Centre for
Conservation &
Restoration Science

BEATBOX: Developing accessible methods for studying insect vibrational signals with insights from stonefly drumming

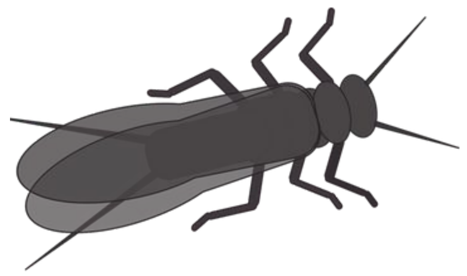
Jess Lister[1]

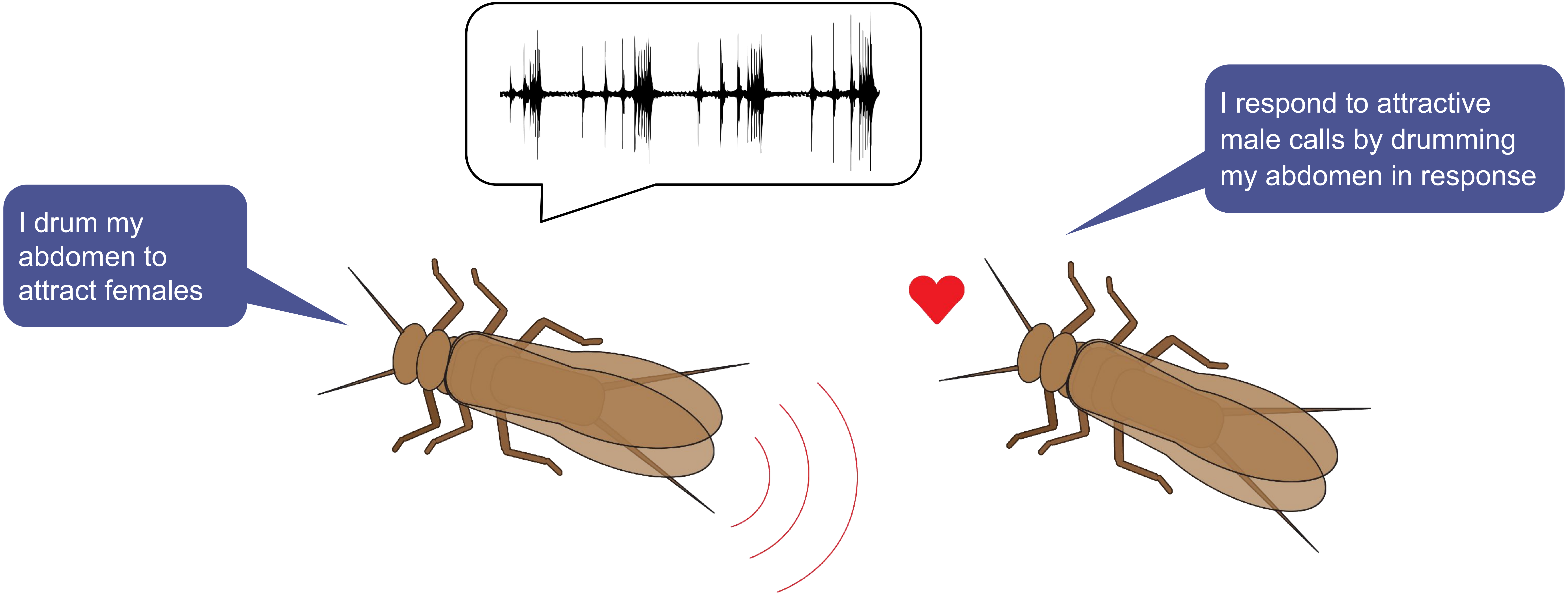
jess.lister@napier.ac.uk

Supervised by Jennifer Dodd[1] Iain McGregor[1] Craig Macadam[2] Matt Wale[1]

1 - Centre for Conservation & Restoration Science, School of Applied Sciences, Edinburgh Napier University

2 – Buglife, Scotland




I drum my abdomen to attract females
I respond to attractive male calls by drumming my abdomen in response

Perlodes mortoni

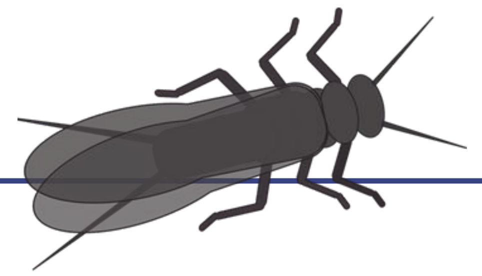
Perla carlukiana

Brachyptera putata

Key Challenges

Biological

- Short, seasonal lifespan of target species.
- Only virgin females respond to male drumming.
- Males emerge before females.



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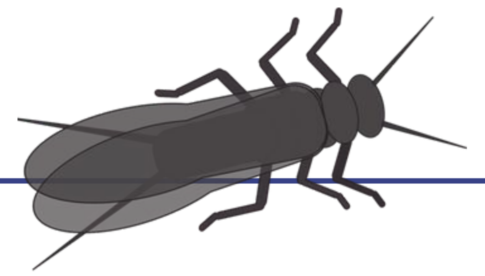
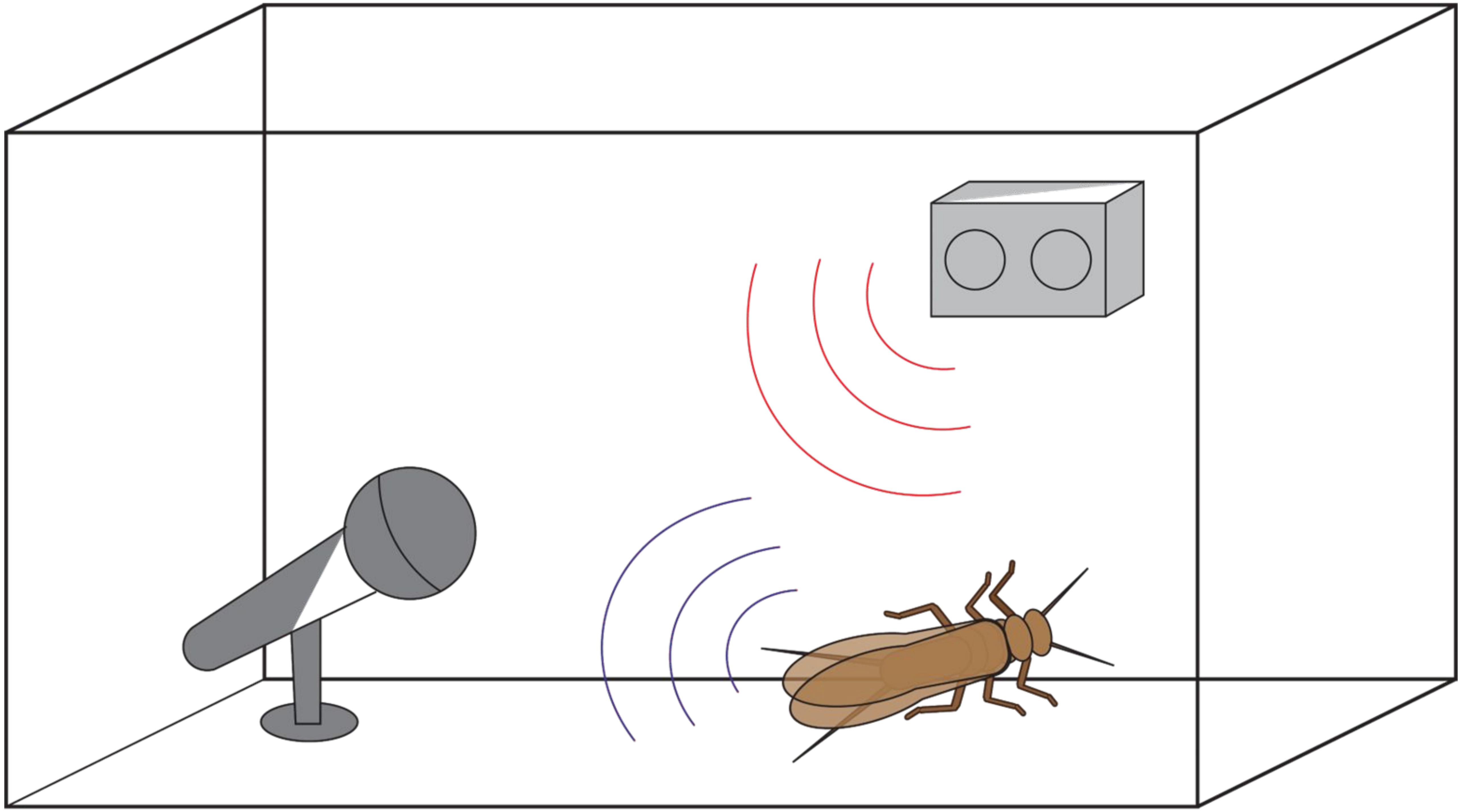
Technological

- High cost and technical complexity of current methods for recording and playing substrate-borne vibrations.
- Lack of standardised, replicable methods to record stonefly drumming.
- Sound recording requires no or low background noise.

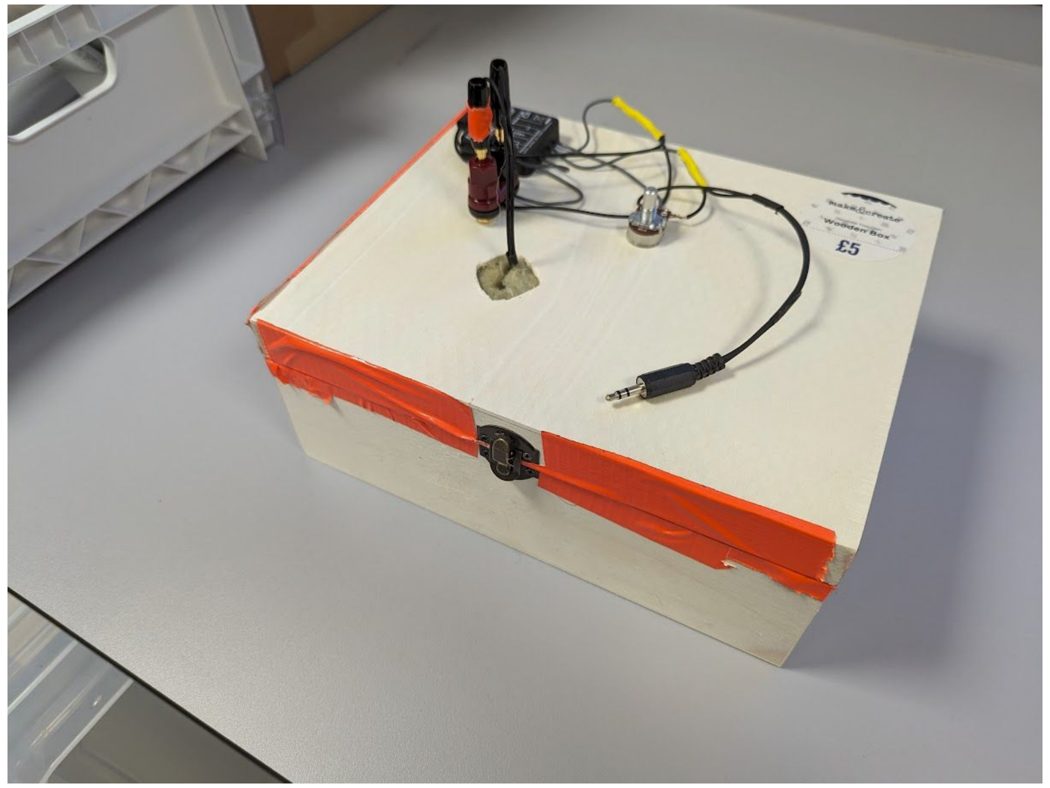
Ideal set-up

- **Cost effective** – affordable on a research budget.
- **Accurate** – able to capture variations in amplitude, frequency and temporal patterns stonefly drumming.
- **Repeatable** – standardised across species and individuals.
- **Scalable** – multiple individuals recorded at once.
- **Quiet** – isolated from background laboratory noise.





The BEATBOX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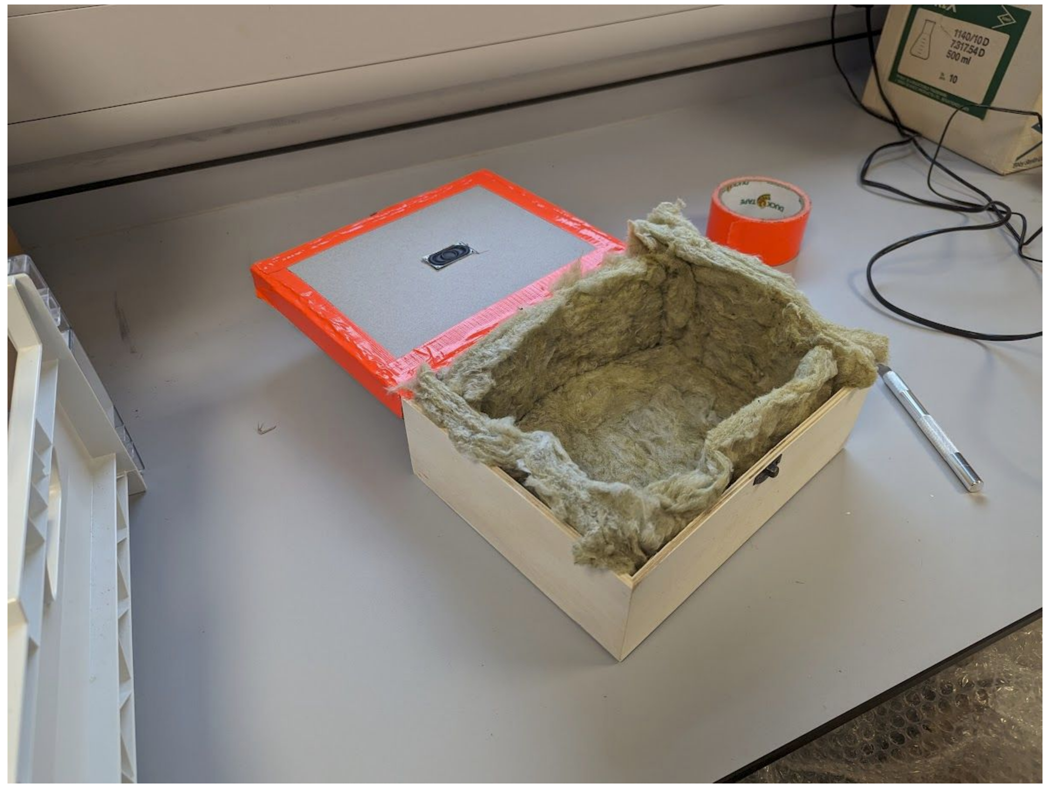
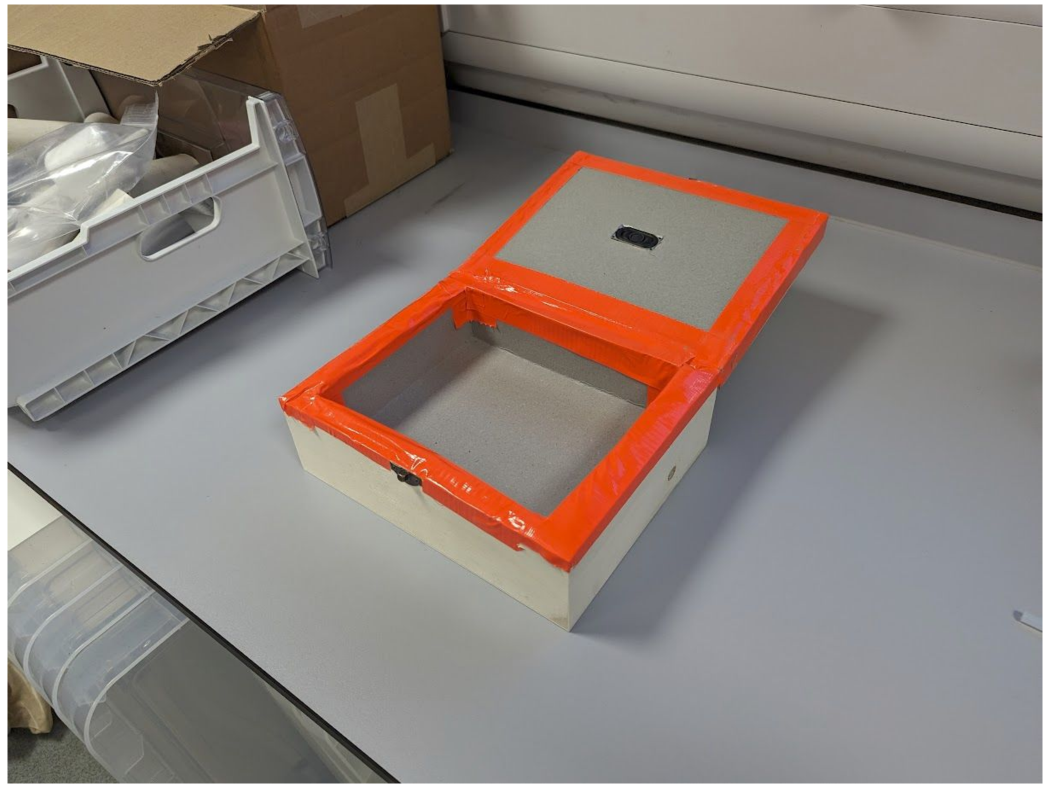
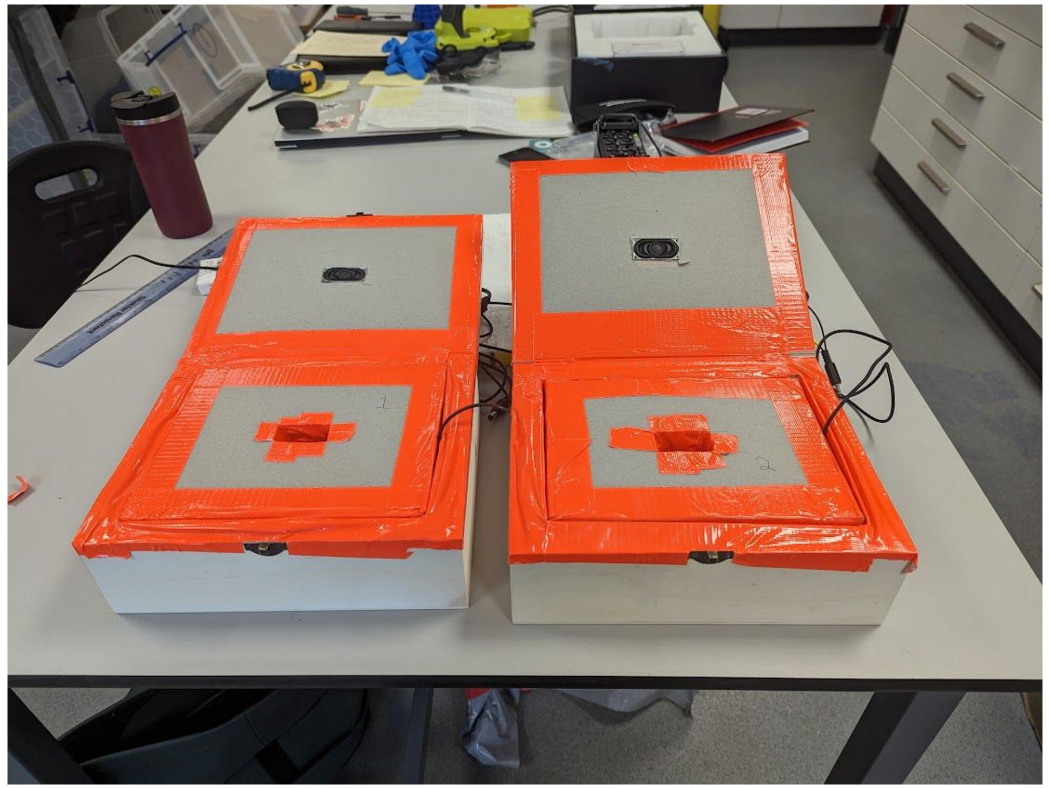
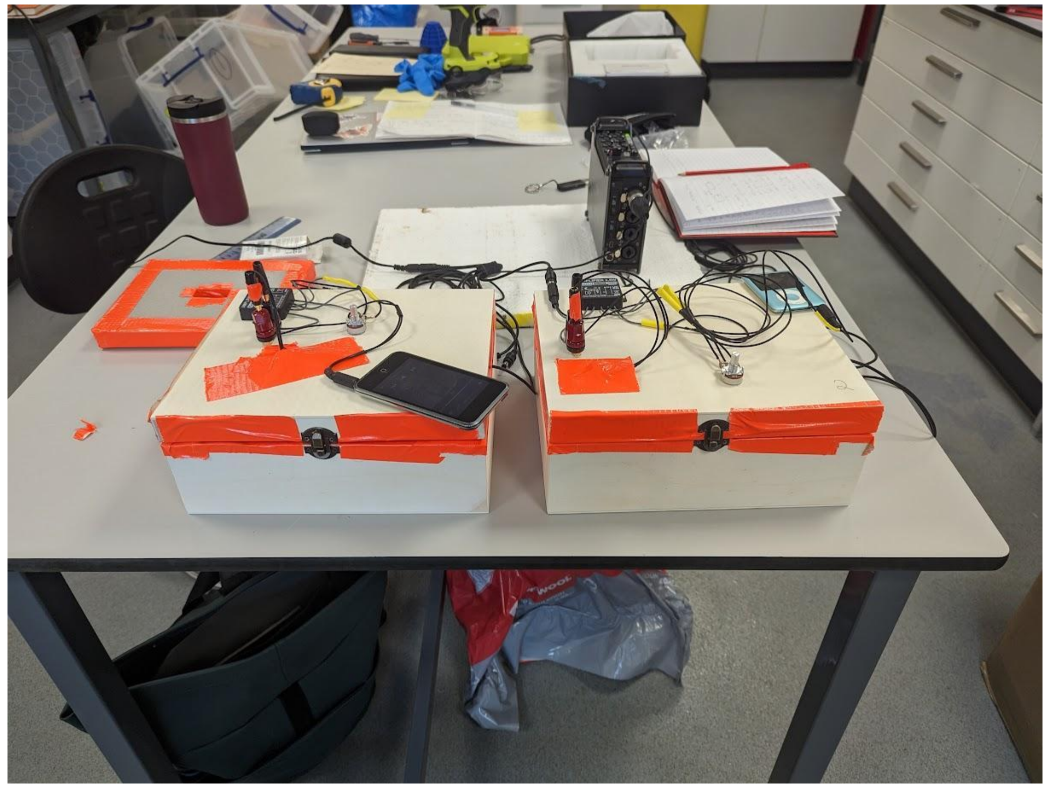







AquaClear



Aim

To test how well insulation works to reduce sound leakage from one BEATBOX to another.

