“CHEEP” SHOTS:

SUSPENSE AT THE WILDLIFE PRESERVE

THE SEARCH FOR THE ROSE-CRESTED BLUE PIPIT

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INTRODUCTION

One of Mistford's most beloved local residents, the Rose-Crested Blue Pipit, may be in jeopardy. Local human residents and members of the Pangera Ornithology Conservation Society have noticed an alarming decrease in the number of nesting pairs of the blue pipit in the Boonsong Lekagul Wildlife Preserve, just to the northeast of the city. An initial investigation implicated a local manufacturing firm called Kasios and accused them of dumping the banned substance, Methylosmolene, in the northwest region of the wildlife preserve.

Kasios has presented itself as being an eco-friendly company and feels that they are being singled out unfairly. They have launched their own investigation into the issues raised in the report and have presented sound recordings from within the wildlife preserve that they claim show that the blue pipit is thriving and plentiful.

Professors and students at Mistford College and members of the ornithology society, questioning the intentions of the company, have asked for help with the situation. Data scientists have been provided by the college with verified bird call and song data from within the preserve, including recordings made over the last 35 years. Mistford College and the ornithology society hope this data, machine learning, and visual analytics will uncover what is impacting the blue pipit. Kasios, meanwhile, expects that the analysis will clear them of any wrongdoing.

This report will detail the findings in the investigation into the "Suspense at the Wildlife Preserve", and will attempt to meet the following goals.

SCENARIO GOALS

- Using the bird call collection and the included map of the Wildlife Preserve, characterize the patterns of all of the bird species in the Preserve over the time of the collection. Please assume we have a reasonable distribution of sensors and human collectors providing the recordings, so that the patterns are reasonably representative of the bird locations across the area. Do you detect any trends or anomalies in the patterns?

- Turn your attention to the set of bird calls supplied by Kasios. Does this set support the claim of Pipits being found across the Preserve? A machine learning approach using the bird call library may help your investigation. What is the role of visualization in your analysis of the Kasios bird calls?

- Formulate a hypothesis concerning the state of the Rose Crested Blue Pipit. What are your primary pieces of evidence to support your assertion? What next steps should be taken in the investigation to either support or refute Kasios' claim that the Pipits are actually thriving across the Boonsong Lekagul Wildlife Preserve?

HYPOTHESIS

The Rose-Crested Blue Pipit population is decreasing as a result of migration away from a dumping site and possibly polluted air.

DATA DESCRIPTION

Mistford College provided a dataset containing 2081 row containing these features: ID, species of bird, vocalization type (call or song), quality of recording (A, B, C, D, E, or none), time of day, date, and location, including an x-coordinate and a y-coordinate from a 200 x 200 map. There are 19 different bird species.

Bird Name	Count
Bent-beak Riffraff	72
Blue-collared Zipper	67
Bombadil	140
Broad-winged Jojo	94
Canadian Cootamum	82
Carries Champagne Pipit	104
Darkwing Sparrow	86
Eastern Corn Skeet	88
Green-tipped Scarlet Pipit	88
Lesser Birchbeere	150
Orange Pine Plover	215
Ordinary Snape	94
Pinkfinch	73
Purple Tooting Tout	73
Qax	53
Queenscoat	241
Rose-Crested Blue Pipit	186
Scrawny Jay	91
Vermillion Trillian	84

Mistford College also provided 2081 mp3 files of verified bird songs and calls from the wildlife preserve, dating from spring 1983 through spring 2018. Rose-Crested Blue Pipit calls and songs make up approximately 9% of the sound files provided. The files are of varying length and vary in quality on a rating from A to E, as described in the information file.

The Kasios Company has provided fifteen mp3 files they claim are recordings of the blue pipit taken recently within the preserve. The locations of the recordings are provided in the information file, but no other information is available.

All data used is available here:
https://github.com/emmanueliarussi/DataScienceCapstone/tree/master/7_FinalProjects/SuspenseWildlifePreserveCheepShots

DATA EXPLORATION

Exploration of the sound files (mp3) provided was begun simply by listening to some of the provided recordings. These particular data scientists, however, are not ornithologists, nor bird enthusiasts, and the bird calls are not distinct enough to gain insight into the species represented.

Sound characteristics were then visually inspected. The Librosa Python package provides numerous methods for analyzing audio files, and will be discussed in more detail later. Librosa also provides methods to graph audio files in a number of formats. Appendix A includes examples of song and call visualizations, as well as visualizations for the test files from Kasios. The primary visualizations explored are:

- Wave plots: Show the "loudness" of audio over time. For mono recordings, the signal strength is filled between -abs(y) and abs(y). For stereo recordings the left channel is visualized above the axis and the right channel below.
- Spectrograms: Show the different wavelengths that make up the sound that humans hear over time with a color component to show the strength at that wavelength.

