Position	0.32800	0.73722
Feather Treatment	>0.0001	>0.0001
Owl Number	Random effect variable	Random effect variable
Interaction Effects:		
Preaural Flap X Right/Left Ear	0.67900	0.86616
Feather Treatment X Right/Left Ear	0.20111	0.01198
Elevation X Right/Left Ear	0.00753	>0.0001

Table 2: P-value table for all independent variables and interaction effects.

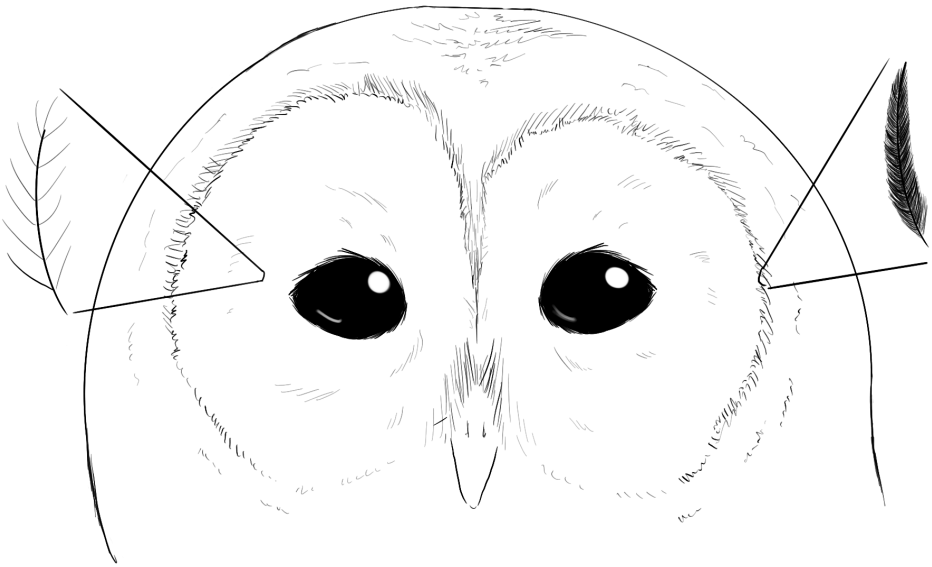


Figure 1: Feathers of the Barred Owl. Dense dark feathers, called reflector feathers, are found along the edge of the facial disk. In comparison, light, “fluffy” feathers are found on the facial region known as auricular feathers.



Figure 2: Pinning the ears of the Barred Owl. The microphone is attached to a pin and positioned at the ear entrance. Two pins are used to position the preaural flap.