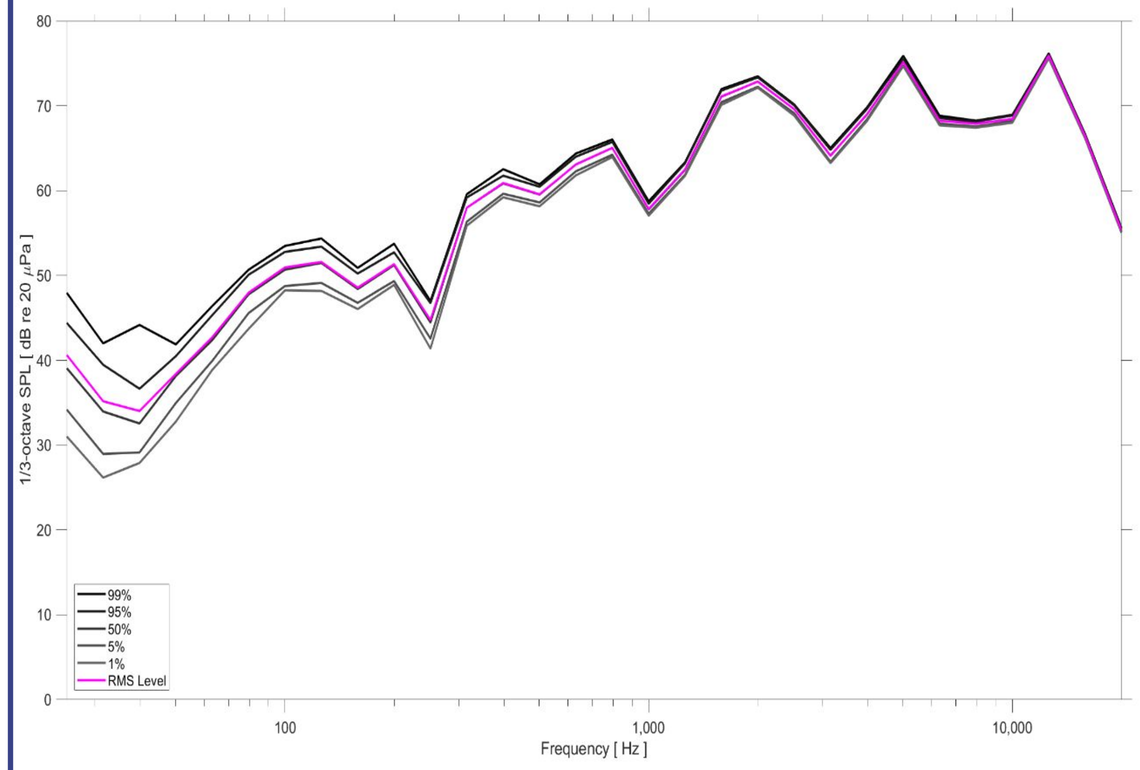
Methods

Pink noise was played in one box and sound transmission was measured by recording sound levels simultaneously in the playback BEATBOX **(1)** and an adjacent BEATBOX **(2)**. There was also a control where no sound was played **(3)**.

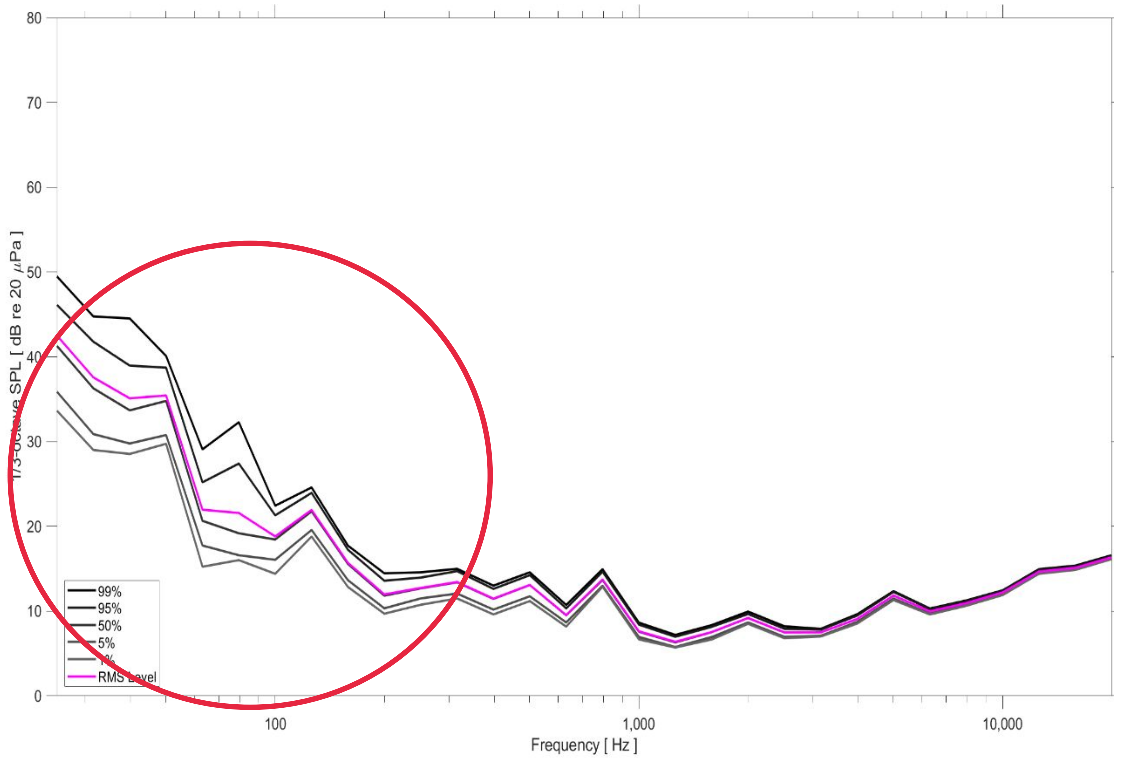
Results

Insulation reduced broadband sound level by 10dB from one box to another, with most leakage occurring in the **lower frequencies.**

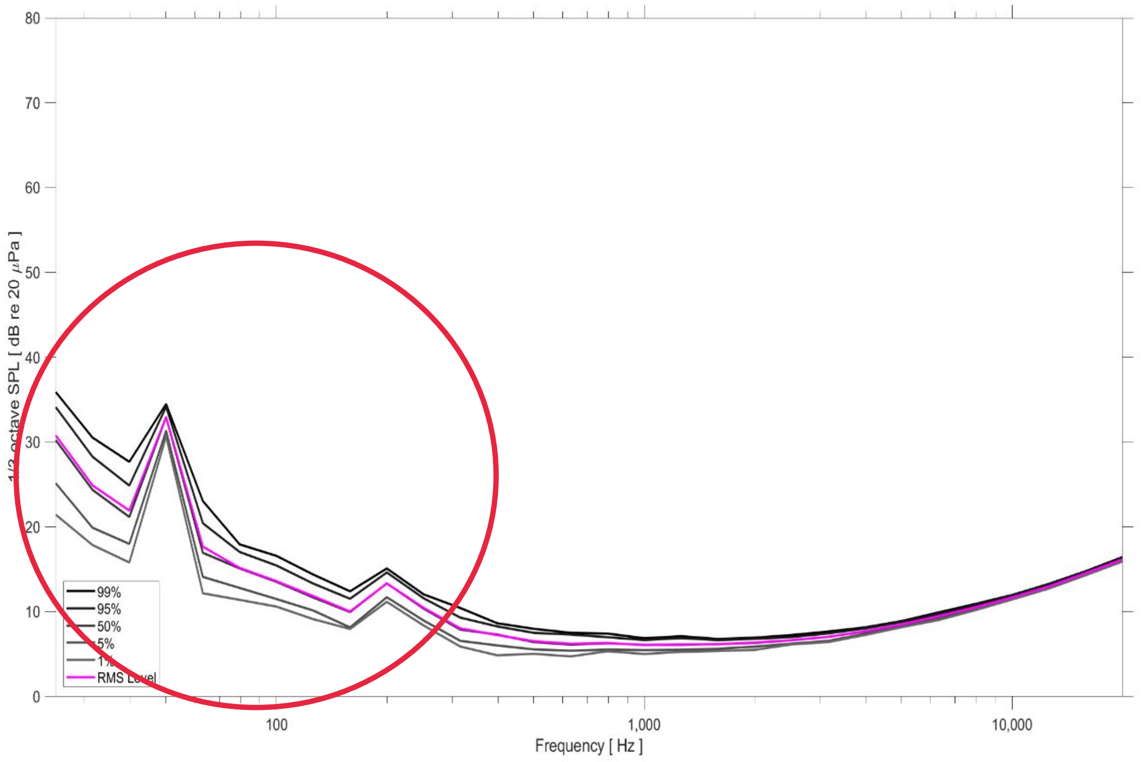
1) Pink noise playing in box



2) Adjacent box (sound leakage)



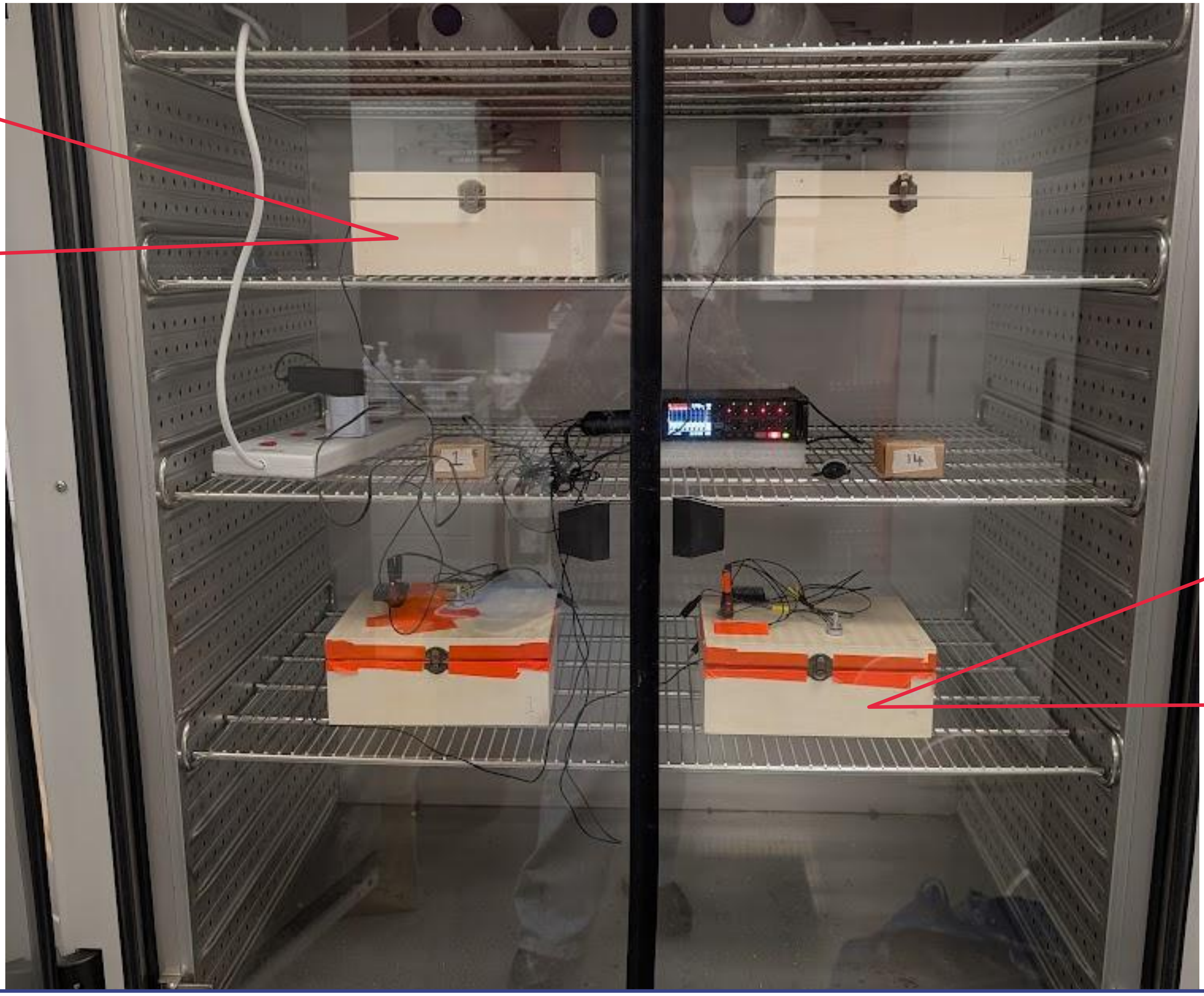
3) No sound control



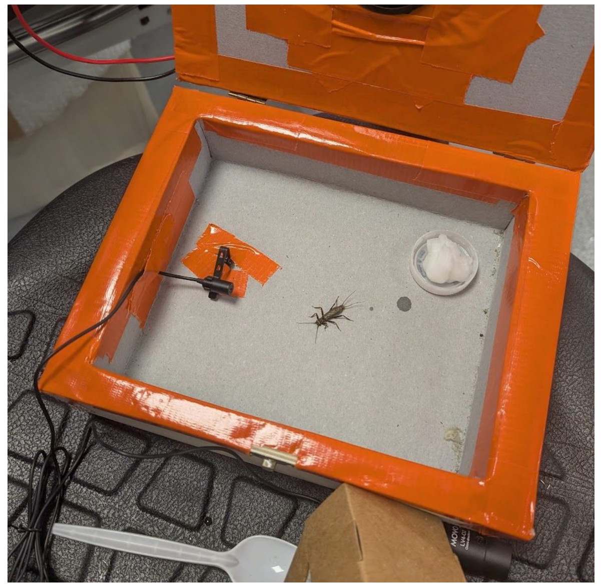
Pink noise contains sound across all frequencies in the audible spectrum, with power decreasing as octave level increases, leading to a lower pitch than white noise. This was used since stoneflies are known to drum at a low pitch.

Stonefly in cardboard box, based on methods in Macadam (2024).

One of each box type was also given an LED light, to find if light or darkness was a requisite for drumming.

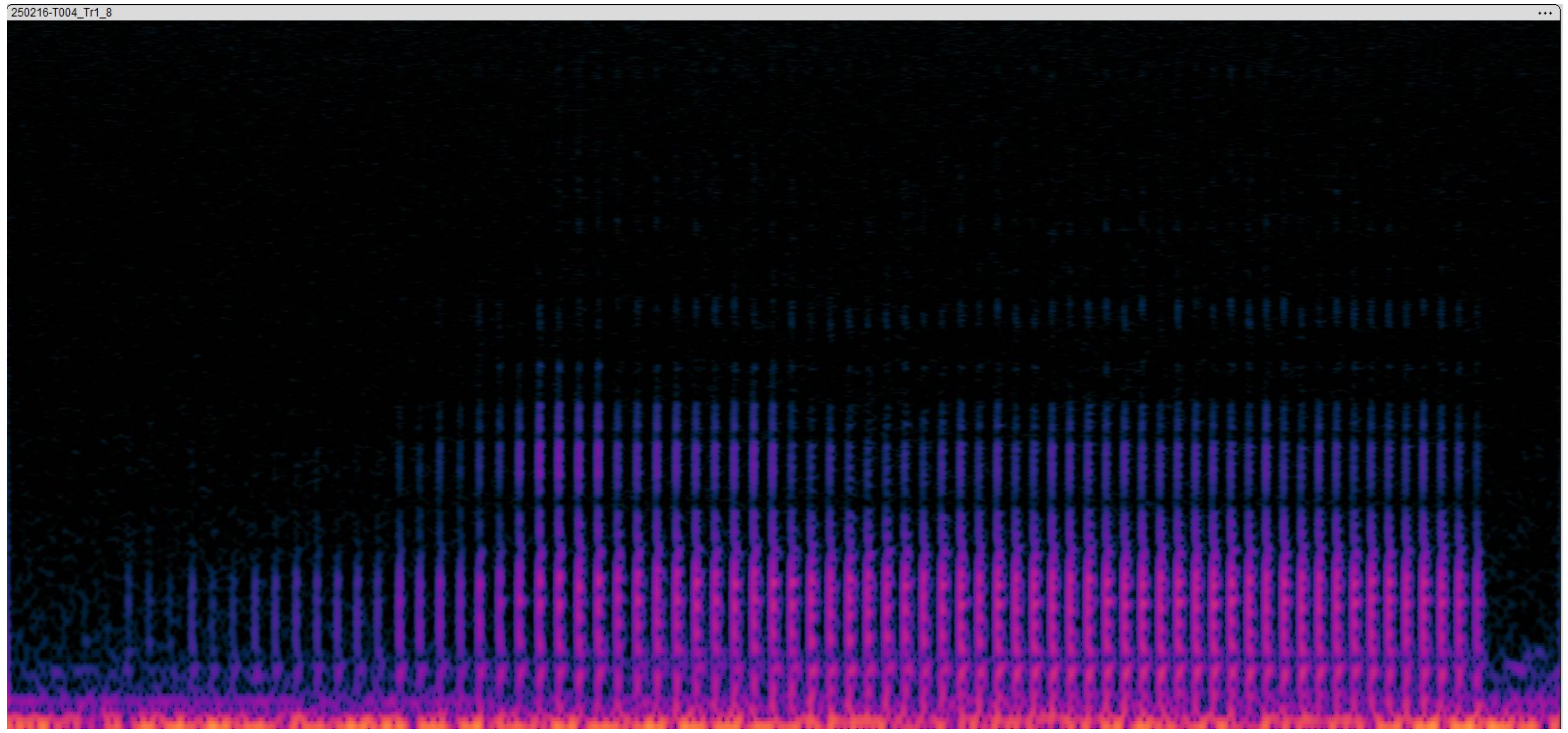


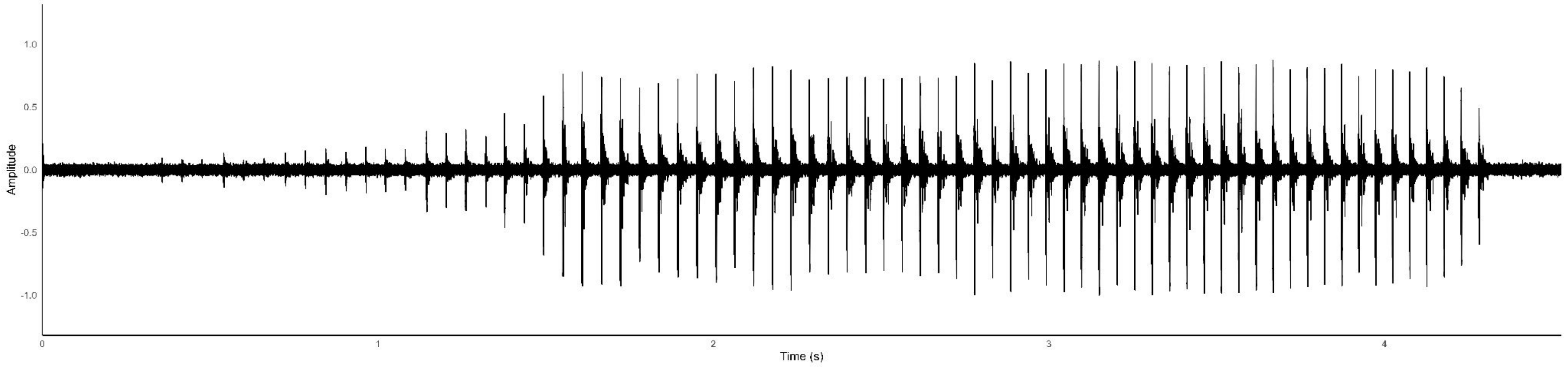
Stonefly in BEATBOX.

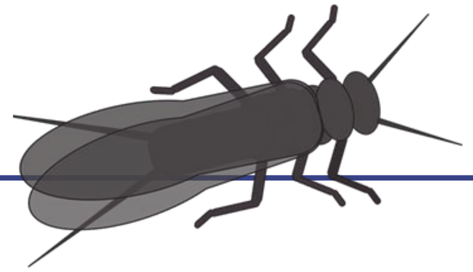


Macadam, C.R., 2024. The drumming signals of the British endemic stonefly Brachyptera putata (Newman)(Plecoptera: Taeniopterygidae). *Entomologist's Monthly Magazine*, *160*(3), pp.195-200.