Representative samples of a Blue Pipit call and a Blue Pipit song were visually compared to the Kasios provided test files (Appendix A). While similarities in some of the forms could be seen, classification of the test files based solely on the visual representation is not possible, especially for novices.

DATA PROCESSING AND FEATURE CONVERSION

The dataset provided by the college with 2081 birds was also explored, cleaned, and processed. All inconsistencies were addressed, including capitalizations. The date feature was converted to a datetime object. Times were converted into categories of morning, afternoon, evening, and night. Columns for season and year were added to the data frame and used to create another column called Season/Year. To prepare for data visualizations, a color was assigned to each bird.

Using this dataset, a variety of data visualizations were created that illustrate bird migrations. Appendix B includes a visualization of the location of all of the birds in the dataset. The migration of all of the birds as well as specifically the Rose-Crested Blue Pipit can be seen on this site:
https://mystery-at-the-preserve.herokuapp.com

For analysis and feature extractions from the sound files, the Librosa package was used. Librosa is a powerful python package specifically for audio and music analysis and for retrieving information from audio. Many features were examined, but for further data processing we focused on two:

- Mel-frequency cepstrum coefficients: represent a sound with a short-term power spectrum, created with a linear cosine transformation of a log power spectrum on the mel scale. The mel scale splits sound into what listeners perceive to be equally distant pitches. The coefficients are derived by taking a fourier transform of a signal, mapping that to the mel scale, taking the log of the powers at each mel frequency, taking the cosine transform of that, and the resulting MFCCs are amplitudes of the resulting spectrum. Ultimately, the MFCCs collectively describe an MFC for an audio clip, approximating the linearly spaced frequencies in the normal spectrum that can be processed by a human's auditory system.
- Chroma-STFT (short time Fourier transforms): finds the sinusoidal frequency and phase content of a sound and maps that to a pitch profile in a single octave.

The 2081 vetted sound recordings provided were of varying length, some in stereo (two channel, left and right) and some in mono (single channel). The Kasios provided test files were also of varying length.

All of the sound recordings were processed as follows:

1. MP3s converted to WAV sound files: All files were saved as mono. (Additionally, Librosa displayed warnings on MP3 files, but not for WAV files.)
2. Normalized over time: The Librosa loaded sound vector was normalized with a standard formula.
3. Stripped of silence: The Librosa "split" function removed any areas determined as silence.
4. Divided into 2 second clips
5. MFCC: Each two second clip was processed, and the MFC coefficient vectors extracted. The mean and standard deviation of each vector was computed.
6. Chroma-STFT: Each two second clip was processed, and the Chroma-STFT vectors extracted. The mean and standard deviation of each vector was computed.
7. Bird name and test file ID: The English bird name was retained for classification for all records processed from the sample files, as was the ID number from the Kasios test files.

The resulting data for the sample files was 56,272 records of a 2X50 array, and the testfile data was 476 records of a 2X50 array.

MODELING

The goal for using machine learning techniques was to use the data and recordings provided by the college to analyze and verify that the data and recordings provided by Kasios are actually of the Rose-Crested Blue Pipit. Two approaches were employed in parallel by the data scientists. The first was a binary approach considering the Rose-Crested Blue Pipit, the much-loved local bird, as the

desired outcome, and all other birds made up the alternate outcome. The second approach aimed to categorize the recordings by the type of bird, resulting in 19 different categories. The college data was used to train the models, parameters were tuned, and then the models were used on the test data provided by Kasios to determine how many and which birds in the test set were Rose-Crested Blue Pipits.

Binary Approach--The data used included full length MFCC clips with means or medians, and initially, attempts to classify by bird type met with minimal success and was not conclusive, with one reason being that the lengths of the clips varied greatly. The focus then changed to a binary approach, predicting the Rose-Crested Blue Pipit or other birds. Because only 9% of the bird data consists of the Rose-Crested Blue Pipit, the dataset was imbalanced. SMOTE was employed with over sampling the desired bird and under-sampling all other birds. Different models, including Decision Tree, Random Forest, OneVsRestClassifier, and MLPClassifier, were applied, some with only minimal success. Ultimately, the best model attempted with SMOTE was the MLPClassifier (alpha=.001, hidden_layer_sizes=[1024,16], solver="sgd", learning_rate='adaptive') which produced the following results:

Accuracy	TestROC_AUC	Precision	Recall	Specificity	F1
0.93	0.912	0.62	0.56	0.97	0.59

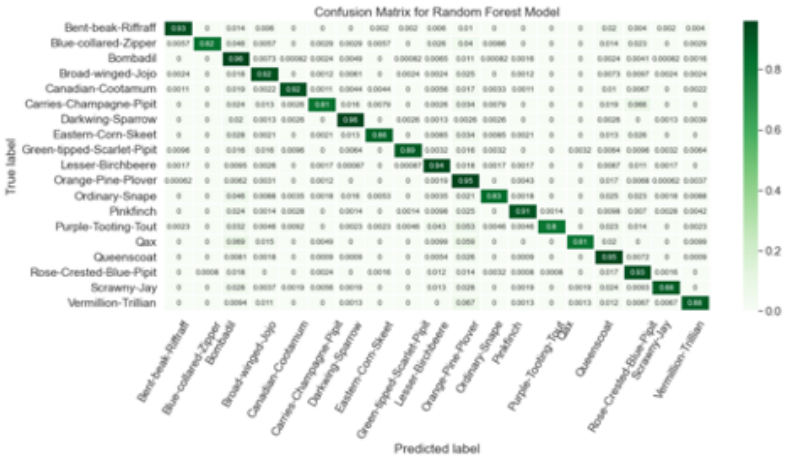
None of these models, when applied to the Kasios test bird dataset, predicted any Rose-Crested Blue Pipits.

Multi Classification Approach--A variety of classification models to identify all 19 of the represented birds were attempted on the processed data. A Random Forest Classifier and a LSTM-RNN performed the best on samples that included songs and calls of quality A, B, C, and D. Classifications attempted on data that did not include C and D quality rated songs and calls tended to result in overfit models.

For all classification runs, the processed two second clips of the sample bird calls were split into training (80%) and validation (20%) sets. The Kasios test recordings served as the test set. Model tuning was attempted with GridSearch and RandomSearch on the Random Forest Classifier, but the hardware being used was not robust enough to complete properly.

Random Forest Classifier on the A, B, C, D quality recordings with 1000 estimator trees, a criterion of ‘Gini’ achieved the following results on the 20% validation set:

	precision	recall	f1-score	support
Bent-beak-Riffraff	0.97	0.93	0.95	501
Blue-collared-Zipper	1.00	0.82	0.90	350
Bombadil	0.83	0.96	0.89	1225
Broad-winged-Jojo	0.93	0.92	0.92	826
Canadian-Cootamum	0.98	0.92	0.95	900
Carries-Champagne-Pipit	0.94	0.81	0.87	378
Darkwing-Sparrow	0.94	0.96	0.95	769
Eastern-Corn-Skeet	0.96	0.86	0.91	470
Green-tipped-Scarlet-Pipit	0.97	0.89	0.93	312
Lesser-Birchbeere	0.92	0.94	0.93	1152
Orange-Pine-Plover	0.84	0.95	0.89	1617
Ordinary-Snape	0.95	0.83	0.89	568
Pinkfinch	0.97	0.91	0.94	713
Purple-Tooting-Tout	0.99	0.80	0.89	437
Qax	0.98	0.81	0.89	203
Queenscoat	0.86	0.95	0.90	1108
Rose-Crested-Blue-Pipit	0.90	0.93	0.91	1254
Scrawny-Jay	0.96	0.88	0.92	539
Vermillion-Trillian	0.95	0.88	0.92	747
accuracy			0.91	14069
macro avg	0.94	0.89	0.91	14069
weighted avg	0.92	0.91	0.91	14069



This model accurately predicted the Blue Pipit 91% of the time, and predicted all bird classification with percentages in the high 80s and above. On the test set of data, the model predicted that four of the 15 recordings were actually Blue Pipit calls or songs.