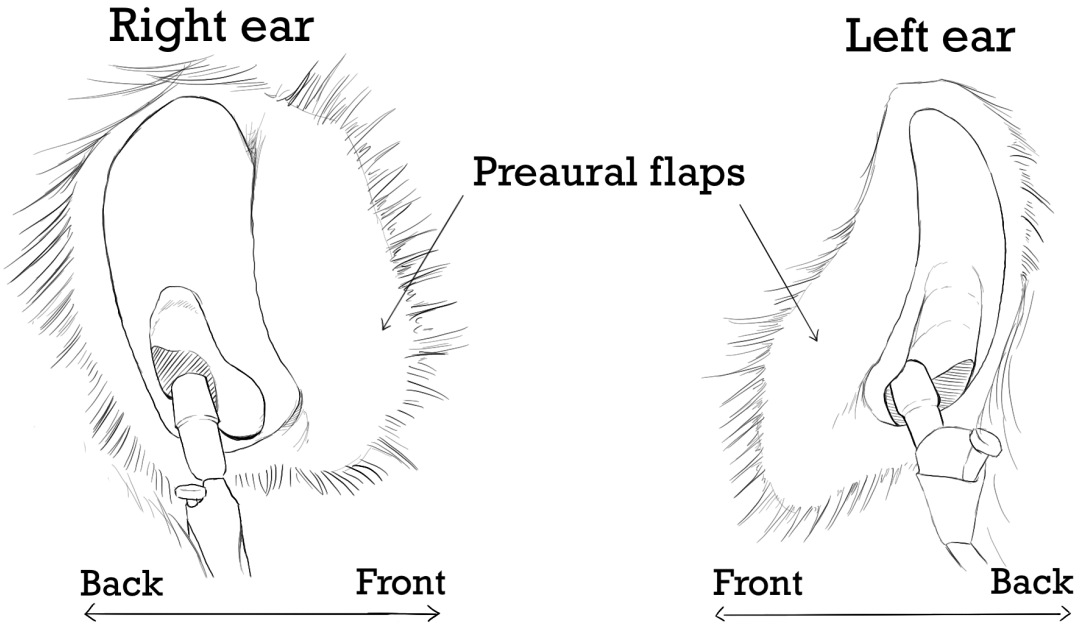


Figure 3: Microphone placement on the right and left ear. The microphone was placed at the bottom of the ear canal.

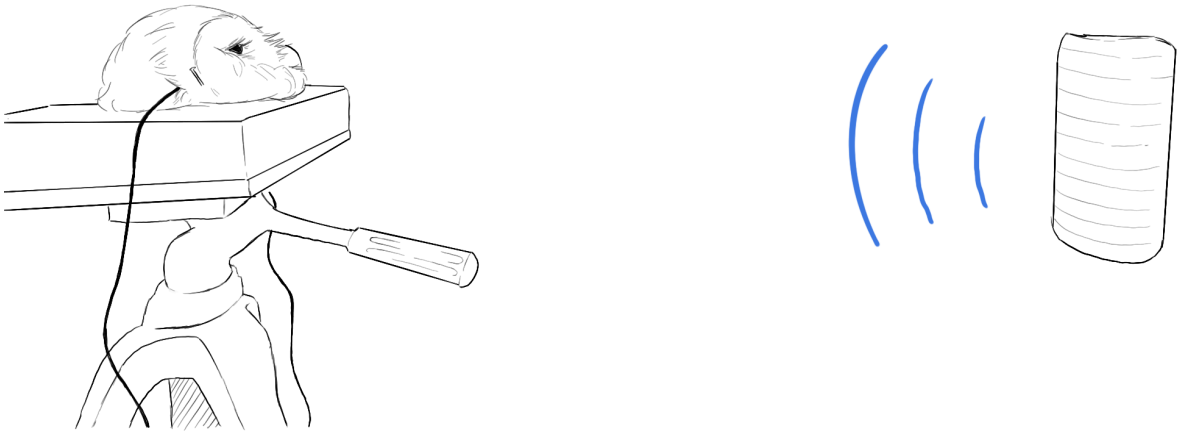


Figure 4: Speaker and owl position. The above image shows testing at an elevation of 0°. The owl is pinned onto a form board; the angle of the form board is adjusted for each elevation. It is tilted upwards 45° for an elevation of +45°, and it is tilted downward by 45° for an elevation of -45°.

All feathers in Place



Auricular Feathers Removed



Reflector Feathers Removed



Figure 5: Feather Treatments The first feather treatment has all feathers in their normal position. The second feather treatment has the auricular feathers removed, leaving only the reflector feathers and the contour feathers on the sides and back of the head. In the final feather treatment, the reflector feathers are removed, leaving the owl with only the contour feathers and no feathers within the facial disk.