Brachyptera putata







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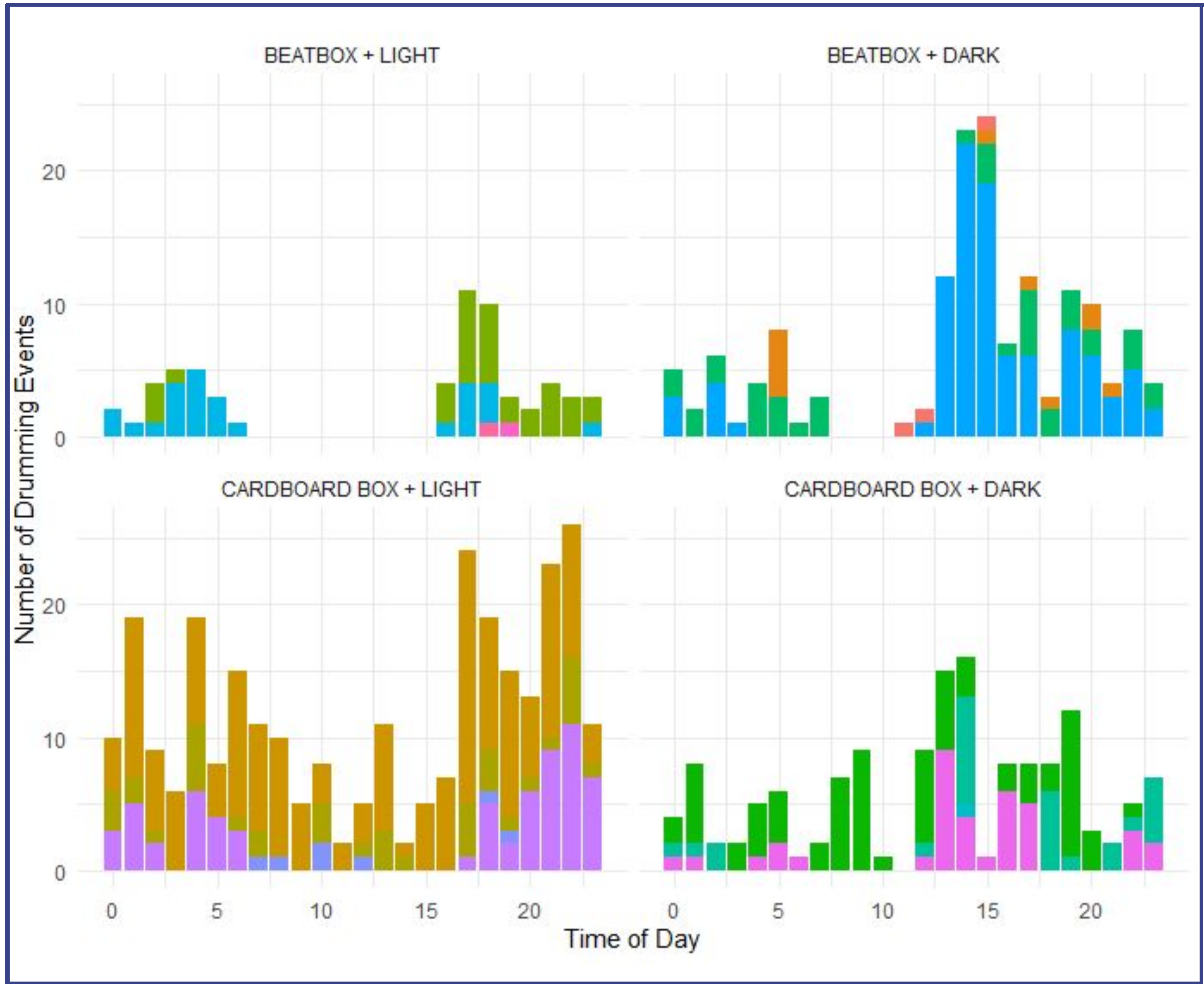


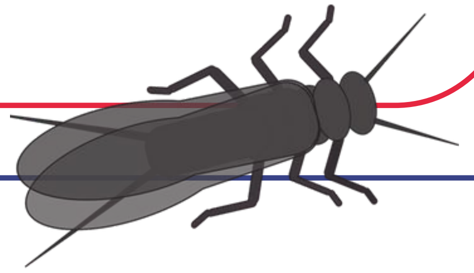
Figure 1: Number of drumming events per hour over 24 hours for male *Brachyptera puatata* under different light conditions and box types. Each colour represents a unique stonefly individual.

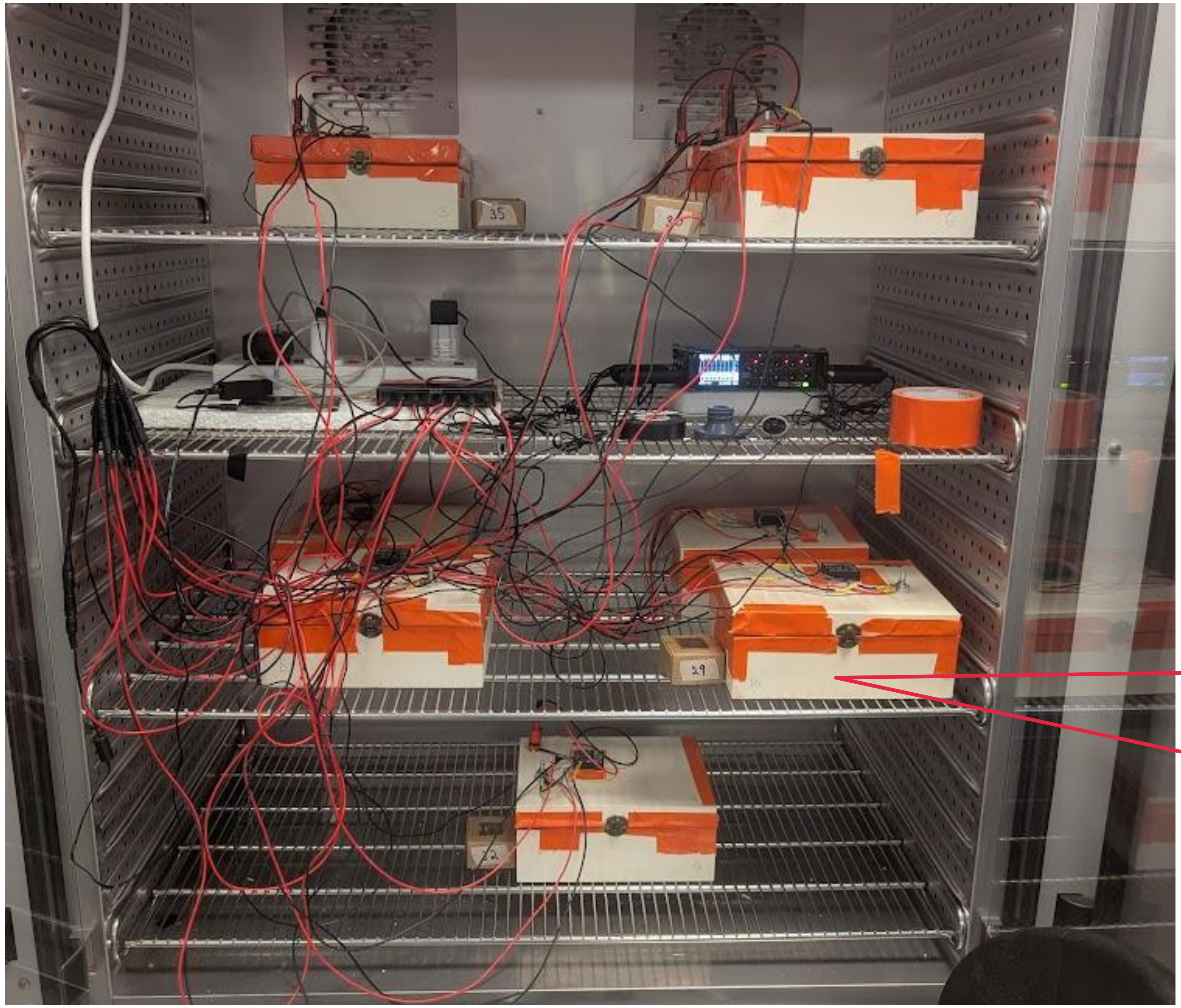
Table 1: Results of a generalised linear model with negative binomial errors modelling the number of drumming events each hour with a random intercept for stonefly ID to account for potential heterogeneity among individuals.

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	0.873	0.683	1.278	0.201
Temperature	**-0.473**	**0.038**	**-12.394**	**<0.001**
Time (Sin)	**-0.284**	**0.058**	**-4.866**	**<0.001**
Time (Cos)	-0.078	0.063	-1.227	0.220
Box Type	0.666	0.575	1.159	0.247
Light	-0.042	0.574	-0.073	0.942

RESULTS

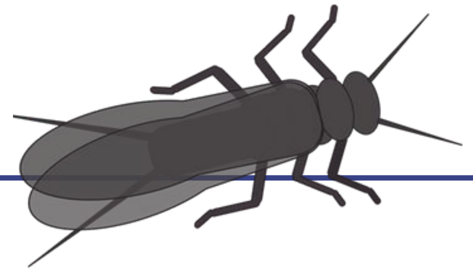
- No significant effect of box type or light.
- Increase in temperature correlated with reduction in drumming.
- Daily rhythmic pattern of drumming, with reduced effort in the morning.
- Evidence for circadian rhythm since daily pattern in drumming independent of light level.



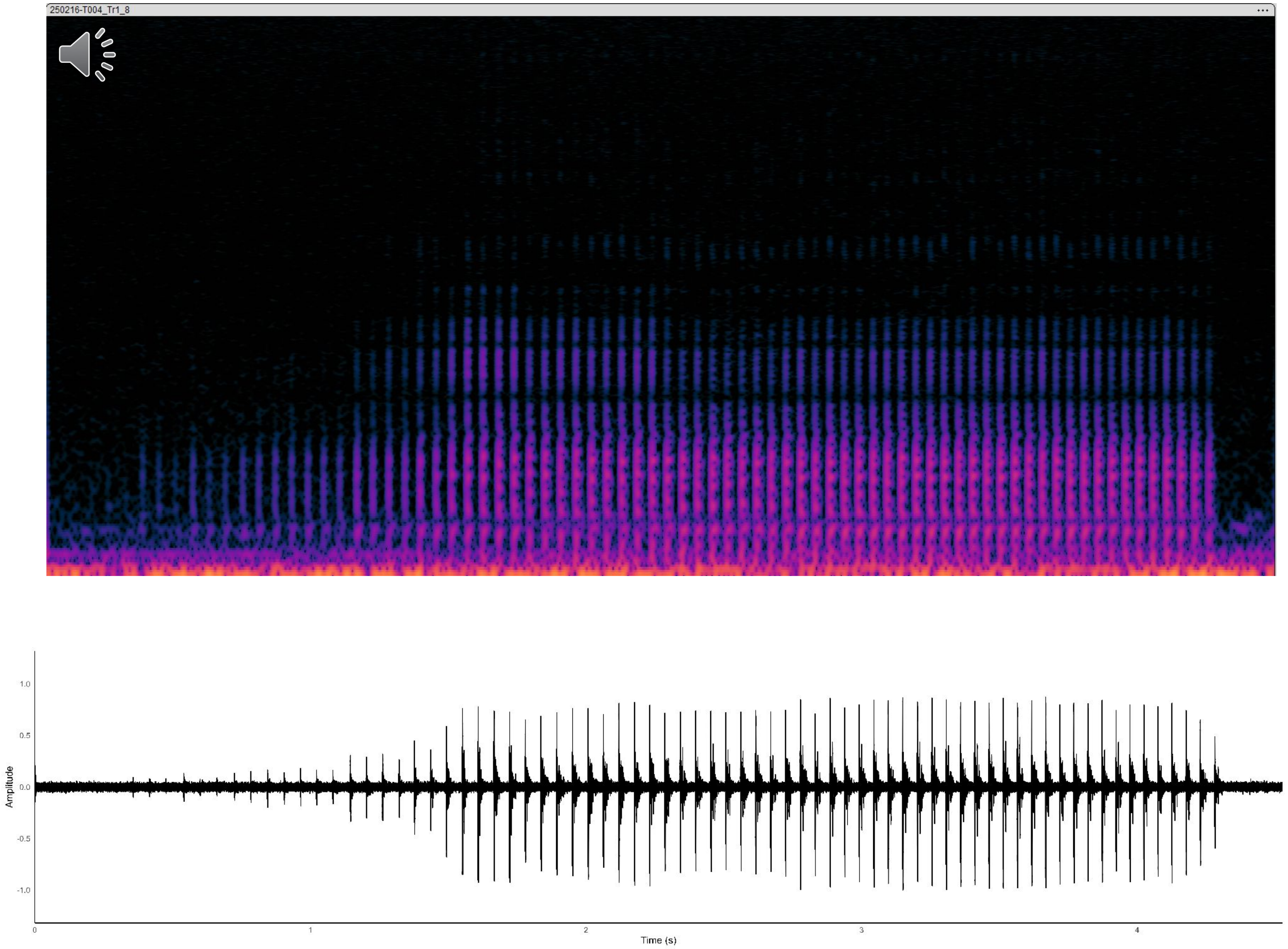


Adult and juvenile male stoneflies were collected from the Water of Leith (*Perlodes mortoni*) and Tweed (*Perla carlukiana*).

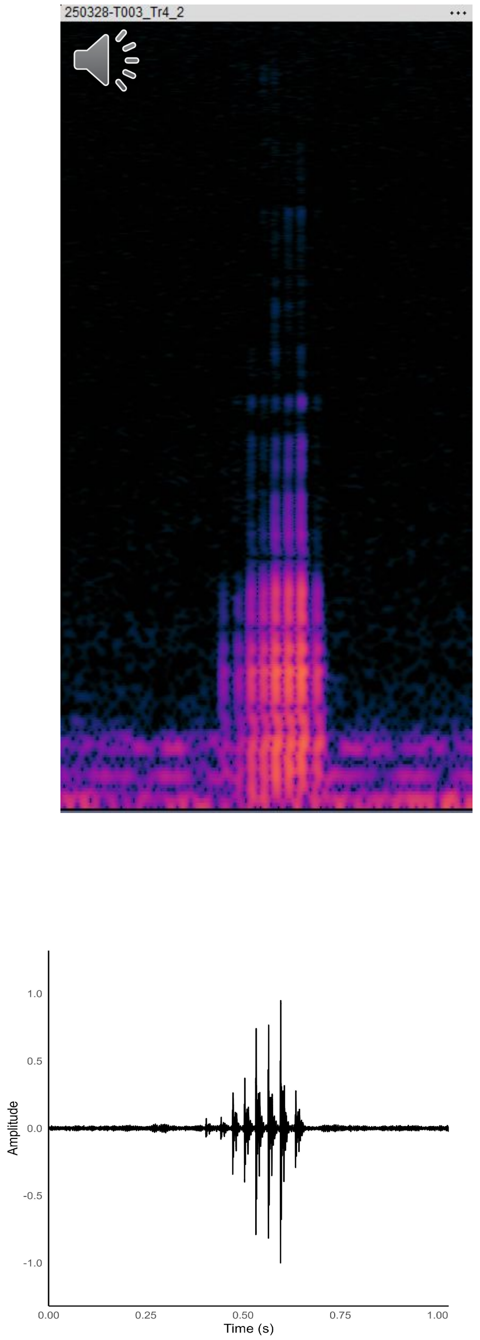
Males were placed in one of the sixteen boxes and recorded for 24 hours.



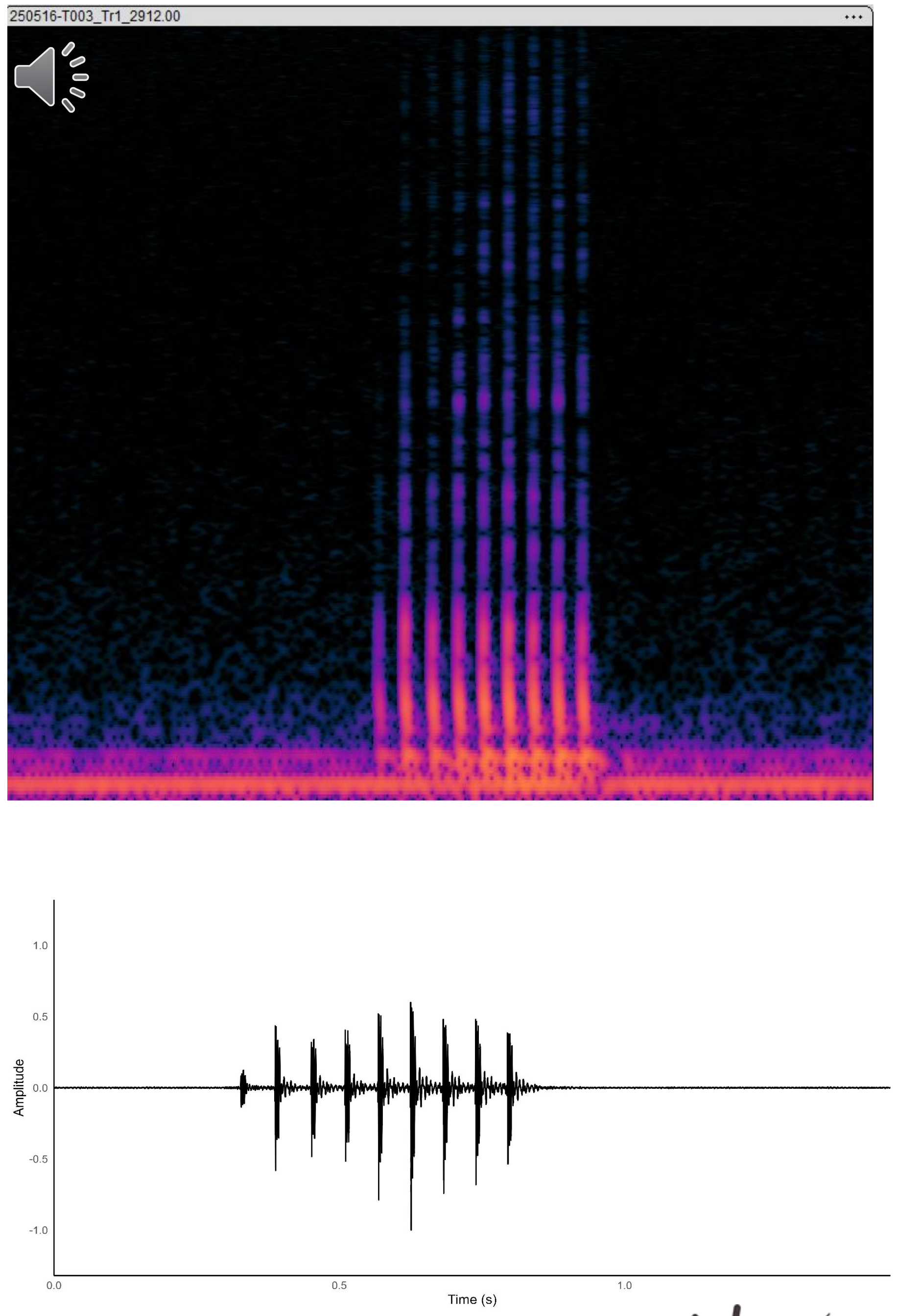
Brachyptera putata

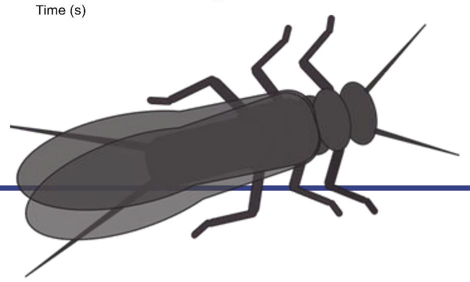


Perlodes mortoni



Perla carlukiana

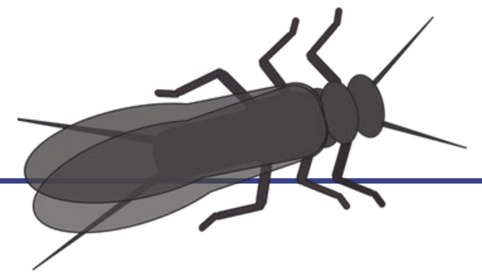




New Challenges

Too much data

- 528 GB (792 hours) of recordings for *B. putata, P. mortoni and P. carlukiana* from 2025 alone!
- Would take months (if not years) to annotate manually.



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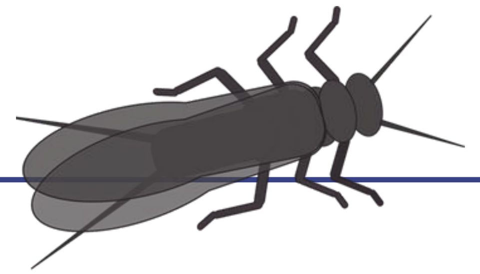
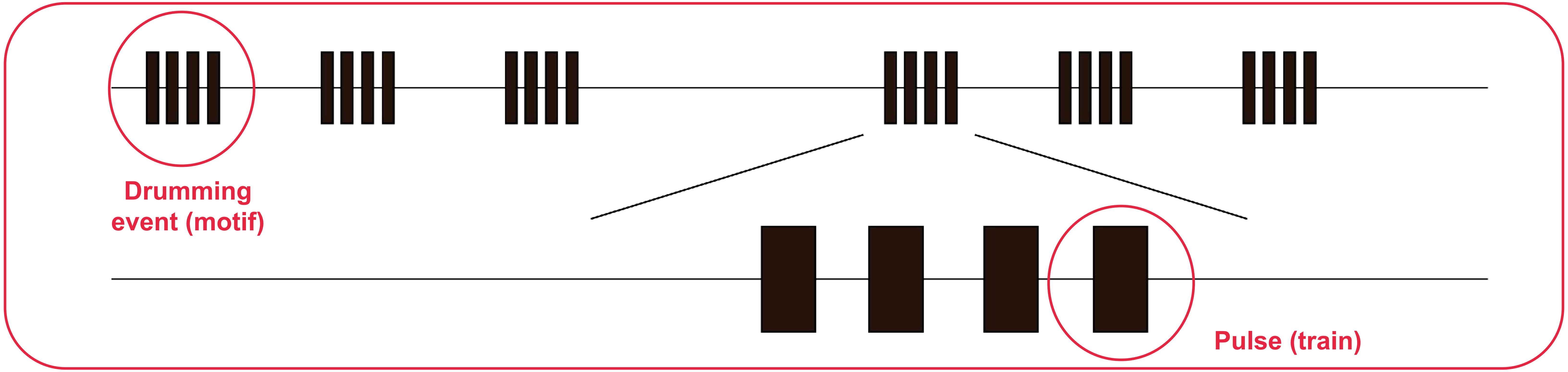
Solution

RIBBIT

- A programme in R developed for automatic detection of frog calls based on their periodic structure.
- Optimised parameters for each species and tested by comparing to a selection of files that were annotated manually.
- Chosen parameters achieved 75% sensitivity and eliminated 99% of files.





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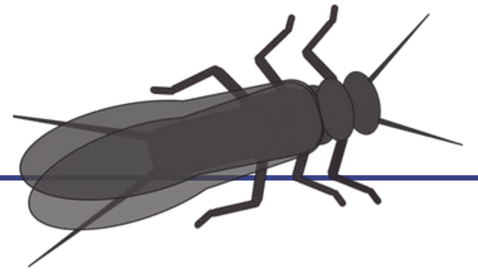
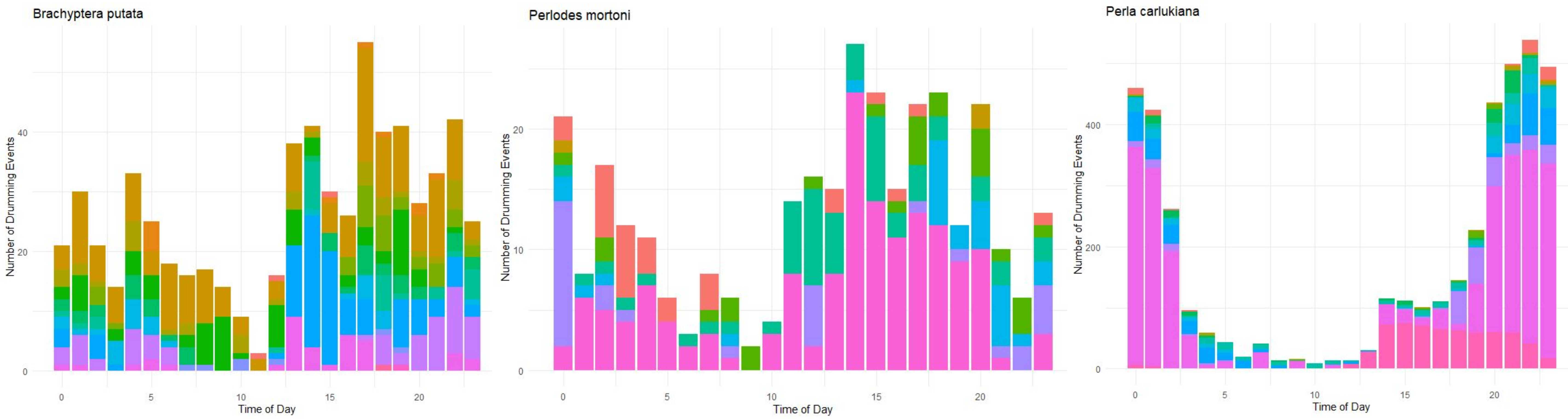


Figure 2: Number of drumming events per hour over 24 hours for male stoneflies. Each colour represents a unique stonefly individual. Also shown are results of generalised linear models with negative binomial errors modelling the number of drumming events each hour with a random intercept for stonefly ID to account for potential heterogeneity among individuals.