The LSTM RNN model was run with the optimizer = 'adam', the loss function of 'SparseCategoricalCrossEntropy', the performance metric of 'acc' over 25 epochs, and achieved the following results on the 20% validation set:

	precision	recall	f1-score	support
Bent-beak-Riffraff	0.95	0.97	0.96	501
Blue-collared-Zipper	0.85	0.91	0.88	350
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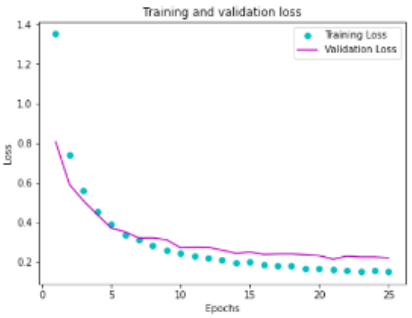

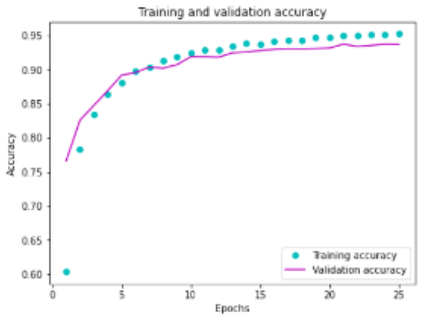

Blue Pipit calls and songs were correctly predicted 94% of the time on the validation set. There are beginning signs of overfitting, but the results are acceptable. This model predicted that three of the Kasios provided test recordings were actually of the Blue Pipit.

EVALUATION/CONCLUSIONS

Goal 1: Do you detect any trends or anomalies in the patterns?

Several graphs documenting the location of birds over time (seasonally and in five-year intervals) illustrate trends in bird migration. (This site has two interactive graphs: https://mystery-at-the-preserve.herokuapp.com.) Rose-Crested Blue Pipits at one time inhabited the area around the

dumping site but clearly have moved away. Over time, these birds have settled southwest of the dumping area. In the dataset the nearest last sighting of the Rose-Crested Blue Pipit occurred in Spring 2017.

The pattern is not limited to only the Rose-Crested Blue Pipits. These interactive graphs also portray the migration of almost all birds from the dumping area. There are a few exceptions:

- Darkwing Sparrow—Spring 2018
- Jojo—Spring 2016 and Summer 2017
- Eastern Corn Skeet—Winter 2017
- Carries Champagne Pipit—Fall 2017

Another clear anomaly of note is that none of the Kasios test bird recordings are near the dumping site. This omission creates suspicion about the validity of the Kasios data.

Goal 2a: What is the role of visualization in your analysis of the Kasios bird calls?

During initial examination of the test recordings provided by Kasios, as with the vetted samples from Mistford College, the periods of silence in the Wave plots of the recordings were noted and motivated stripping the silence from the samples.

The interactive maps show a clear trend of all birds moving away from the alleged dumping site. Additionally, the map shows that none of the Kasios provided recordings were made near the dumping site. This is suspicious at best from a company that is trying to prove that they did not do anything wrong.

The classification models determined that the test sites 2, 9, 13 and possibly 14 were the only test files identified as Blue Pipits. These sites are further away from the dumping site than where it appears the Blue Pipit has moved. While this does not prove any wrongdoing by Kasios - it is quite possible there are nesting pairs in that area of the Preserve - they did not provide proof that the Blue Pipit is plentiful in areas where our research indicates that they are.

Goal 2b: Does this set support the claim of Blue Pipits being found across the Preserve?

No. Kasios' claim that the 15 test recordings prove that the Blue Pipit is plentiful in the preserve are not supported by the results acquired in this analysis. The binary classifier predicted that none of the recordings provided by Kasios were actually Blue Pipits. Both multi class classification methods attempted showed that at most four of the provided files were actually Blue Pipit.

Goal 3a: Formulate a hypothesis concerning the state of the Rose-Crested Blue Pipit. What are your primary pieces of evidence to support your assertion?

Hypothesis: The Rose-Crested Blue Pipit population is decreasing in the Boonsong Lekagul Wildlife Preserve, and the bird has been forced to shift territories because of pollution resulting from an illegal dumping site in the Preserve.

The animated map, showing bird locations over time in the Preserve, clearly shows that all bird species - not just the Blue Pipit - are less likely to be heard near the dumping site.

Kasios claims that the 15 files they have provided for analysis are all recordings made of Blue Pipits. However, machine learning data analysis of those recordings indicate that at most four of the recordings are actually Blue Pipit songs or calls. Kasios may not be intentionally trying to deceive the concerned parties in the area, but their position raises some concerns.

Additional suspicions exist since none of the 15 files provided by Kasios were recorded near the dumping site.

Goal 3b: (Actionable Insights): What next steps should be taken in the investigation to either support or refute the Kasios claim that the Pipits are actually thriving across the Boonsong Lekagul Wildlife Preserve?

Continue to record all bird locations in the preserve, map future changes in the populations and locations, and investigate if more contamination has occurred in other areas of the Preserve.

Analyze the water and air in the Preserve in representative locations to determine if pollutants are still present.

Pursue methods to clean up the Preserve if pollutants are present.