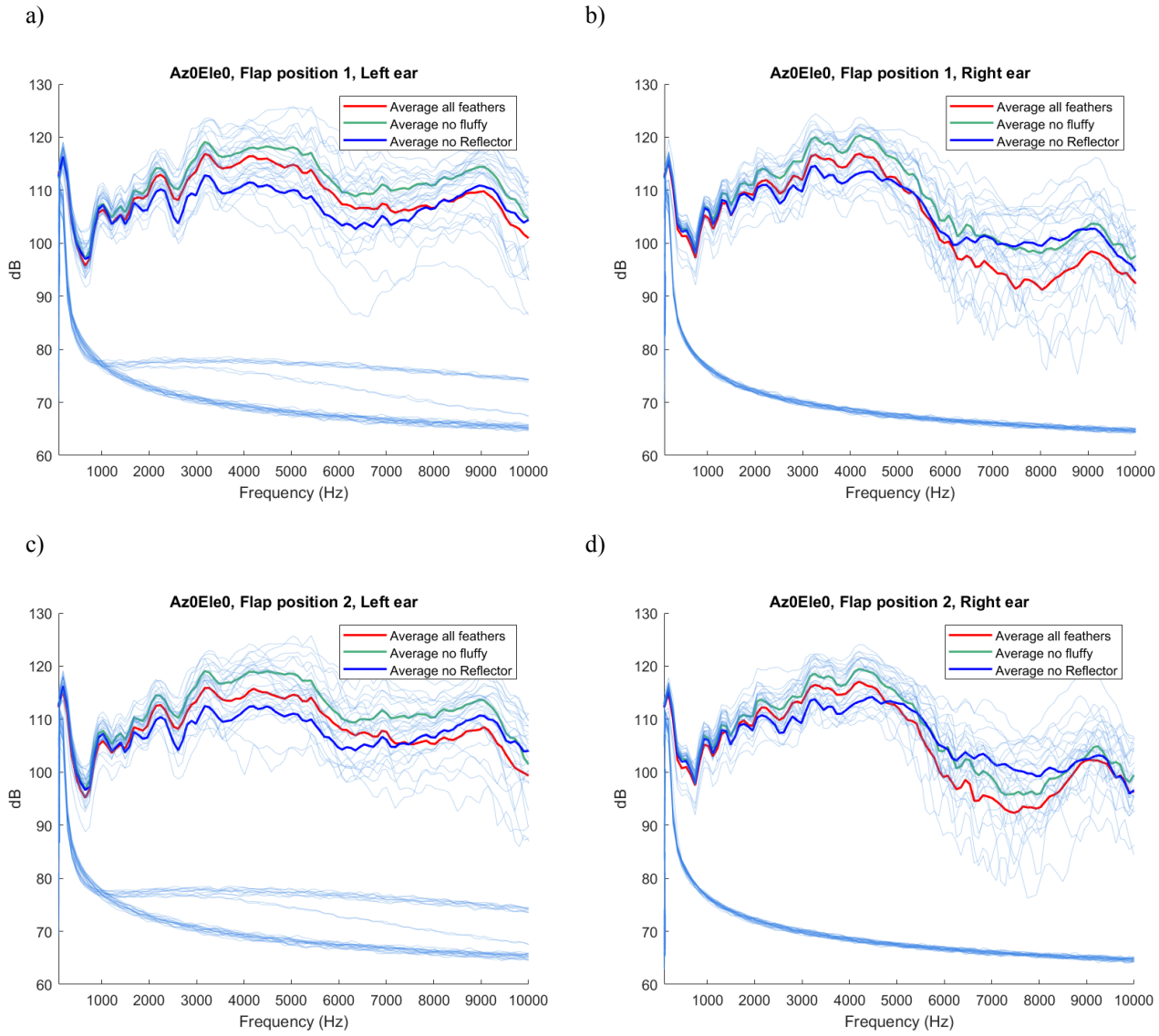


Figure 6: All recorded data at elevation of zero a) Left ear data for all owl heads positioned level with the speaker, with preauricular flap closed. b) Right ear data for all owl heads positioned level with the speaker, with the preauricular flap closed. c) Left ear data for all owl heads positioned level with the speaker, with the preauricular flap open. d) Right ear data for all owl heads positioned level with the speaker, with the preauricular flap open.