Predictor	Estimate	Std. Error	z value	p value
(Intercept)	-2.24	1.54	-1.46	0.14
Temperature	-0.24	0.12	-2.05	0.04*
Time (Sin)	8.24	1.69	4.87	<0.001**
Time (Cos)	3.01	1.43	2.10	0.04*
Temperature:Time (Sin)	-0.73	0.14	-5.27	<0.001**
Temperature:Time (Cos)	-0.25	0.12	-2.14	0.03*

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	-2.55	1.07	-2.39	0.02*
Temperature	-0.04	0.06	-0.80	0.42
Time (Sin)	-3.02	0.83	-3.64	<0.001**
Time (Cos)	0.58	0.57	1.01	0.31
Temperature:Time (Sin)	0.13	0.04	3.08	0.0003*
Temperature:Time (Cos)	-0.03	0.03	-0.97	0.33

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(Intercept)	-73.99	3.40	-21.75	<0.001**
Temperature	3.04	0.14	21.05	<0.001**
Time (Sin)	-21.60	3.08	-7.01	<0.001**
Time (Cos)	-64.12	2.88	-22.30	<0.001**
Temperature:Time (Sin)	0.86	0.13	6.58	<0.001**
Temperature:Time (Cos)	2.81	0.12	22.88	<0.001**

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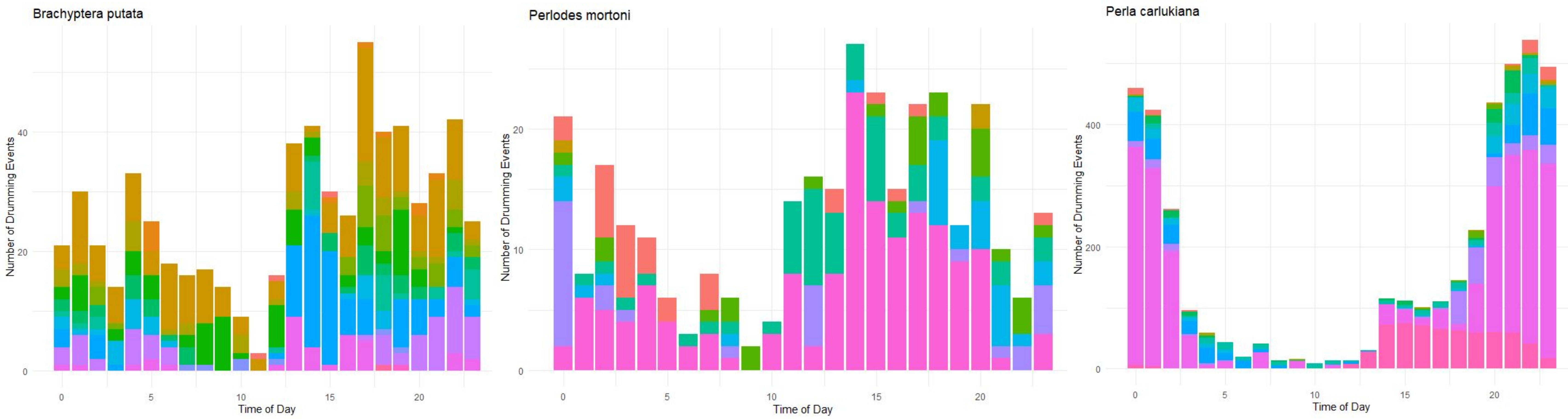

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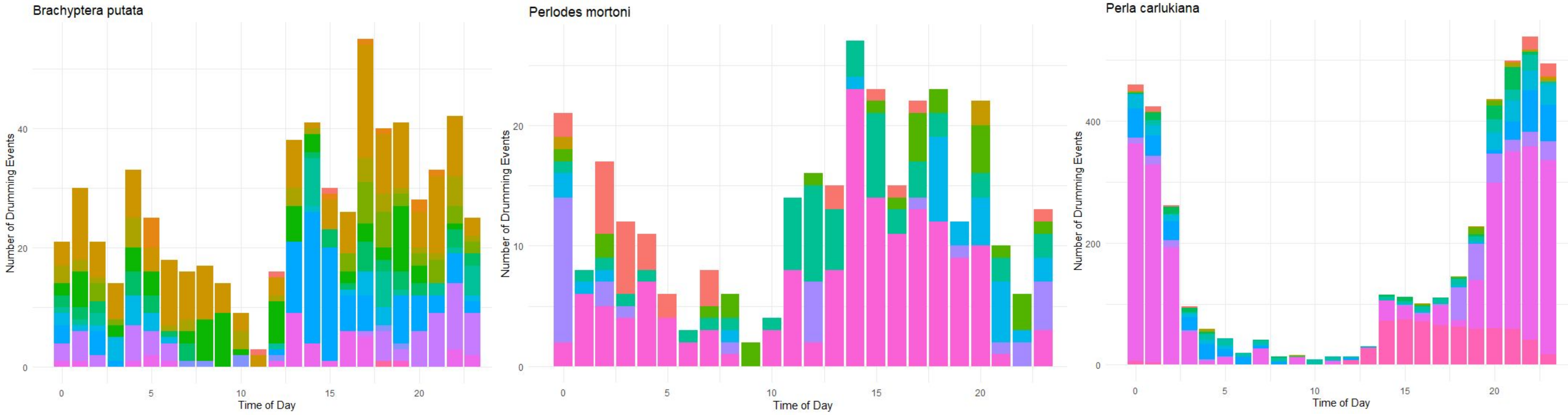

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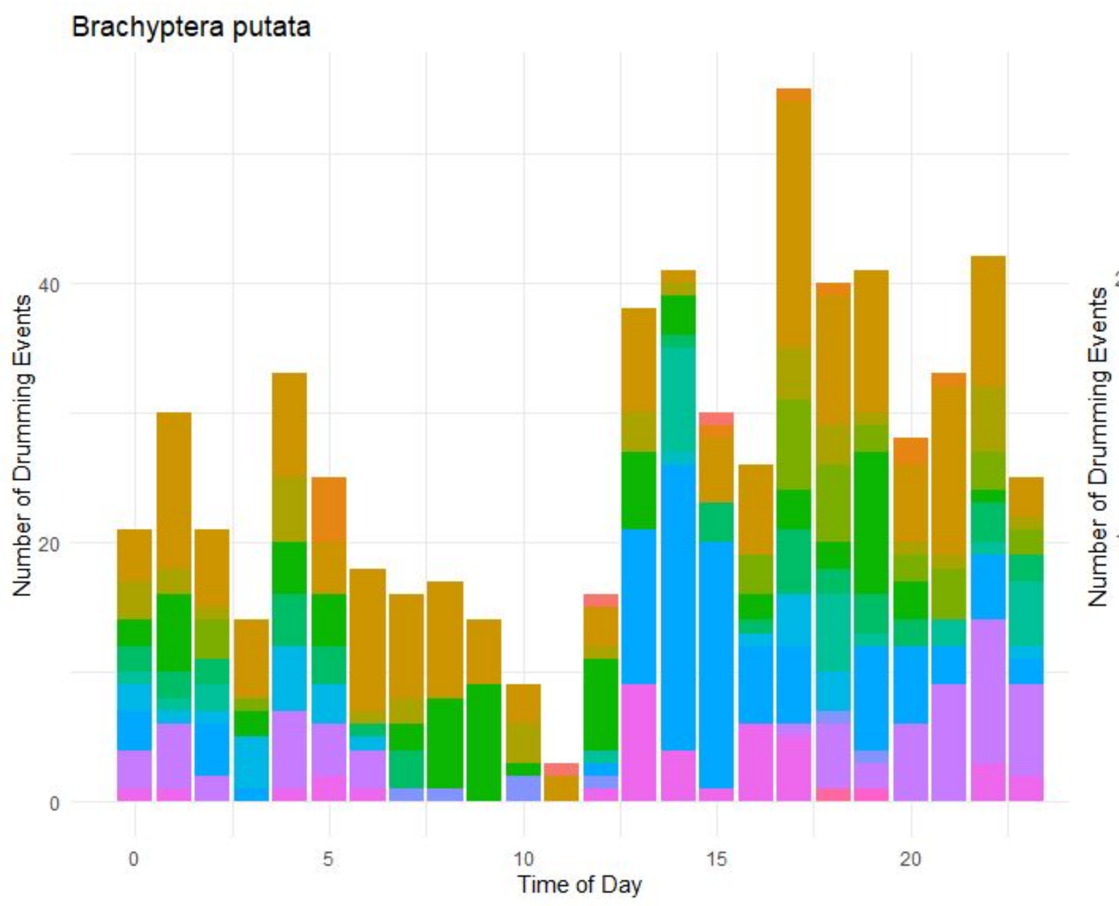

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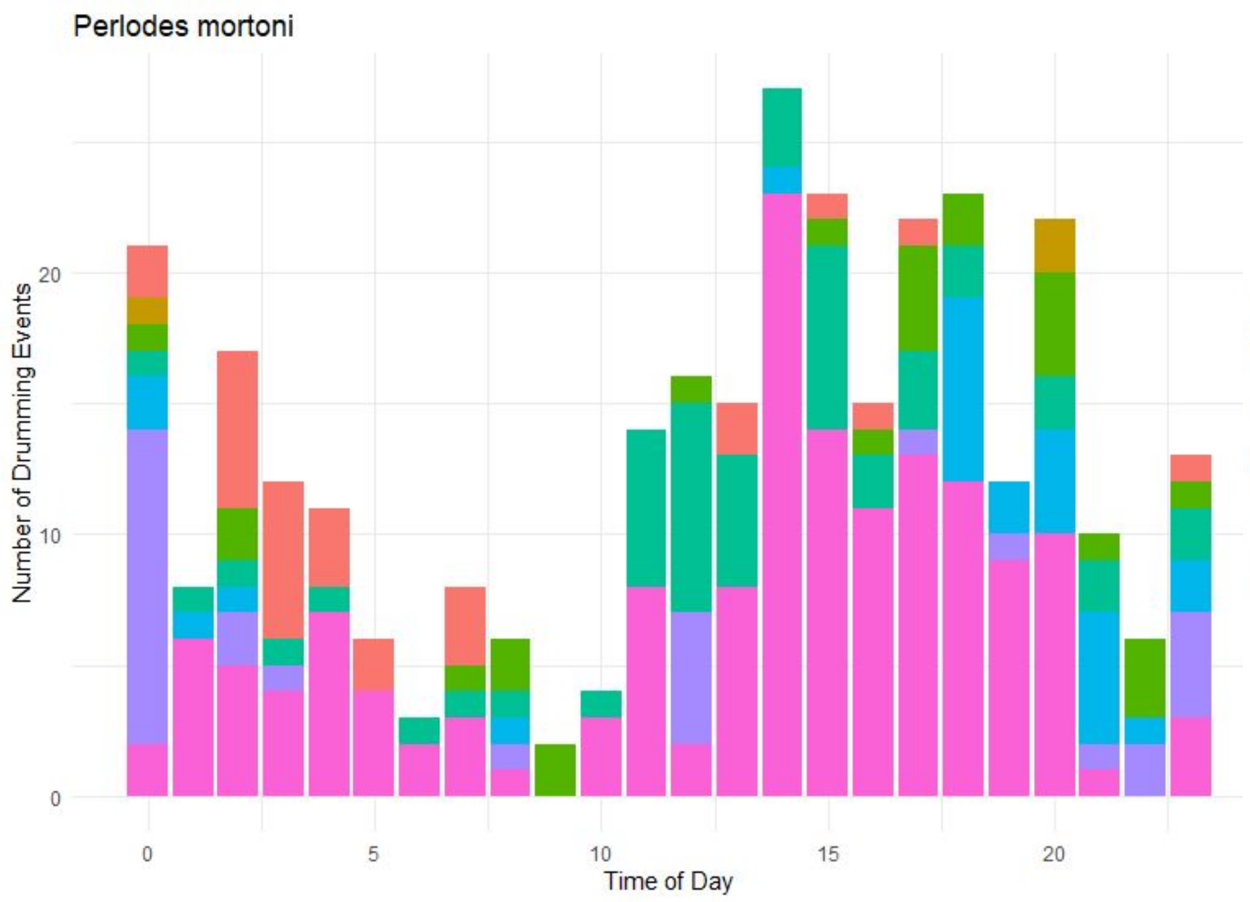

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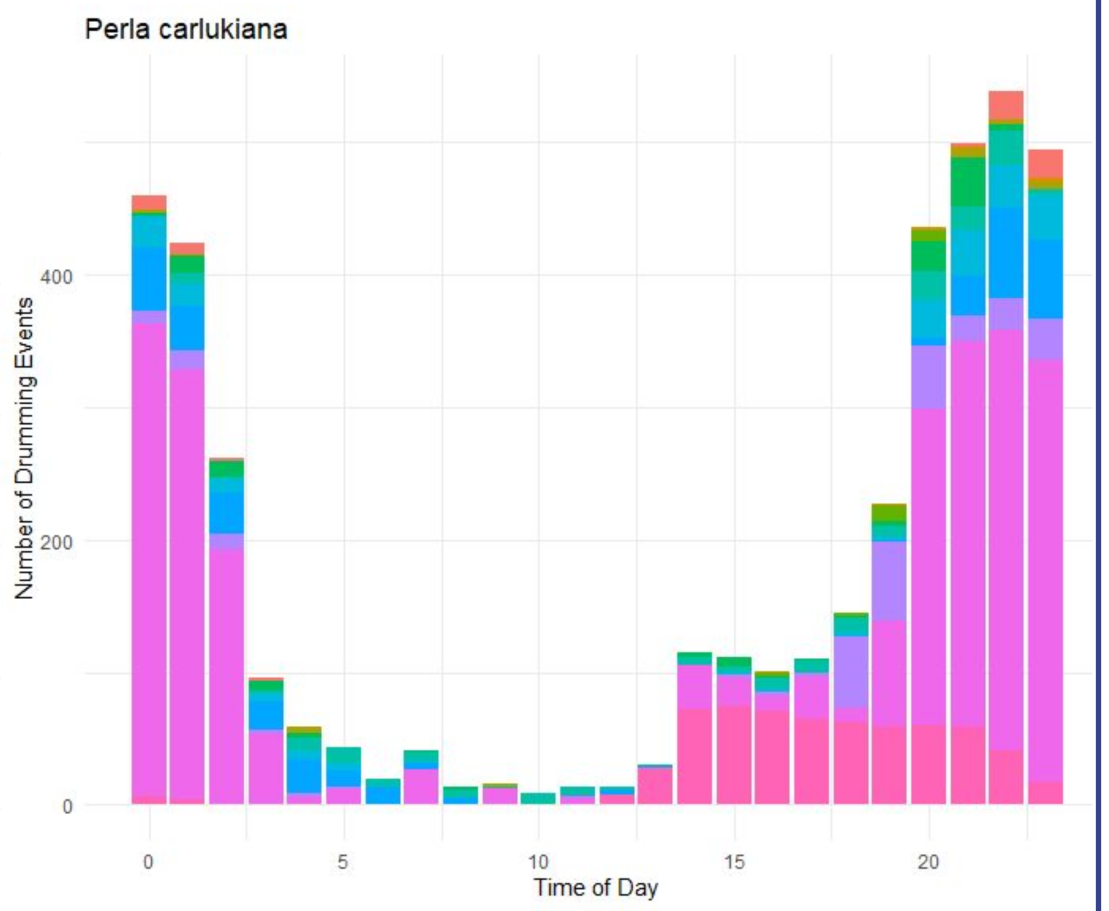

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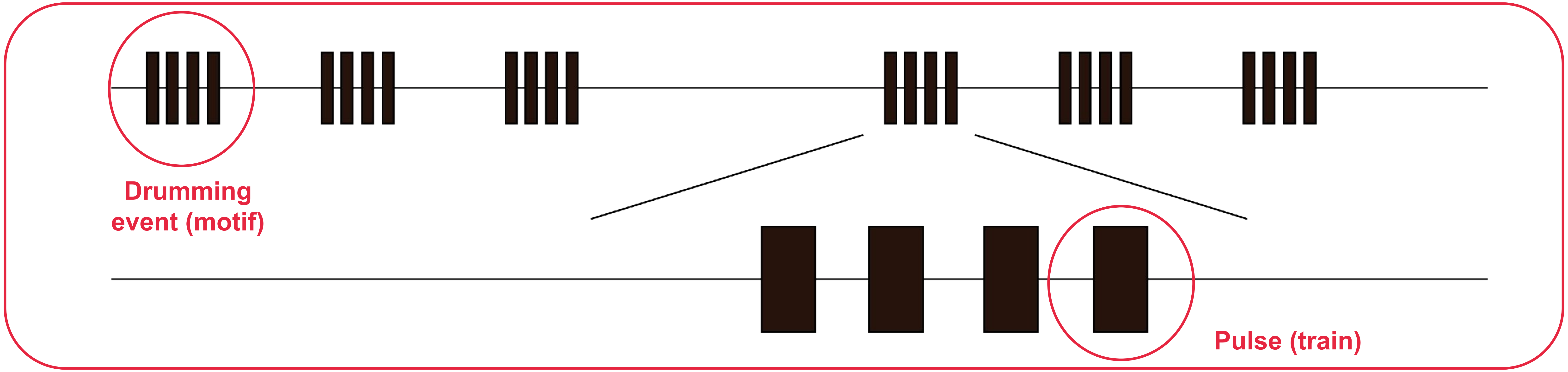
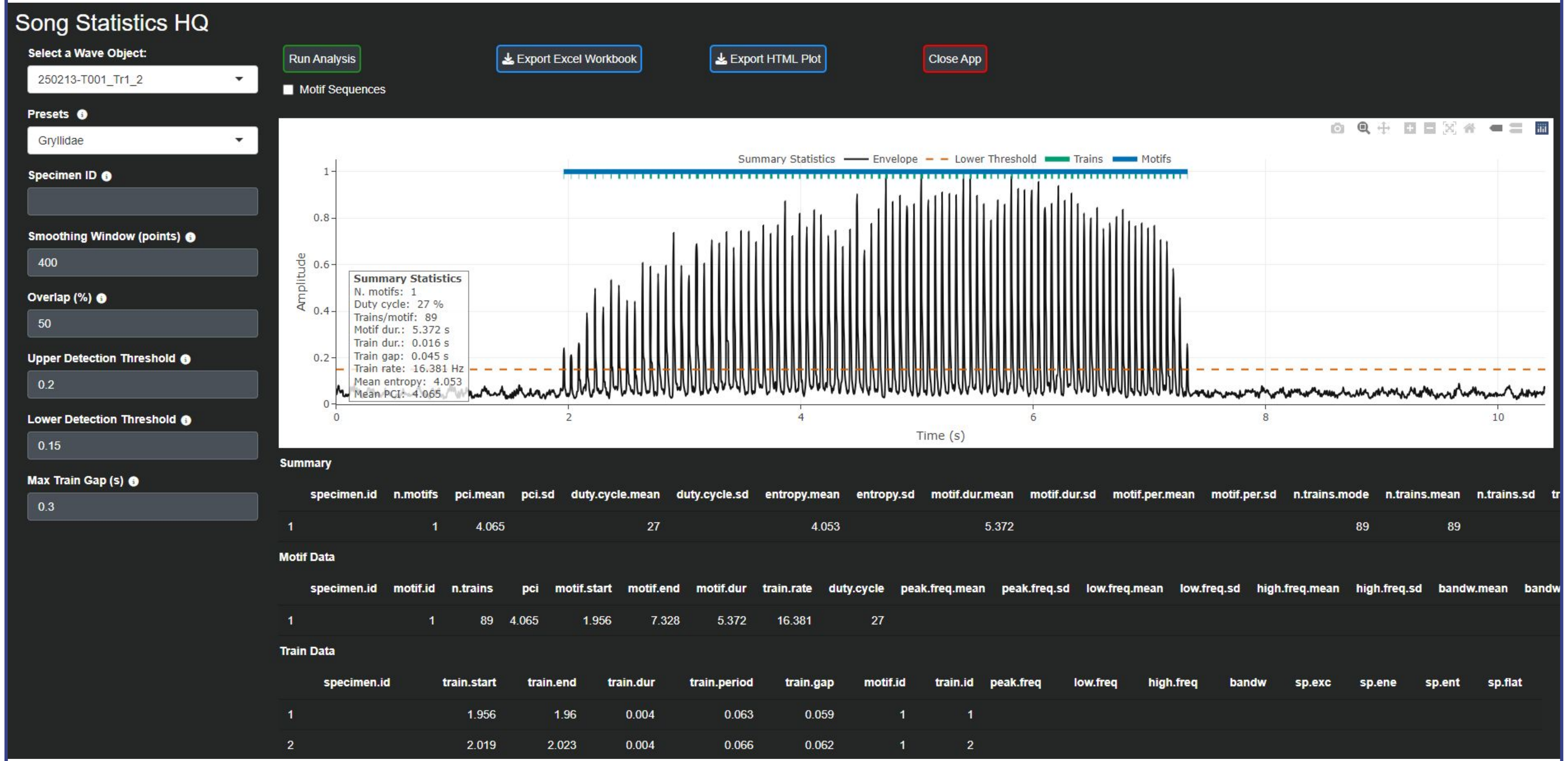


Solutions



Rthoptera

- A programme in R developed for accurate analysis of temporal and spectral measurements of insect acoustic signals.
- *song_stats_hq* uses a threshold amplitude to detect trains, allowing for description of calling behaviour of individuals and species (motif duration, train number and train rate) and how they vary.