Determine if other data, such as satellite imagery, exists of the Preserve. Changes in air quality, ground vegetation, roads, and building sites may also be affecting the wildlife.

Explore the disruption to all bird species caused by the changing locations to determine if the birds are competing for territories.

Key Insights, Data Science Conclusions

Librosa is a powerful Python collection of music and sound analysis tools that loads and decodes audio as a time series. The research conducted in this endeavor, while barely scratching the surface of what Librosa is capable of doing, required a bit of a learning curve.

The Librosa data extraction, machine learning models, and model tuning techniques explored required powerful hardware resources. Many kernels were harmed during the completion of this project, especially early in the process, as we attempted to understand the various components being used.

Not surprisingly, an LSTM RNN proved to be effective at classifying the bird songs and calls. If trained correctly, they have great flexibility to deal with complex data.

Check out the streamlit version of this report here: https://mystery-at-the-preserve.herokuapp.com/

Code can also be accessed on GitHub: https://github.com/LeighAnn-DU/Mystery-at-the-Preserve

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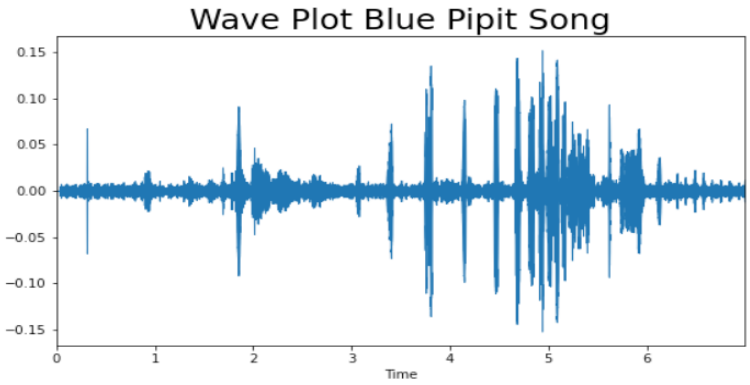
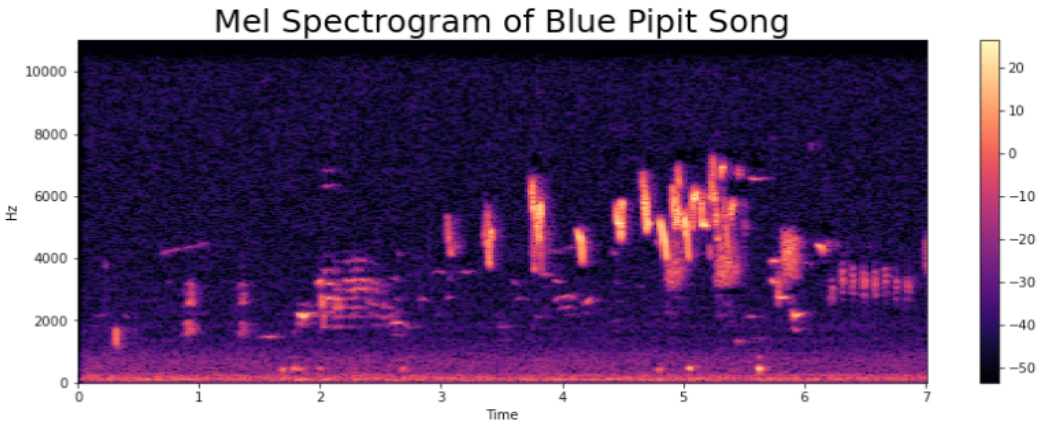
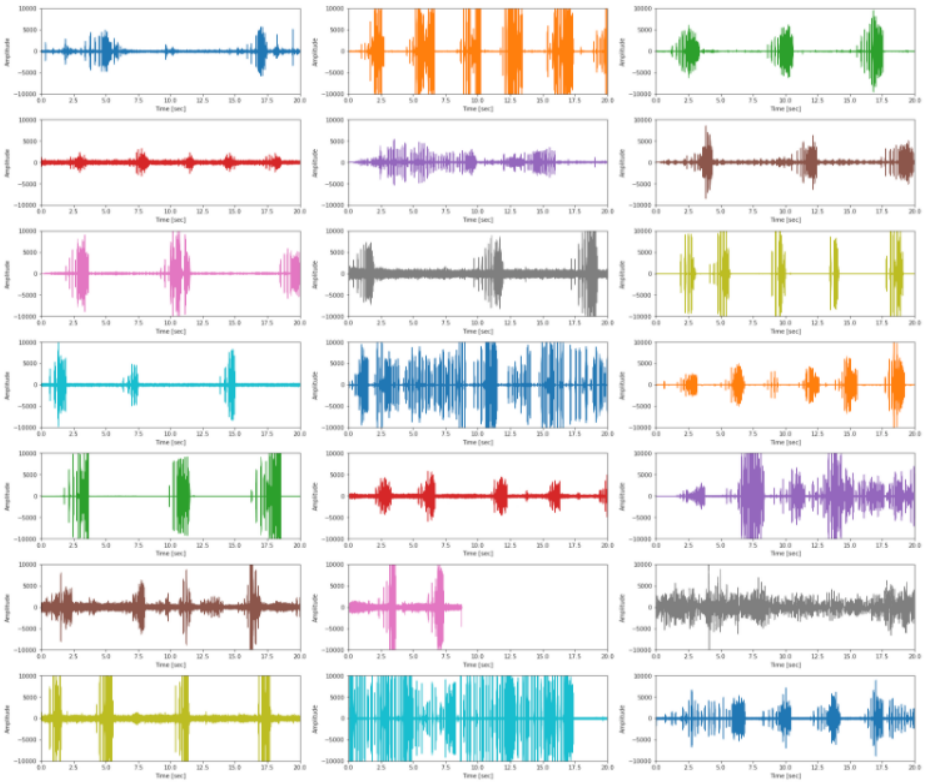
APPENDIX A