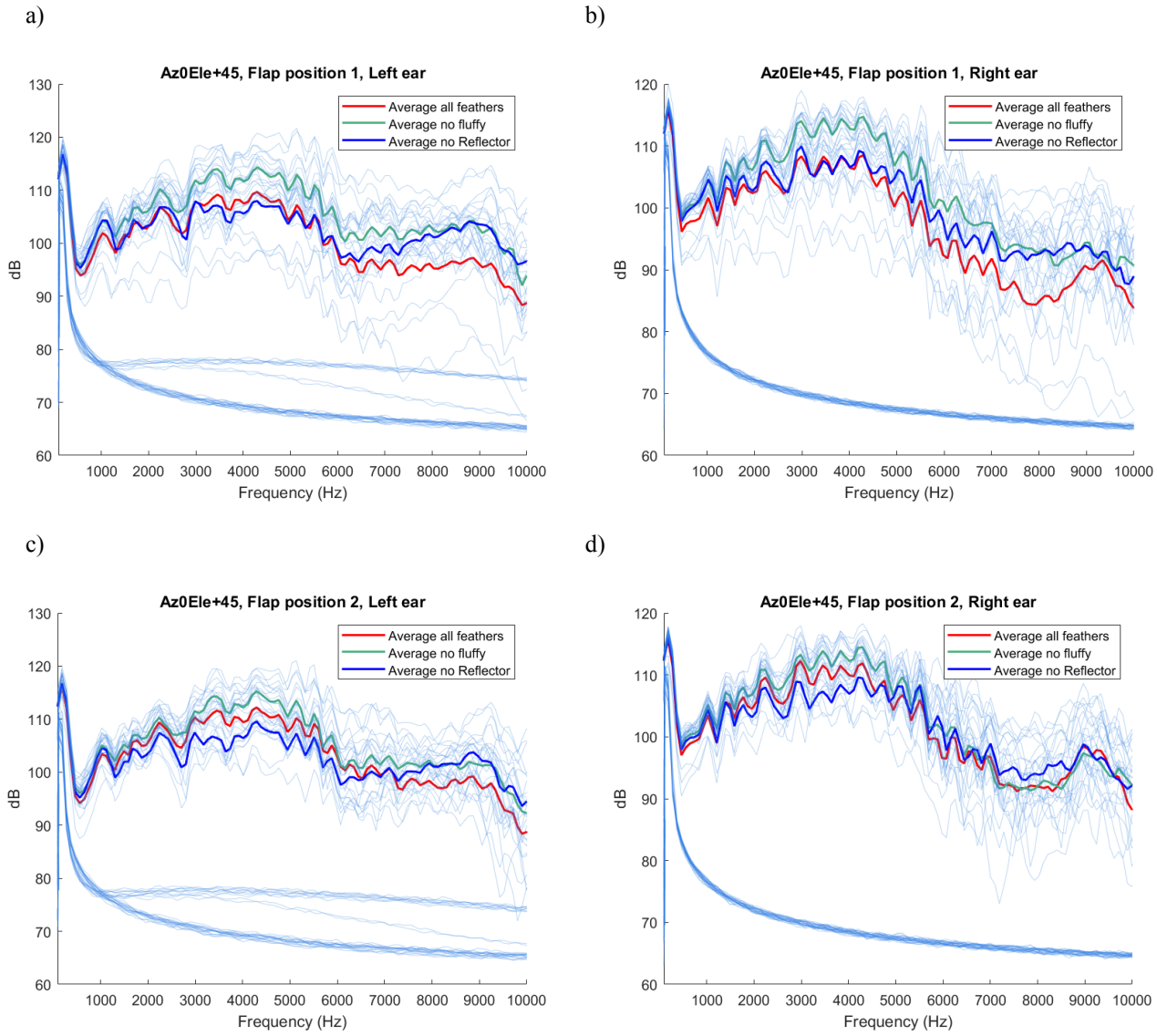


Figure 7: All recorded data at elevation of +45 a) Left ear data for all owl heads angled 45° above the speaker with the preauricular flap closed. b) Right ear data for all owl heads angled 45° above the speaker with the preauricular flap closed. c) Left ear data for all owl heads angled 45° above the speaker with the preauricular flap open. d) Right ear data for all owl heads angled 45° above the speaker with the preauricular flap open.