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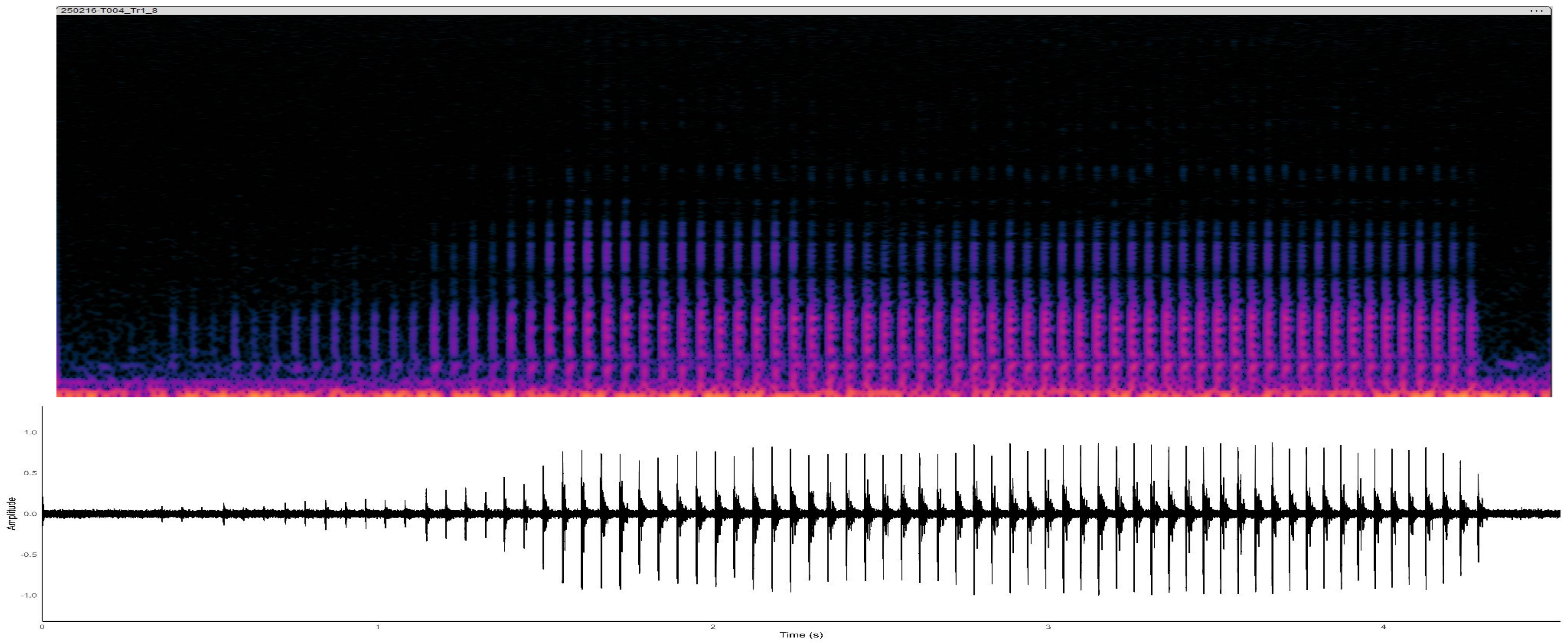
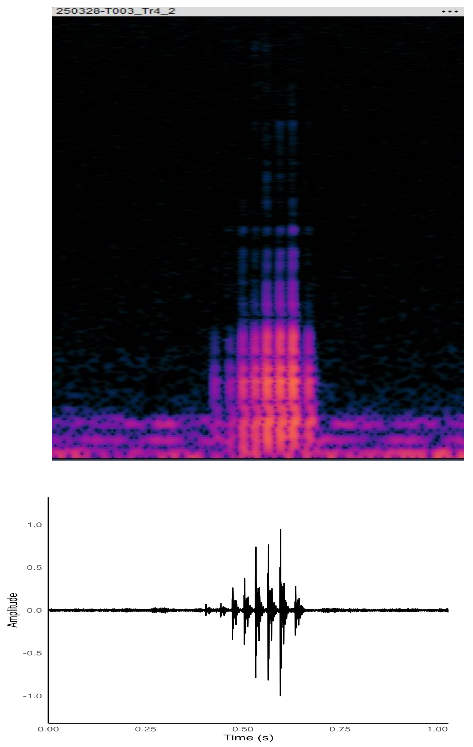
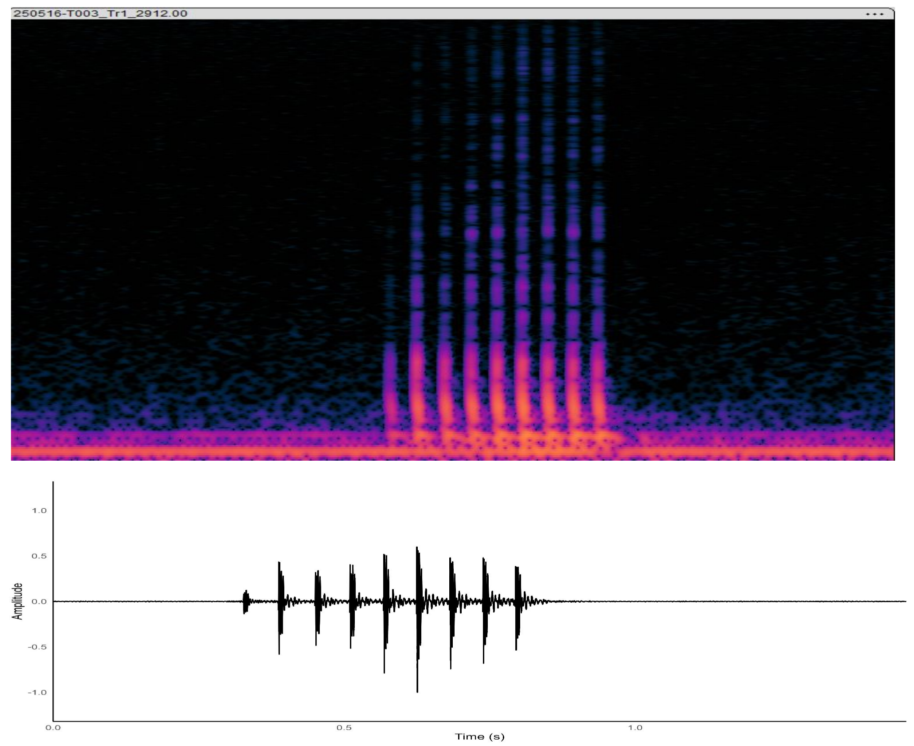
Brachyptera putata



Perlodes mortoni



Perla carlukiana



Species	Recording Dates	Temperature in °C	Mean motif duration in s	Mean number of trains	Mean train rate
Brachyptera putata	13/02/25 - 17/02/25	11.2 – 14.4	4.38	69.9	15.9
Perlodes mortoni	28/03/25 - 09/04/25 23/03/26 - 16/04/26	14.4 – 23.1	0.24	5.82	20.1
Perla carlukiana	16/05/25 - 03/06/25	22.8 – 23.5	0.4	7.72	16.8

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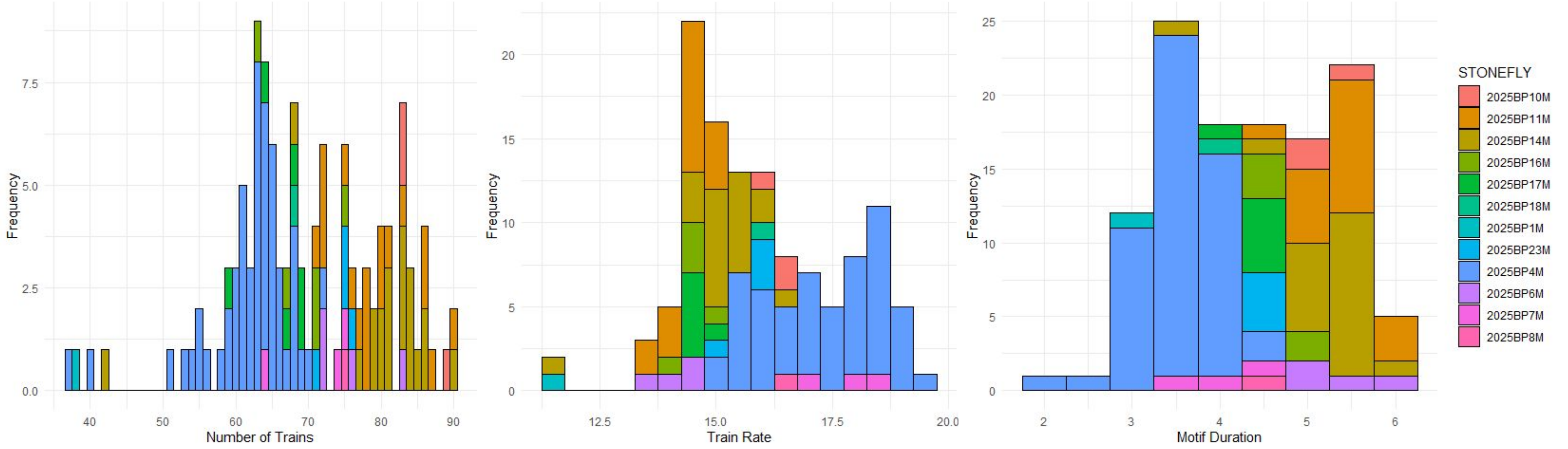
Figure 3: The frequency of occurrence of drumming events with different values for number of trains, train rate, and motif duration for species *Brachyptera putata.* Each colour represents a unique stonefly individual.



Species	Recording Dates	Temperature (°C)	Mean motif duration (s)	Mean number of trains	Mean train rate
Brachyptera putata	13/02/25 - 17/02/25	11.2 - 14.4	4.38	69.9	15.9

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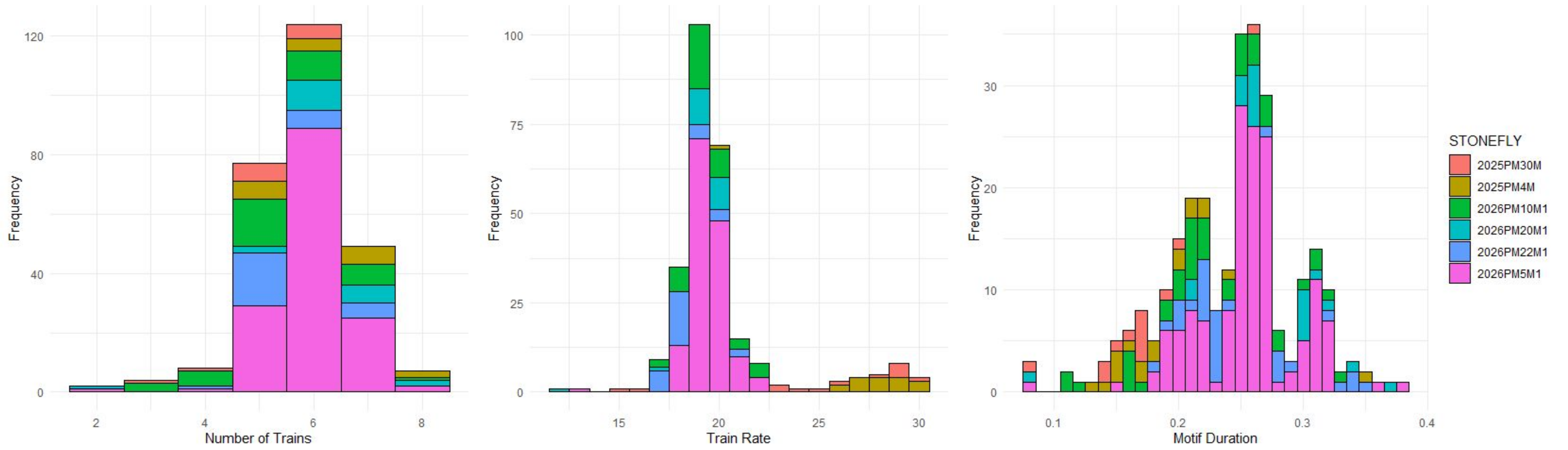
Figure 4: The frequency of occurrence of drumming events with different values for number of trains, train rate, and motif duration for species *Perlodes mortoni.* Each colour represents a unique stonefly individual.



Species	Recording Dates	Temperature (°C)	Mean motif duration (s)	Mean number of trains	Mean train rate
Perlodes mortoni	28/03/25 - 09/04/25 23/03/26 - 16/04/26	14.4 - 23.1	0.24	5.82	20.1

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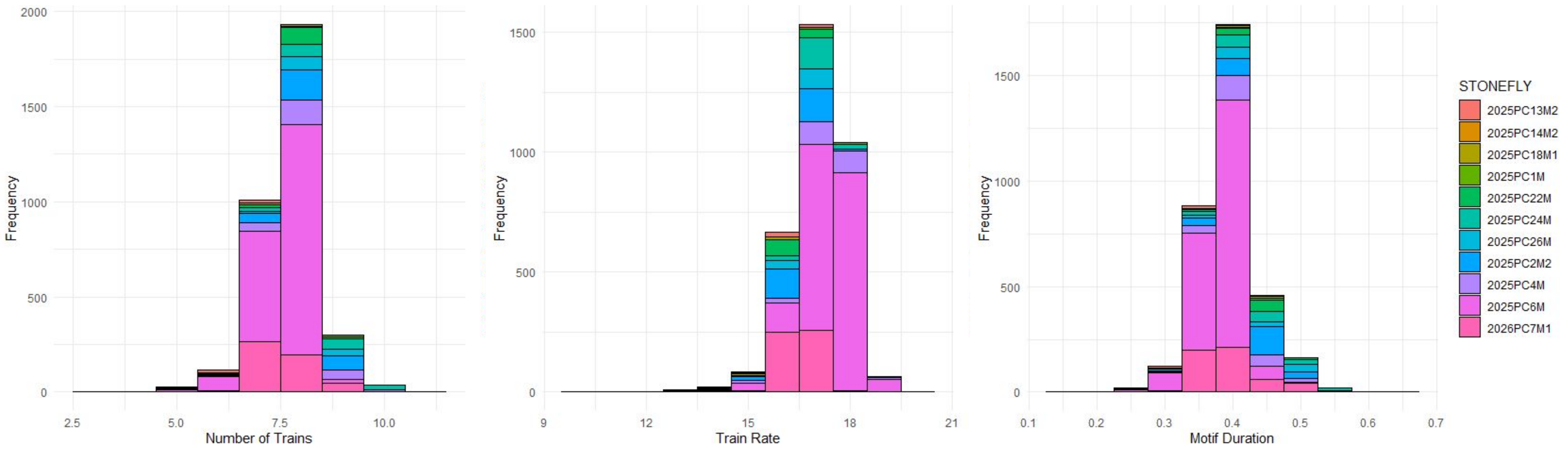
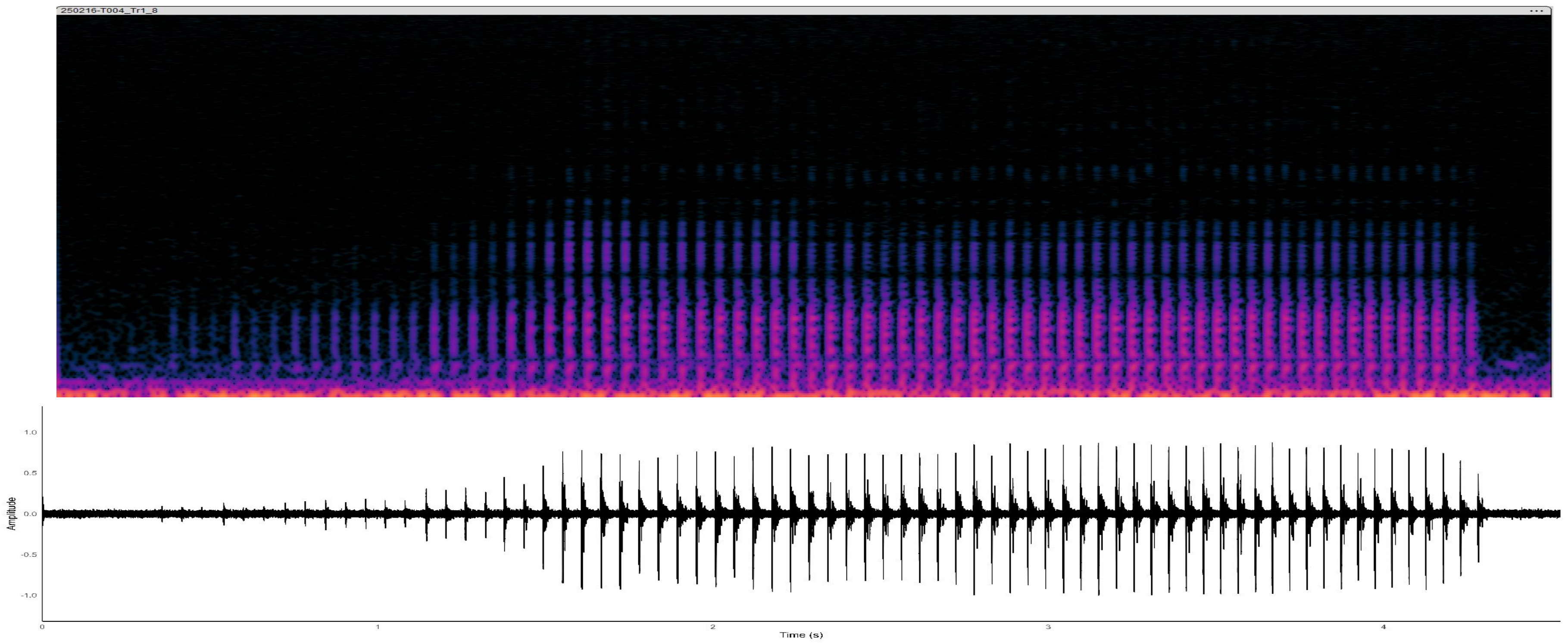
Figure 5: The frequency of occurrence of drumming events with different values for number of trains, train rate, and motif duration for species *Perla carlukiana.* Each colour represents a unique stonefly individual.

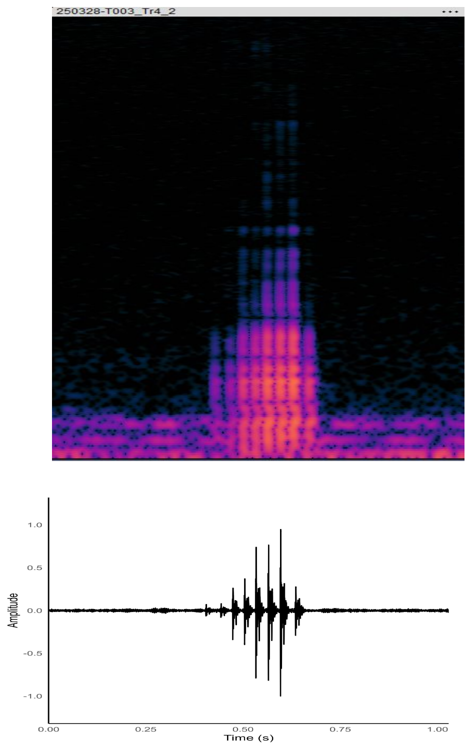


Species	Recording Dates	Temperature (°C)	Mean motif duration (s)	Mean number of trains	Mean train rate
Perla carlukiana	16/05/25 - 03/06/25	22.8 - 23.5	0.4	7.72	16.8

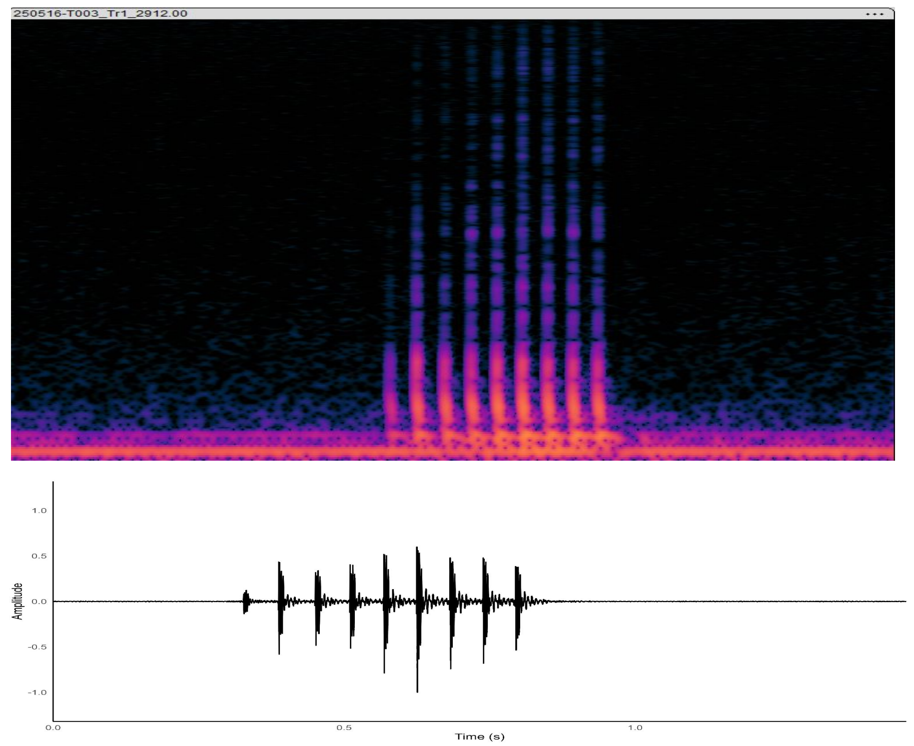
Brachyptera putata



Perlodes mortoni



Perla carlukiana



Species	Recording Dates	Temperature in °C	Motif duration in s (mean)	Number of trains (mean)	Train rate (mean)
Brachyptera putata	13/02/25 - 17/02/25	11.2 – 14.4	1.99 – 6.07 4.38	37 – 90 69.9	11.5 – 19.4 15.9
Perlodes mortoni	28/03/25 - 09/04/25 23/03/26 - 16/04/26	14.4 – 23.1	0.08 – 0.38 0.24	2 – 8 5.82	12.4 – 30.5 20.1
Perla carlukiana	16/05/25 - 03/06/25	22.8 – 23.5	0.13 – 0.59 0.4	3 – 10 7.72	9.9 – 19.3 16.8