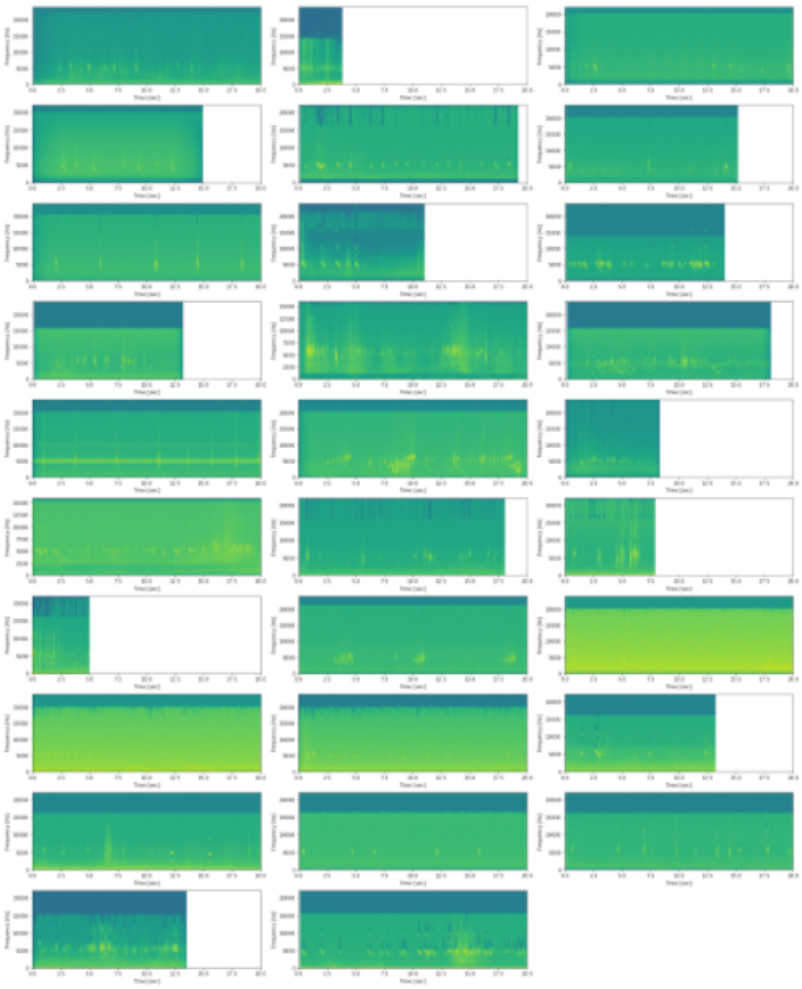




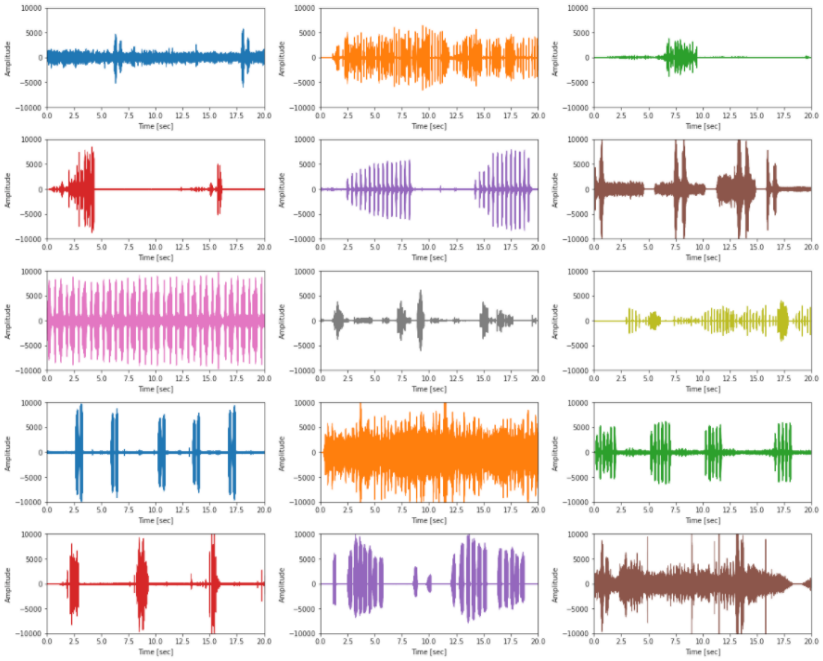
Rose-creasted Blue