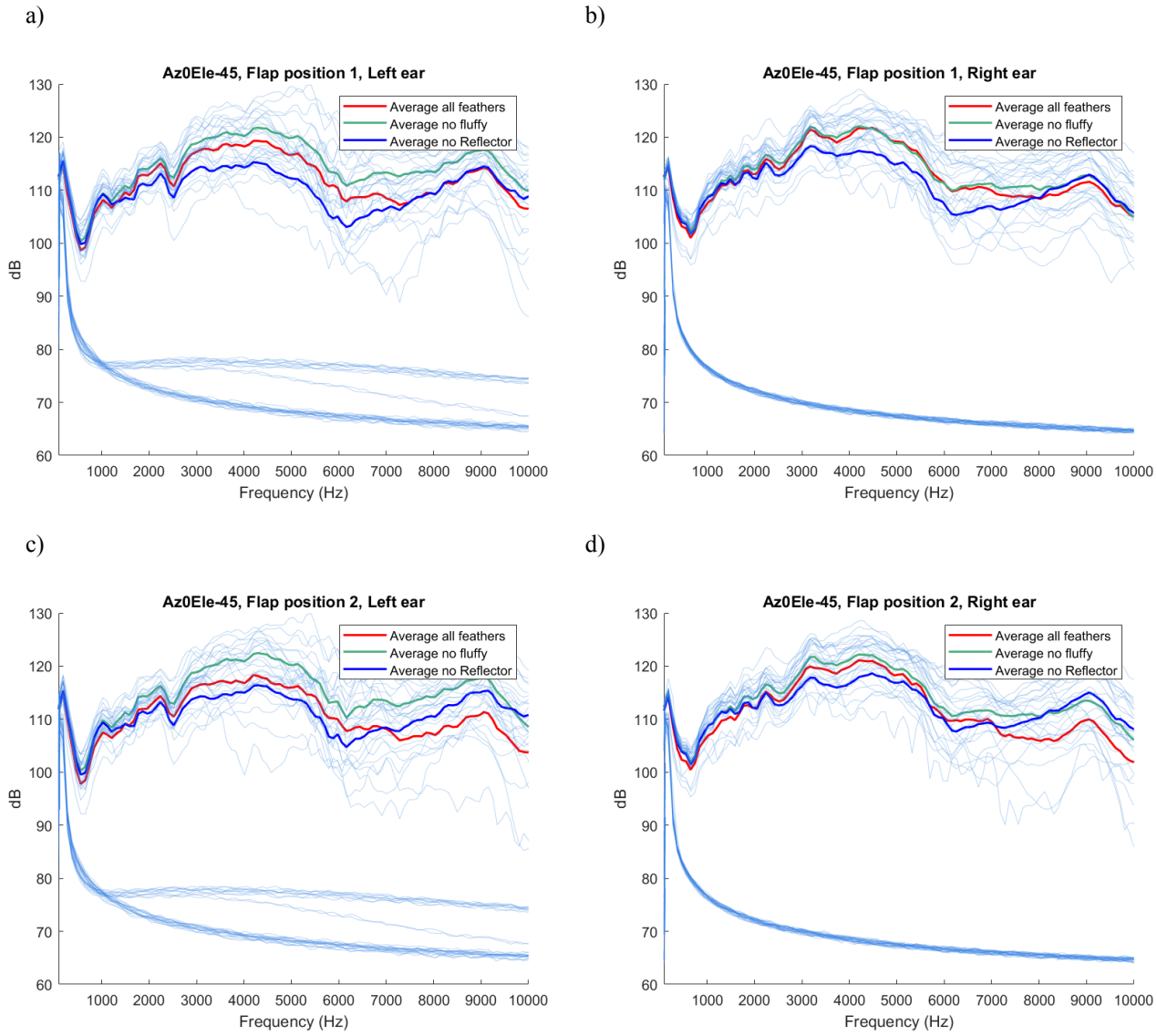


Figure 8: All recorded data at elevation of -45 a) Left ear data for all owl heads angled 45° below the speaker with the preauricular flap closed. b) Right ear data for all owl heads angled 45° below the speaker with the preauricular flap closed. c) Left ear data for all owl heads angled 45° below the speaker with the preauricular flap open. d) Right ear data for all owl heads angled 45° below the speaker with the preauricular flap open.

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