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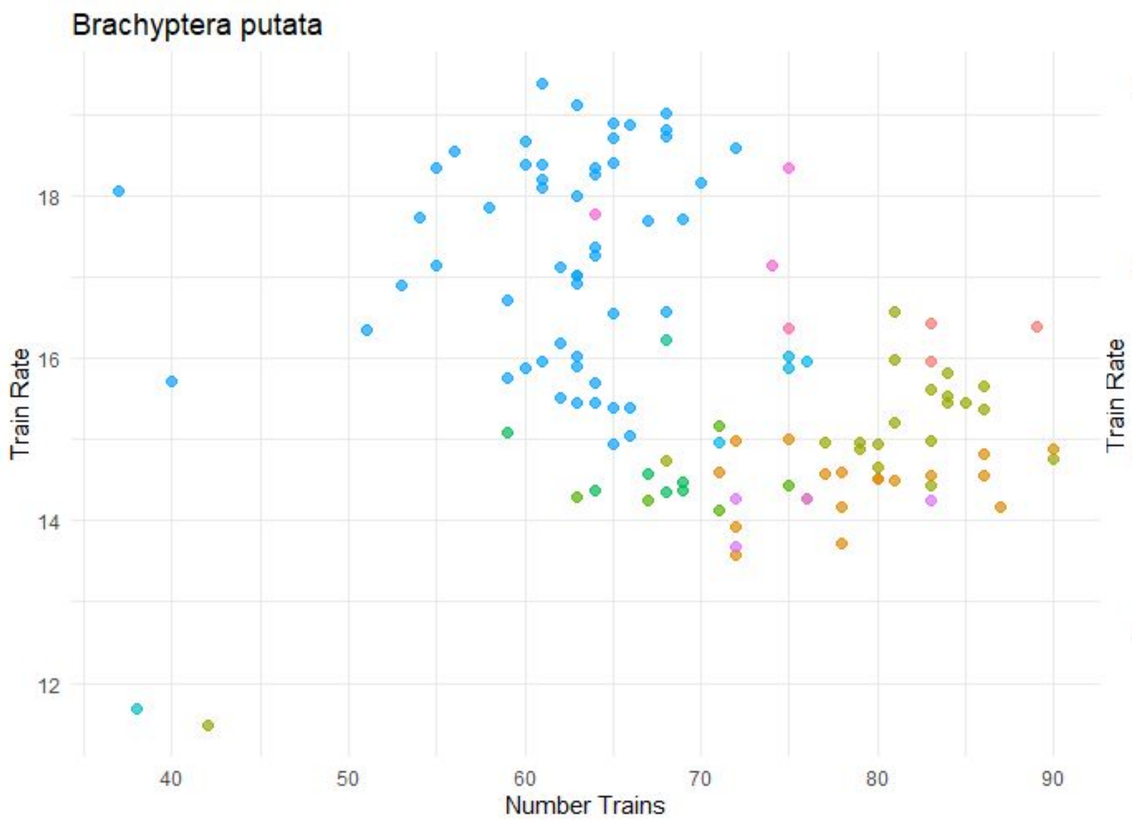
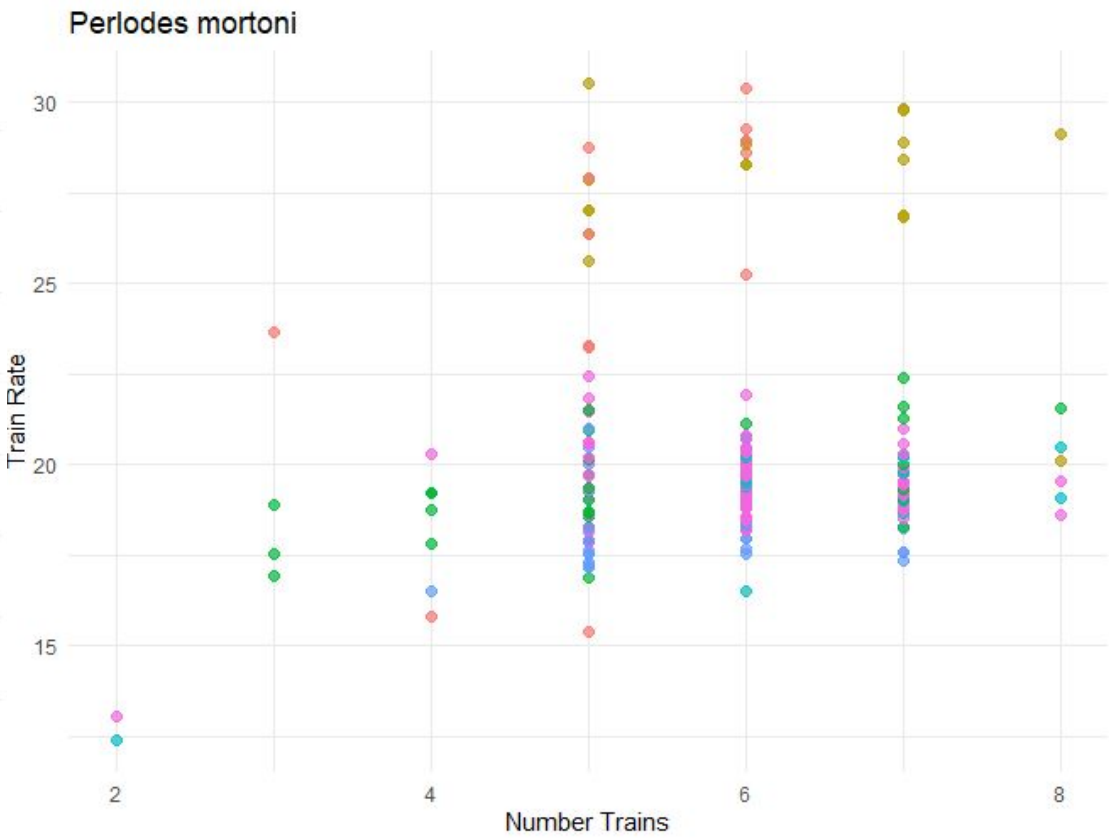
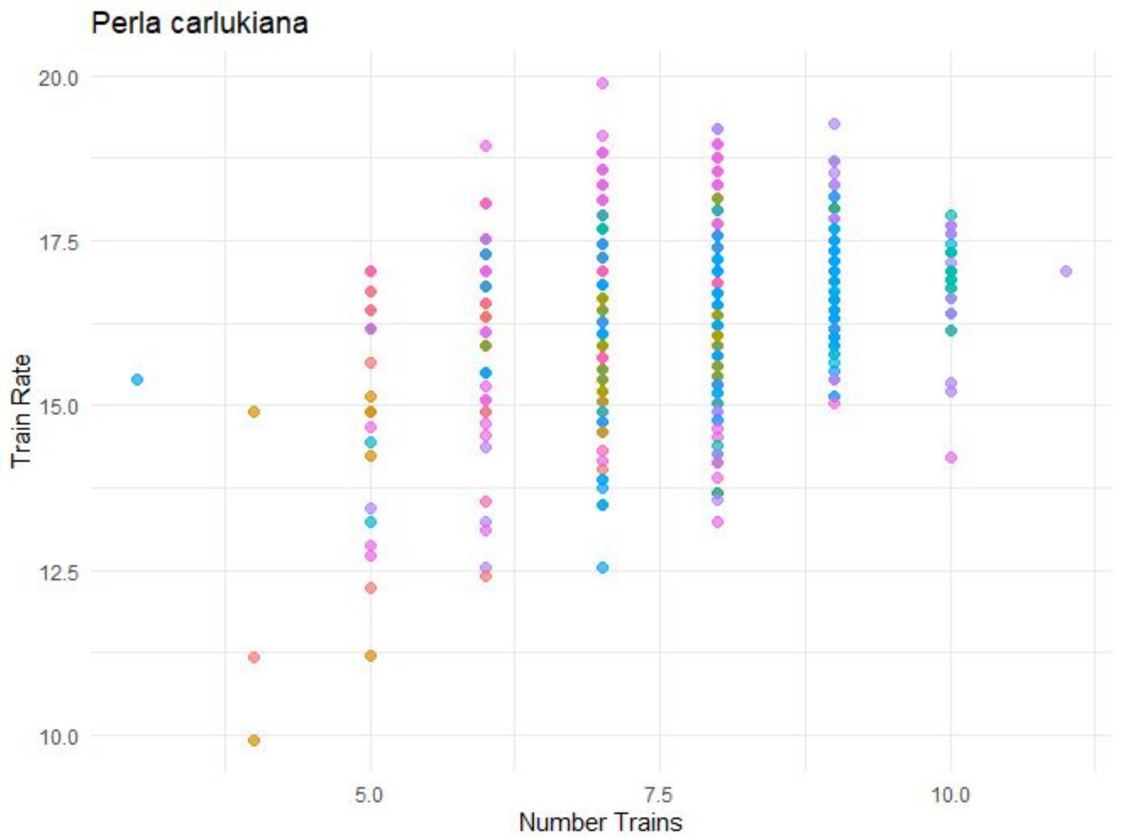
Figure 6: Relationship between number of trains per drumming event and train rate for each species. Each colour represents a unique stonefly individual. Also shown are results of generalised linear models with negative binomial errors modelling the effect of temperature, time of day, and number of trains on train rate with a random intercept for stonefly ID to account for potential heterogeneity among individuals.



Predictor	Estimate	Std. Error	z value	p value
(Intercept)	-3.36	1.82	-1.85	0.06
Temperature	1.30	0.14	9.49	<0.001**
Number of Trains	0.03	0.01	4.13	<0.001**
Time (Sin)	-1.73	0.57	-3.01	0.002*
Time (Cos)	-0.93	0.61	-1.53	0.13
Number of Trains:Time (Sin)	0.02	0.01	2.89	0.004*
Number of Trains:Time (Cos)	0.01	0.01	1.79	0.07

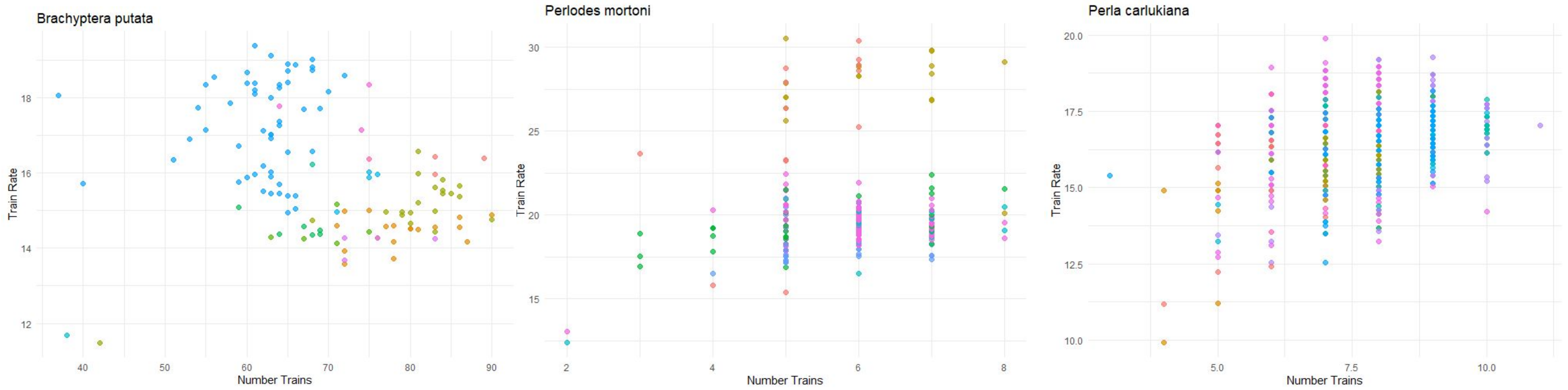


Predictor	Estimate	Std. Error	z value	p value
(Intercept)	2.99	1.67	1.78	0.07
Temperature	0.90	0.09	10.49	<0.001**
Number of Trains	0.47	0.10	4.65	<0.001**
Time (Sin)	-0.05	0.76	-0.07	0.95
Time (Cos)	-0.41	0.79	-0.52	0.60
Number of Trains:Time (Sin)	-0.03	0.13	-0.26	0.79
Number of Trains:Time (Cos)	-0.02	0.14	-0.14	0.89



Predictor	Estimate	Std. Error	z value	p value
(Intercept)	4.05	2.31	1.75	0.08
Temperature	0.46	0.10	4.67	<0.001**
Number of Trains	0.21	0.03	8.36	<0.001**
Time (Sin)	0.71	0.22	3.20	0.001*
Time (Cos)	-0.15	0.24	-0.62	0.53
Number of Trains:Time (Sin)	-0.09	0.03	-3.20	0.001*
Number of Trains:Time (Cos)	0.05	0.03	1.54	0.12

Figure 6: Relationship between number of trains per drumming event and train rate for each species. Each colour represents a unique stonefly individual. Also shown are results of generalised linear models with negative binomial errors modelling the effect of temperature, time of day, and number of trains on train rate with a random intercept for stonefly ID to account for potential heterogeneity among individuals.



Brachyptera putata

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	-3.36	1.82	-1.85	0.06
Temperature	1.30	0.14	9.49	<0.001**
Number of Trains	**0.03**	**0.01**	**4.13**	**<0.001****
Time (Sin)	-1.73	0.57	-3.01	0.002*
Time (Cos)	-0.93	0.61	-1.53	0.13
Number of Trains:Time (Sin)	0.02	0.01	2.89	0.004*
Number of Trains:Time (Cos)	0.01	0.01	1.79	0.07

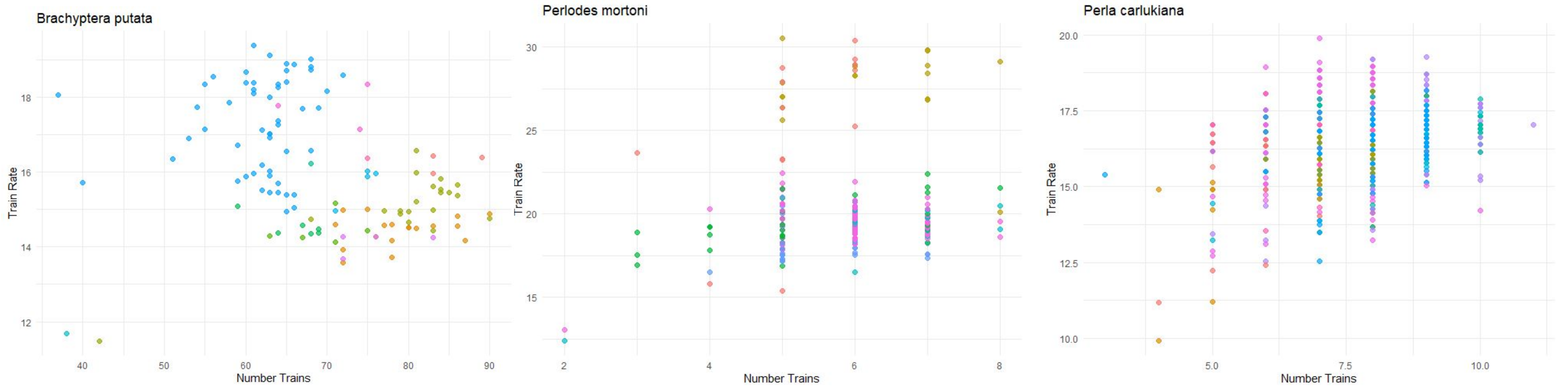
Perlodes mortoni

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	2.99	1.67	1.78	0.07
Temperature	0.90	0.09	10.49	<0.001**
Number of Trains	**0.47**	**0.10**	**4.65**	**<0.001****
Time (Sin)	-0.05	0.76	-0.07	0.95
Time (Cos)	-0.41	0.79	-0.52	0.60
Number of Trains:Time (Sin)	-0.03	0.13	-0.26	0.79
Number of Trains:Time (Cos)	-0.02	0.14	-0.14	0.89

Perla carlukiana

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	4.05	2.31	1.75	0.08
Temperature	0.46	0.10	4.67	<0.001**
Number of Trains	**0.21**	**0.03**	**8.36**	**<0.001****
Time (Sin)	0.71	0.22	3.20	0.001*
Time (Cos)	-0.15	0.24	-0.62	0.53
Number of Trains:Time (Sin)	-0.09	0.03	-3.20	0.001*
Number of Trains:Time (Cos)	0.05	0.03	1.54	0.12

Figure 6: Relationship between number of trains per drumming event and train rate for each species. Each colour represents a unique stonefly individual. Also shown are results of generalised linear models with negative binomial errors modelling the effect of temperature, time of day, and number of trains on train rate with a random intercept for stonefly ID to account for potential heterogeneity among individuals.



Predictor	Estimate	Std. Error	z value	p value
(Intercept)	-3.36	1.82	-1.85	0.06
Temperature	**1.30**	**0.14**	**9.49**	**<0.001****
Number of Trains	0.03	0.01	4.13	<0.001**
Time (Sin)	-1.73	0.57	-3.01	0.002*
Time (Cos)	-0.93	0.61	-1.53	0.13
Number of Trains:Time (Sin)	0.02	0.01	2.89	0.004*
Number of Trains:Time (Cos)	0.01	0.01	1.79	0.07

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	2.99	1.67	1.78	0.07
Temperature	**0.90**	**0.09**	**10.49**	**<0.001****
Number of Trains	0.47	0.10	4.65	<0.001**
Time (Sin)	-0.05	0.76	-0.07	0.95
Time (Cos)	-0.41	0.79	-0.52	0.60
Number of Trains:Time (Sin)	-0.03	0.13	-0.26	0.79
Number of Trains:Time (Cos)	-0.02	0.14	-0.14	0.89

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	4.05	2.31	1.75	0.08
Temperature	**0.46**	**0.10**	**4.67**	**<0.001****
Number of Trains	0.21	0.03	8.36	<0.001**
Time (Sin)	0.71	0.22	3.20	0.001*
Time (Cos)	-0.15	0.24	-0.62	0.53
Number of Trains:Time (Sin)	-0.09	0.03	-3.20	0.001*
Number of Trains:Time (Cos)	0.05	0.03	1.54	0.12

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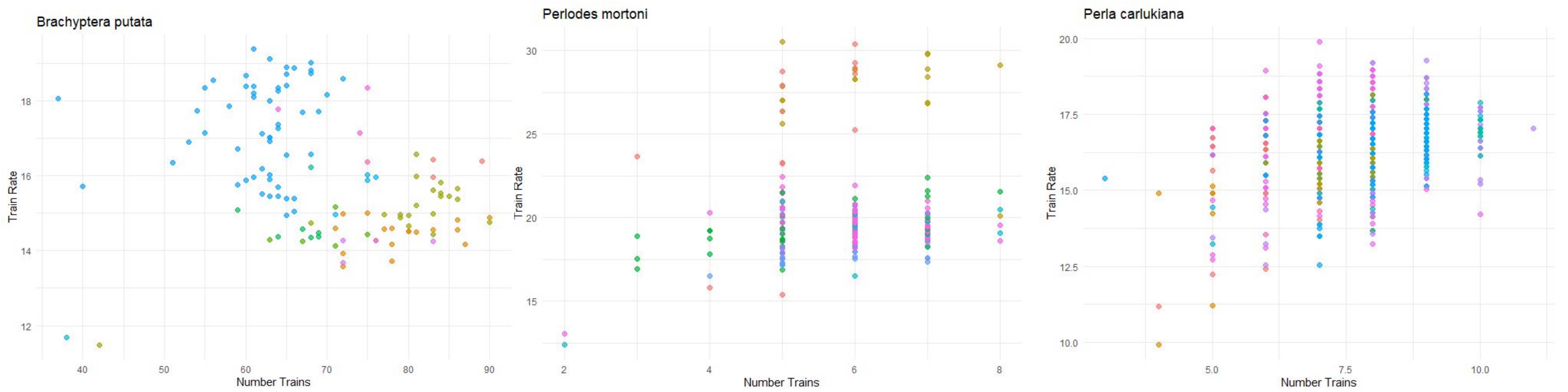
Figure 6: Relationship between number of trains per drumming event and train rate for each species. Each colour represents a unique stonefly individual. Also shown are results of generalised linear models with negative binomial errors modelling the effect of temperature, time of day, and number of trains on train rate with a random intercept for stonefly ID to account for potential heterogeneity among individuals.



Brachyptera putata

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	-25.31	4.47	-5.66	<0.001**
Temperature	3.14	0.36	8.69	<0.001**
Number of Trains	**0.35**	**0.06**	**5.53**	**<0.001****
Time (Sin)	-0.09	0.08	-1.06	0.29
Time (Cos)	0.09	0.14	0.66	0.51
Temperature:Number of Trains	**-0.03**	**0.01**	**-5.28**	**<0.001****

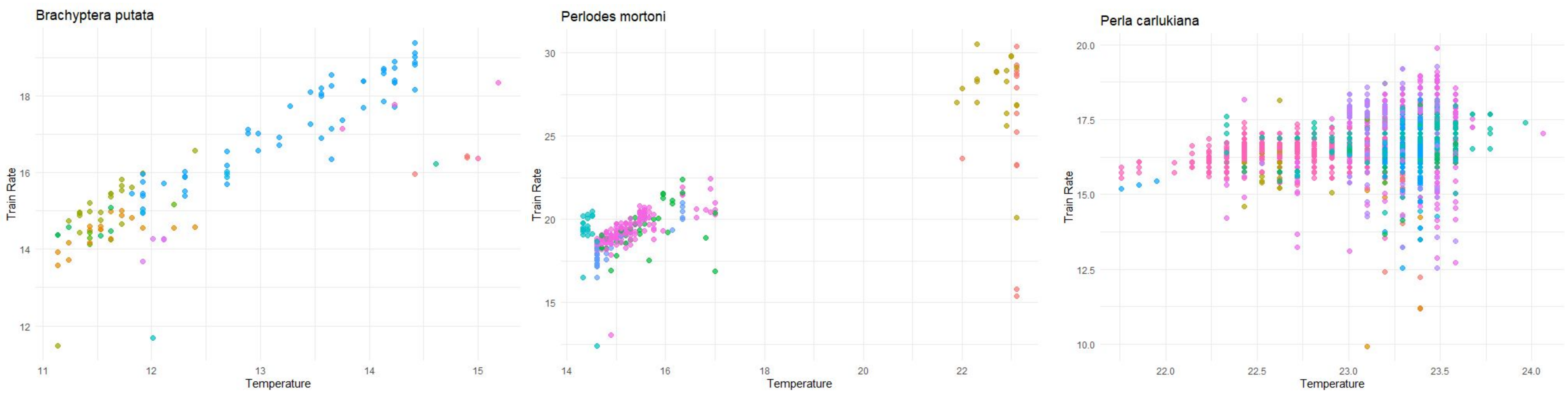
Perlodes mortoni

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	0.06	3.89	0.01	0.99
Temperature	1.07	0.23	4.59	<0.001**
Number of Trains	0.99	0.62	1.59	0.11
Time (Sin)	-0.23	0.15	-1.55	0.12
Time (Cos)	-0.51	0.14	-3.57	<0.001**
Temperature:Number of Trains	-0.03	0.04	-0.82	0.41

Perla carlukiana

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	-17.29	9.83	-1.76	0.08
Temperature	1.36	0.42	3.22	0.001*
Number of Trains	**2.95**	**1.26**	**2.33**	**0.02***
Time (Sin)	0.00	0.03	0.01	0.99
Time (Cos)	0.22	0.05	4.79	<0.001**
Temperature:Number of Trains	**-0.12**	**0.05**	**-2.14**	**0.03***

Figure 7: Effect of temperature on train rate for each species. Each colour represents a unique stonefly individual. Also shown are results of generalised linear models with negative binomial errors modelling the effect of temperature and time of day on train rate with a random intercept for stonefly ID to account for potential heterogeneity among individuals.