Pipit songs



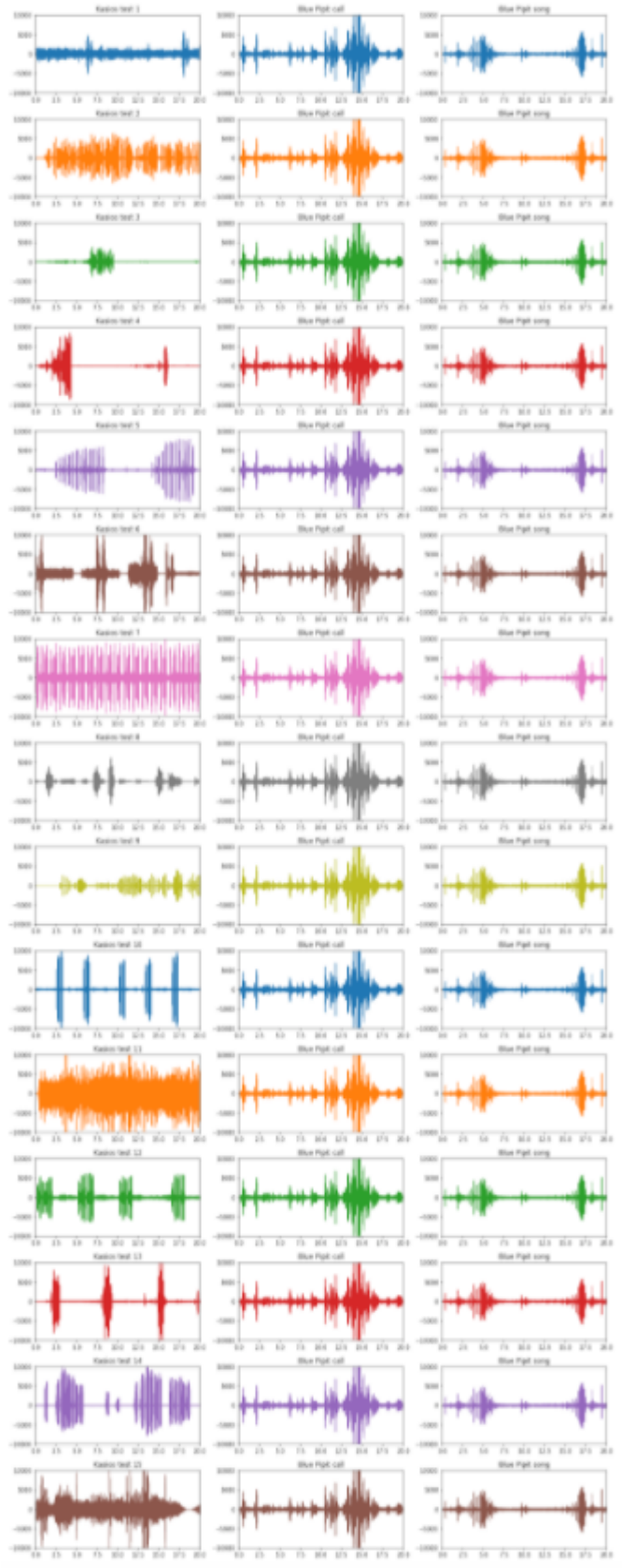
Rose-creasted Blue Pipit Calls Spectrograms