Predictor	Estimate	Std. Error	z value	p value
(Intercept)	2.00	1.95	1.02	0.31
Temperature	1.03	0.15	6.82	<0.001**
Time (Sin)	-1.69	1.05	-1.62	0.11
Time (Cos)	4.26	1.38	3.10	0.002*
Temperature:Time (Sin)	0.11	0.09	1.30	0.19
Temperature:Time (Cos)	-0.36	0.11	-3.13	0.002*

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	5.85	1.11	5.27	<0.001**
Temperature	0.88	0.06	13.63	<0.001**
Time (Sin)	4.60	0.96	4.78	<0.001**
Time (Cos)	-1.25	1.23	-1.02	0.31
Temperature:Time (Sin)	-0.32	0.06	-5.31	<0.001**
Temperature:Time (Cos)	0.06	0.08	0.76	0.45

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	-9.63	5.07	-1.90	0.06
Temperature	1.11	0.22	5.11	<0.001**
Time (Sin)	2.98	3.56	0.84	0.40
Time (Cos)	-18.44	3.57	-5.17	<0.001**
Temperature:Time (Sin)	-0.14	0.15	-0.92	0.36
Temperature:Time (Cos)	0.80	0.15	5.25	<0.001**

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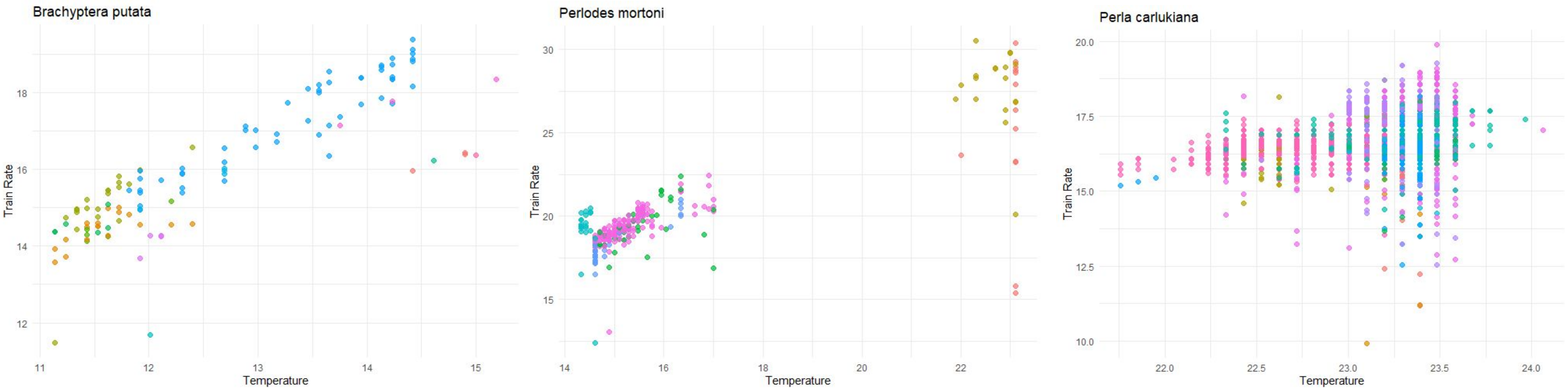
Figure 7: Effect of temperature on train rate for each species. Each colour represents a unique stonefly individual. Also shown are results of generalised linear models with negative binomial errors modelling the effect of temperature and time of day on train rate with a random intercept for stonefly ID to account for potential heterogeneity among individuals.



Brachyptera putata

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	2.00	1.95	1.02	0.31
Temperature	**1.03**	**0.15**	**6.82**	**<0.001****
Time (Sin)	-1.69	1.05	-1.62	0.11
Time (Cos)	4.26	1.38	3.10	0.002*
Temperature:Time (Sin)	0.11	0.09	1.30	0.19
Temperature:Time (Cos)	-0.36	0.11	-3.13	0.002*

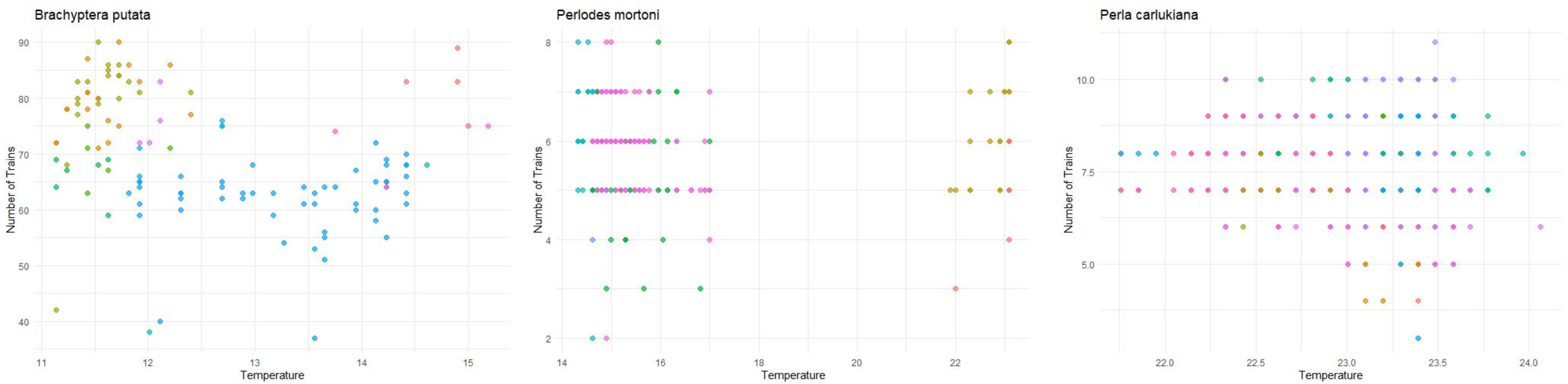
Perlodes mortoni

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	5.85	1.11	5.27	<0.001**
Temperature	**0.88**	**0.06**	**13.63**	**<0.001****
Time (Sin)	4.60	0.96	4.78	<0.001**
Time (Cos)	-1.25	1.23	-1.02	0.31
Temperature:Time (Sin)	-0.32	0.06	-5.31	<0.001**
Temperature:Time (Cos)	0.06	0.08	0.76	0.45

Perla carlukiana

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	-9.63	5.07	-1.90	0.06
Temperature	**1.11**	**0.22**	**5.11**	**<0.001****
Time (Sin)	2.98	3.56	0.84	0.40
Time (Cos)	-18.44	3.57	-5.17	<0.001**
Temperature:Time (Sin)	-0.14	0.15	-0.92	0.36
Temperature:Time (Cos)	0.80	0.15	5.25	<0.001**

Figure 8: Effect of temperature on number of trains per drumming event for each species. Each colour represents a unique stonefly individual. Also shown are results of generalised linear models with negative binomial errors modelling the effect of temperature and time of day on number of trains with a random intercept for stonefly ID to account for potential heterogeneity among individuals.



Predictor	Estimate	Std. Error	z value	p value
(Intercept)	37.43	21.25	1.76	0.08
Temperature	2.59	1.66	1.56	0.12
Time (Sin)	-27.58	14.37	-1.92	0.05
Time (Cos)	4.06	16.61	0.24	0.81
Temperature:Time (Sin)	2.02	1.21	1.68	0.09
Temperature:Time (Cos)	-0.25	1.36	-0.18	0.86

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	7.08	0.99	7.18	<0.001**
Temperature	-0.09	0.06	-1.55	0.12
Time (Sin)	-0.78	0.85	-0.92	0.36
Time (Cos)	-2.31	0.84	-2.76	0.006*
Temperature:Time (Sin)	0.04	0.05	0.75	0.46
Temperature:Time (Cos)	0.16	0.05	3.04	0.002*

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	-12.94	5.25	-2.46	0.01
Temperature	0.87	0.23	3.83	<0.001**
Time (Sin)	-18.45	3.68	-5.02	<0.001**
Time (Cos)	-31.27	3.69	-8.47	<0.001**
Temperature:Time (Sin)	0.77	0.16	4.90	<0.001**
Temperature:Time (Cos)	1.35	0.16	8.60	<0.001**

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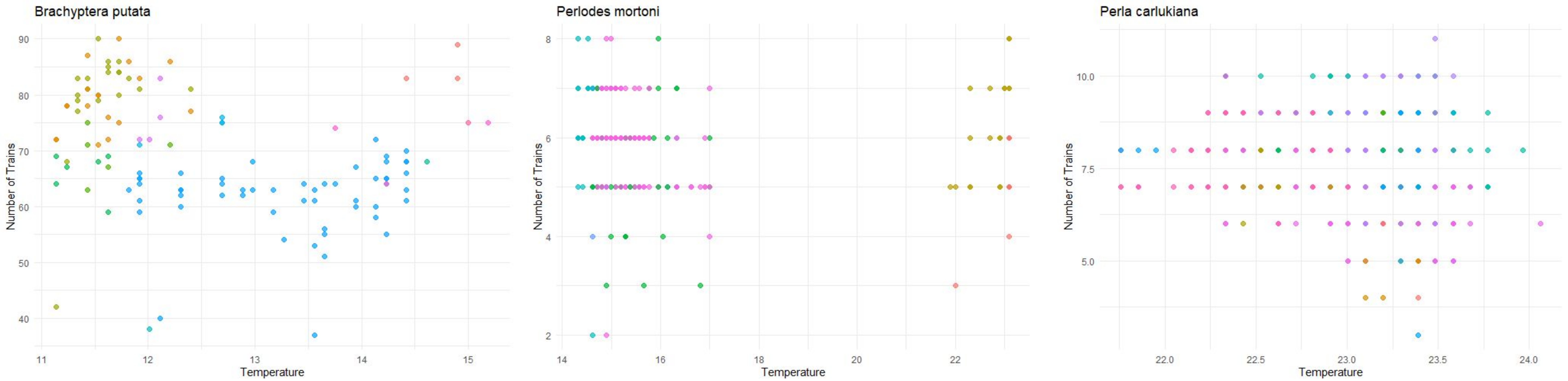
Figure 8: Effect of temperature on number of trains per drumming event for each species. Each colour represents a unique stonefly individual. Also shown are results of generalised linear models with negative binomial errors modelling the effect of temperature and time of day on number of trains with a random intercept for stonefly ID to account for potential heterogeneity among individuals.

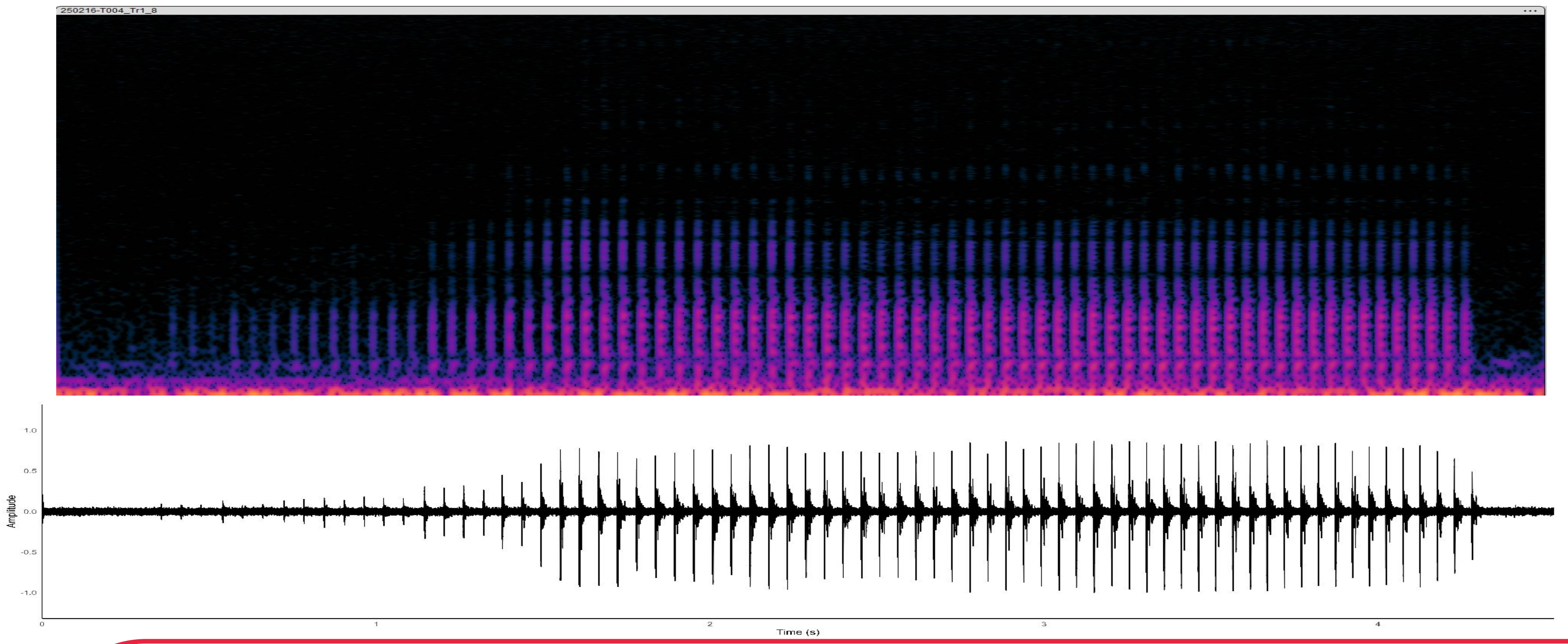


Predictor	Estimate	Std. Error	z value	p value
(Intercept)	37.43	21.25	1.76	0.08
Temperature	2.59	1.66	1.56	0.12
Time (Sin)	-27.58	14.37	-1.92	0.05
Time (Cos)	4.06	16.61	0.24	0.81
Temperature:Time (Sin)	2.02	1.21	1.68	0.09
Temperature:Time (Cos)	-0.25	1.36	-0.18	0.86

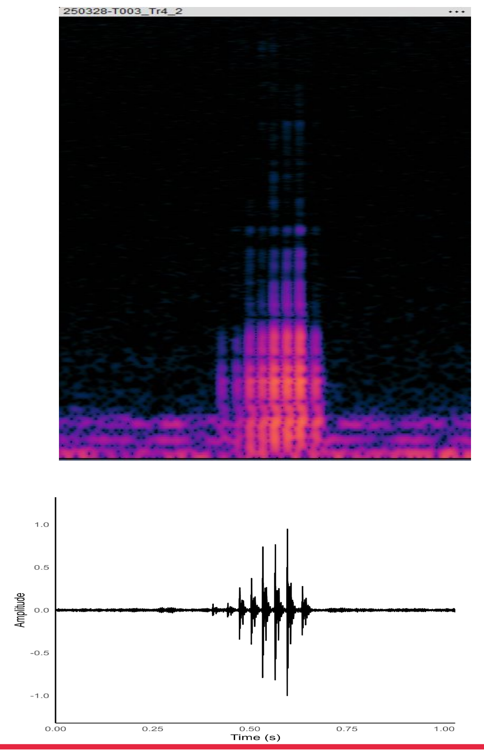
Predictor	Estimate	Std. Error	z value	p value
(Intercept)	7.08	0.99	7.18	<0.001**
Temperature	-0.09	0.06	-1.55	0.12
Time (Sin)	-0.78	0.85	-0.92	0.36
Time (Cos)	-2.31	0.84	-2.76	0.006*
Temperature:Time (Sin)	0.04	0.05	0.75	0.46
Temperature:Time (Cos)	0.16	0.05	3.04	0.002*

Predictor	Estimate	Std. Error	z value	p value
(Intercept)	-12.94	5.25	-2.46	0.01
Temperature	**0.87**	**0.23**	**3.83**	**<0.001****
Time (Sin)	-18.45	3.68	-5.02	<0.001**
Time (Cos)	-31.27	3.69	-8.47	<0.001**
Temperature:Time (Sin)	0.77	0.16	4.90	<0.001**
Temperature:Time (Cos)	1.35	0.16	8.60	<0.001**

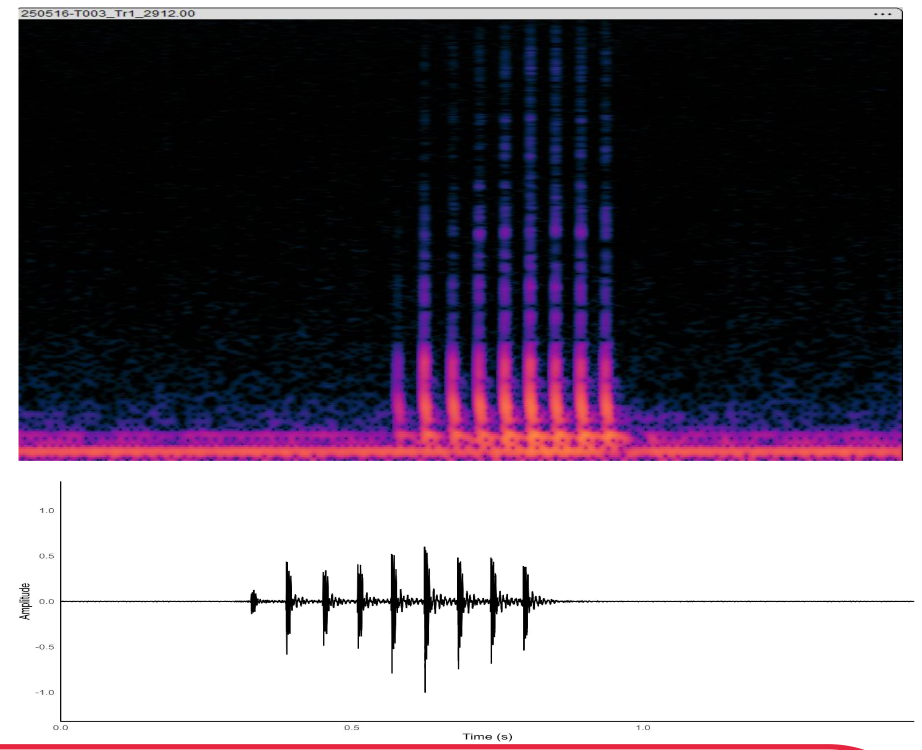
Brachyptera putata



Perlodes mortoni



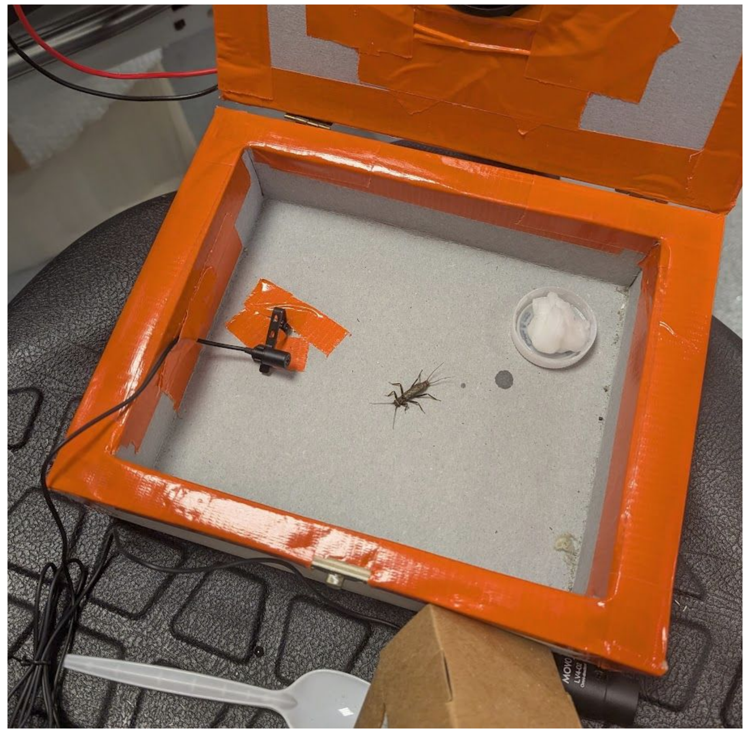
Perla carlukiana

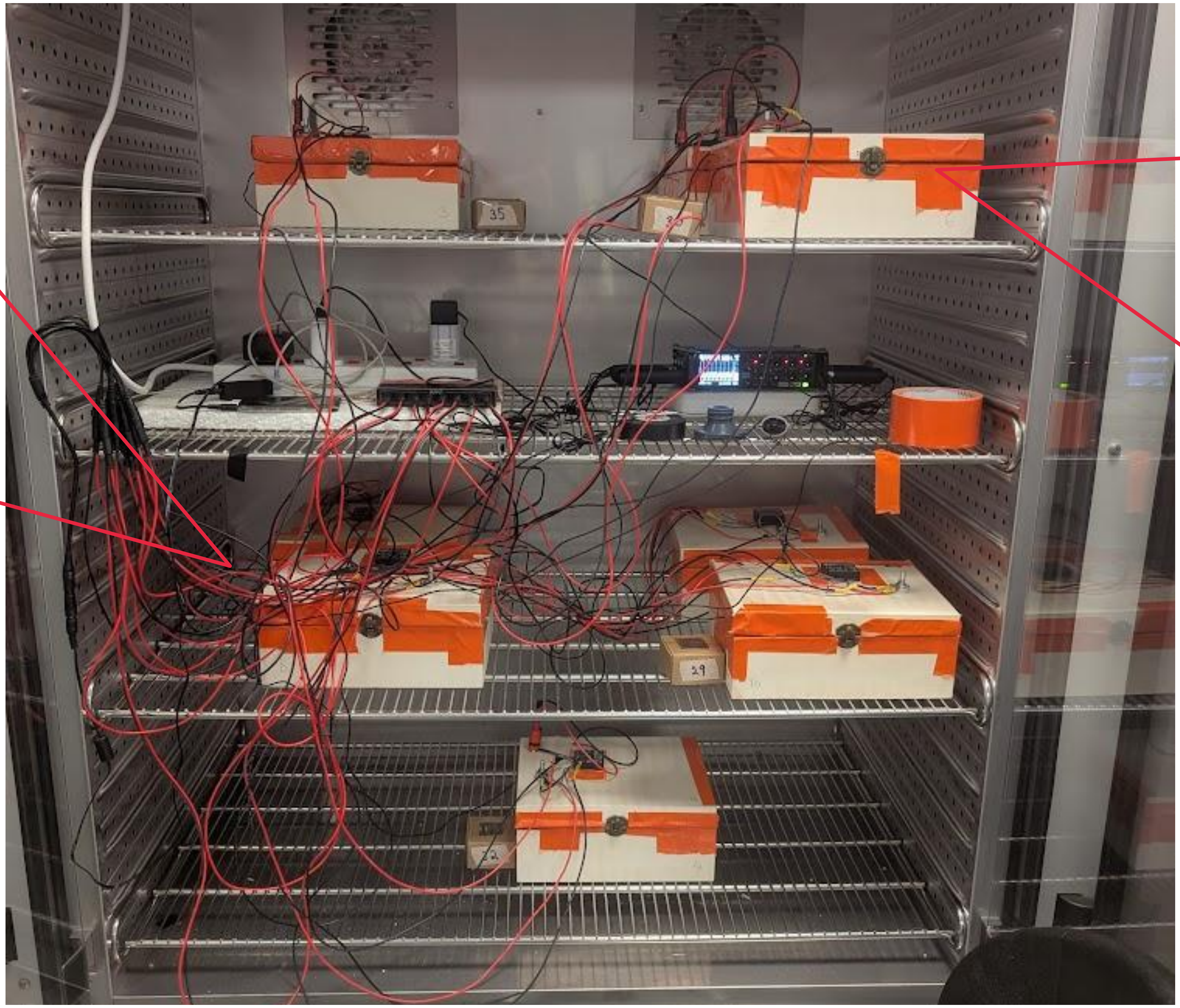


CONCLUSIONS

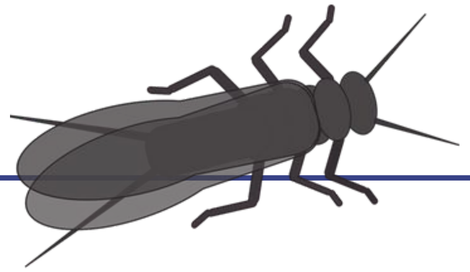
- Rather than a trade-off, there is a positive correlation between train rate and number of trains.
- Train rate significantly affected by time of day and especially temperature.
- If calls with higher train rate and number of trains have a higher cost in terms of effort, but signal a higher fitness to females, then results indicate that stoneflies are investing in more attractive calls at optimal temperatures and time of day.
- Could also be a trade-off between how costly the structure of the call is versus how often each species calls.
- Need to test these assumptions by finding out if females prefer calls with higher train rate, higher number of trains, or both.