Kasios test files



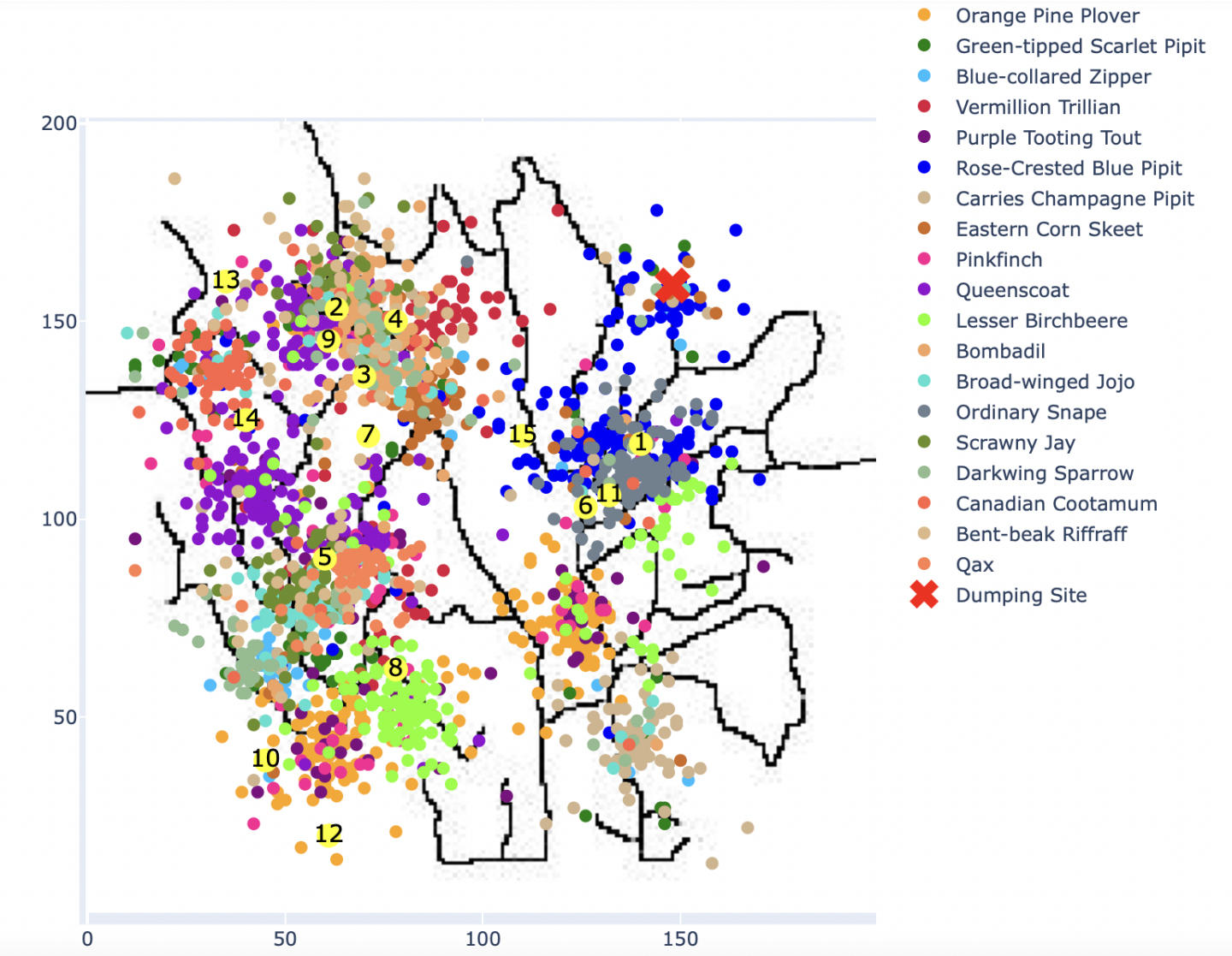
Kasios Recordings compared to Representative Blue Pipit sounds



APPENDIX B

The graph below illustrates the location of all of the birds in the entire dataset. The yellow markers indicate the birds in the Kasios test data. The red **X** is the dumping site.

All Birds in Mistford College Dataset (1983-2018)



Interactive graphs showing the birds per season per year can be observed on this site: https://mystery-at-the-preserve.herokuapp.com

The presentation can also be accessed on GitHub at: https://github.com/LeighAnn-DU/Mystery-at-the-Preserve