PLAYBACK
Females placed in a BEATBOX and played recordings of male drumming from the same species to test if they respond to playbacks of male calls.

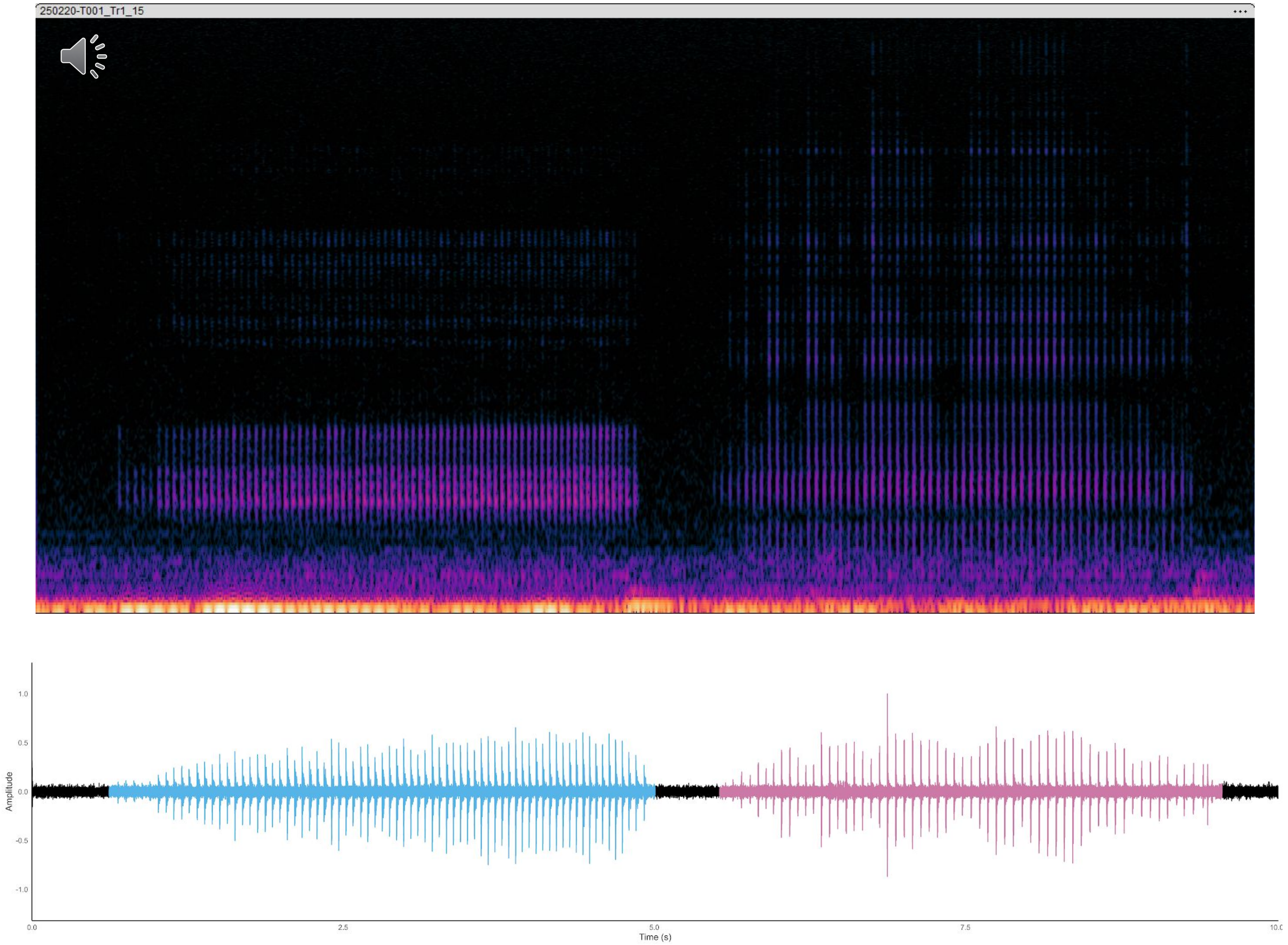




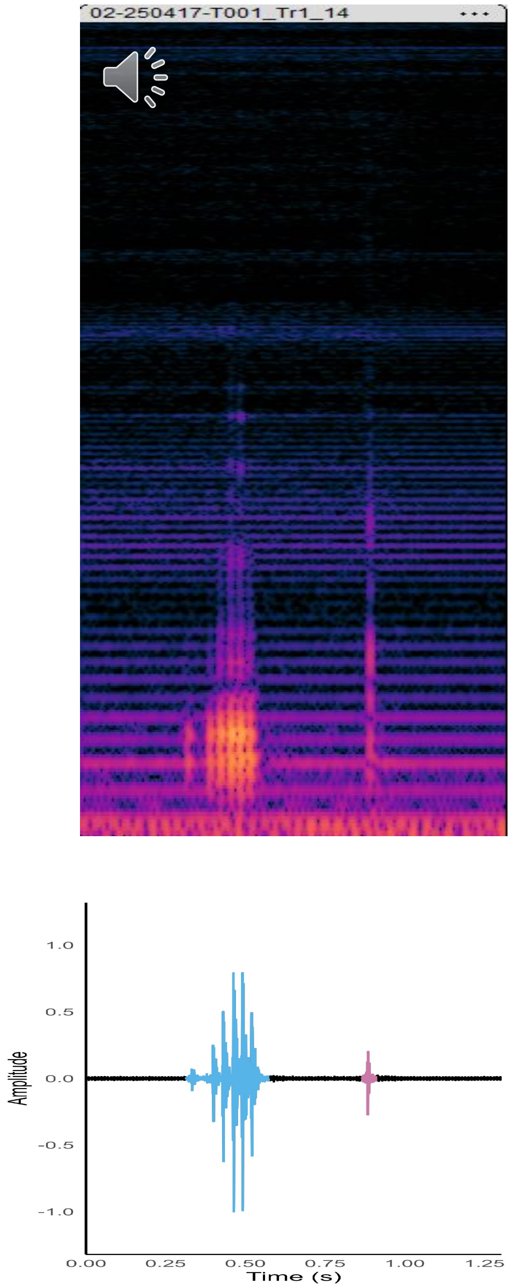
LIVE MALES
A cardboard box containing a female and one containing a conspecific male were placed in a BEATBOX and recorded for an hour.



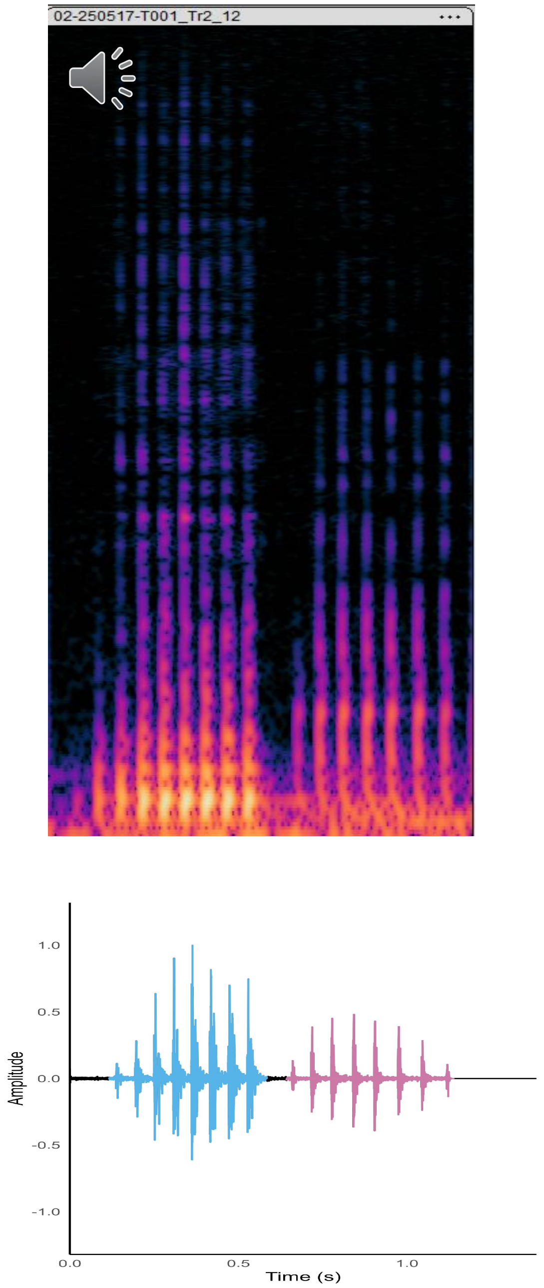
Brachyptera putata

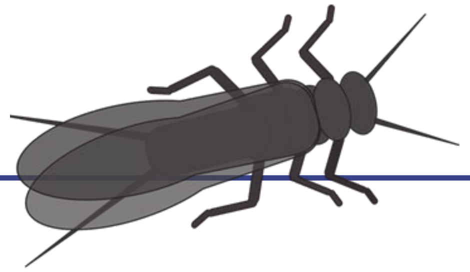


Perlodes mortoni

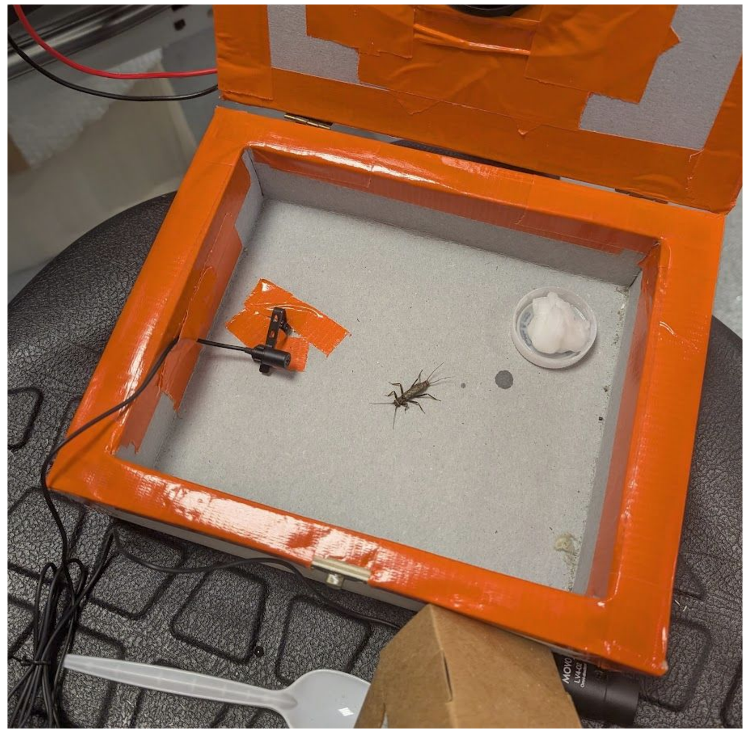


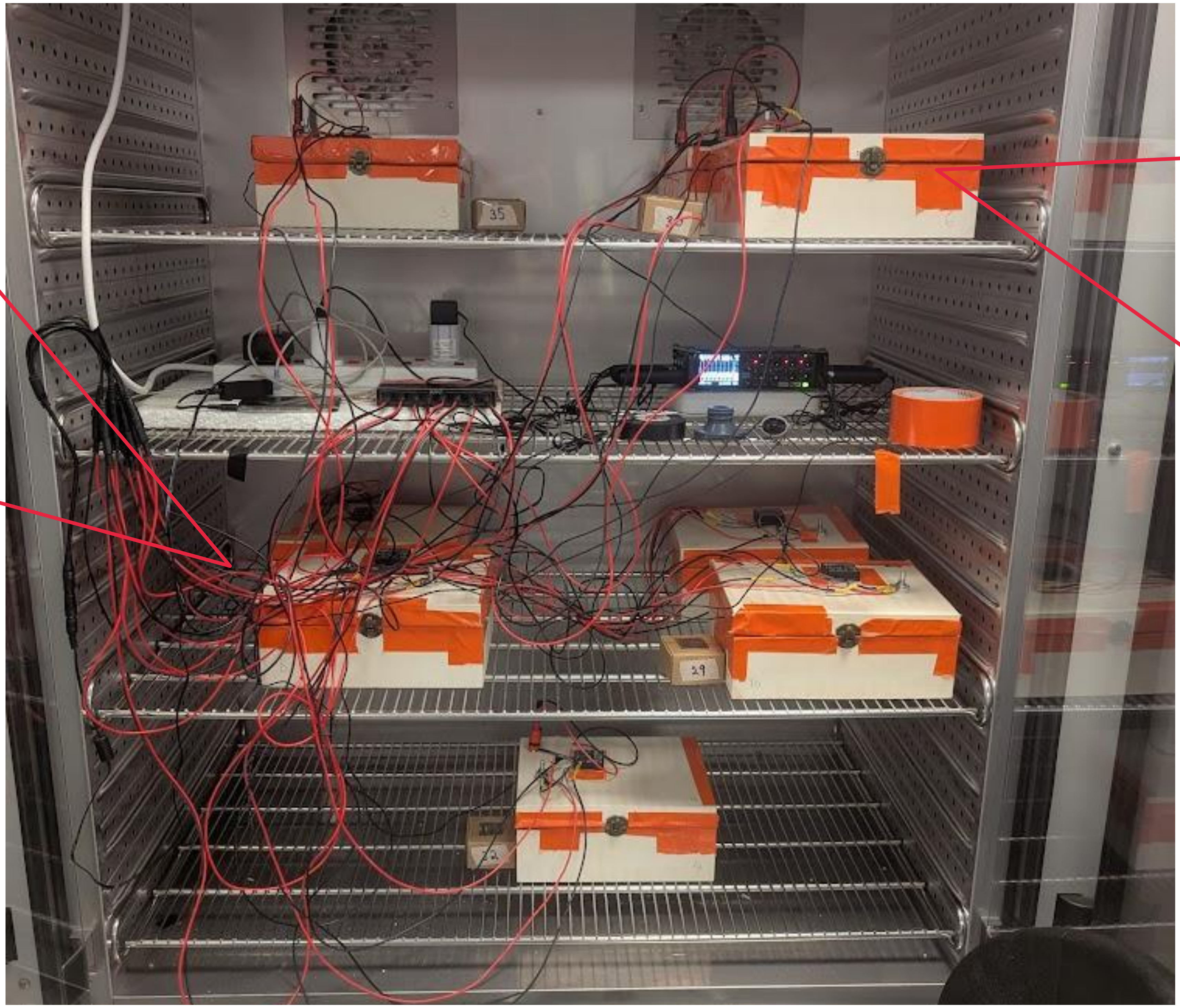
Perla carlukiana





PLAYBACK
Females placed in a BEATBOX and played recordings of male drumming from the same species to test if they respond to playbacks of male calls.





LIVE MALES
A cardboard box containing a female and one containing a conspecific male were placed in a BEATBOX and recorded for an hour.

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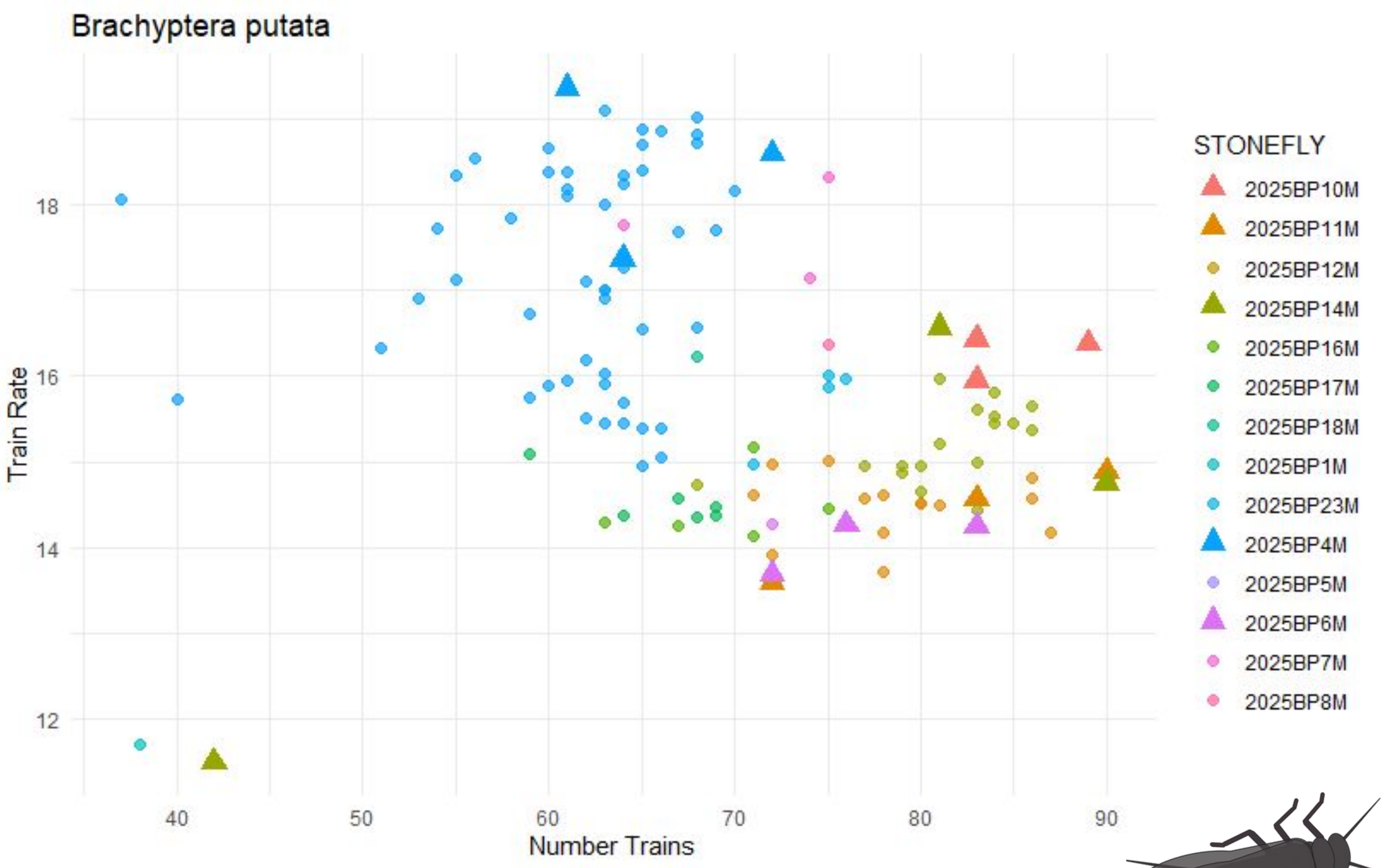
Figure 9: Relationship between number of trains per drumming event and train rate for *Brachyptera putata* males. Each colour represents a unique stonefly individual. Triangles represent the male drumming events played to females.

PLAYBACK
Females placed in a BEATBOX and played recordings of male drumming from the same species to test if they respond to playbacks of male calls.

Tested how train rate and train number affected female response.

Selected three calls from five individuals for each species to encompass a range of train numbers and train rates.



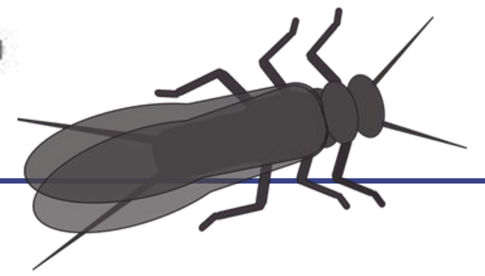
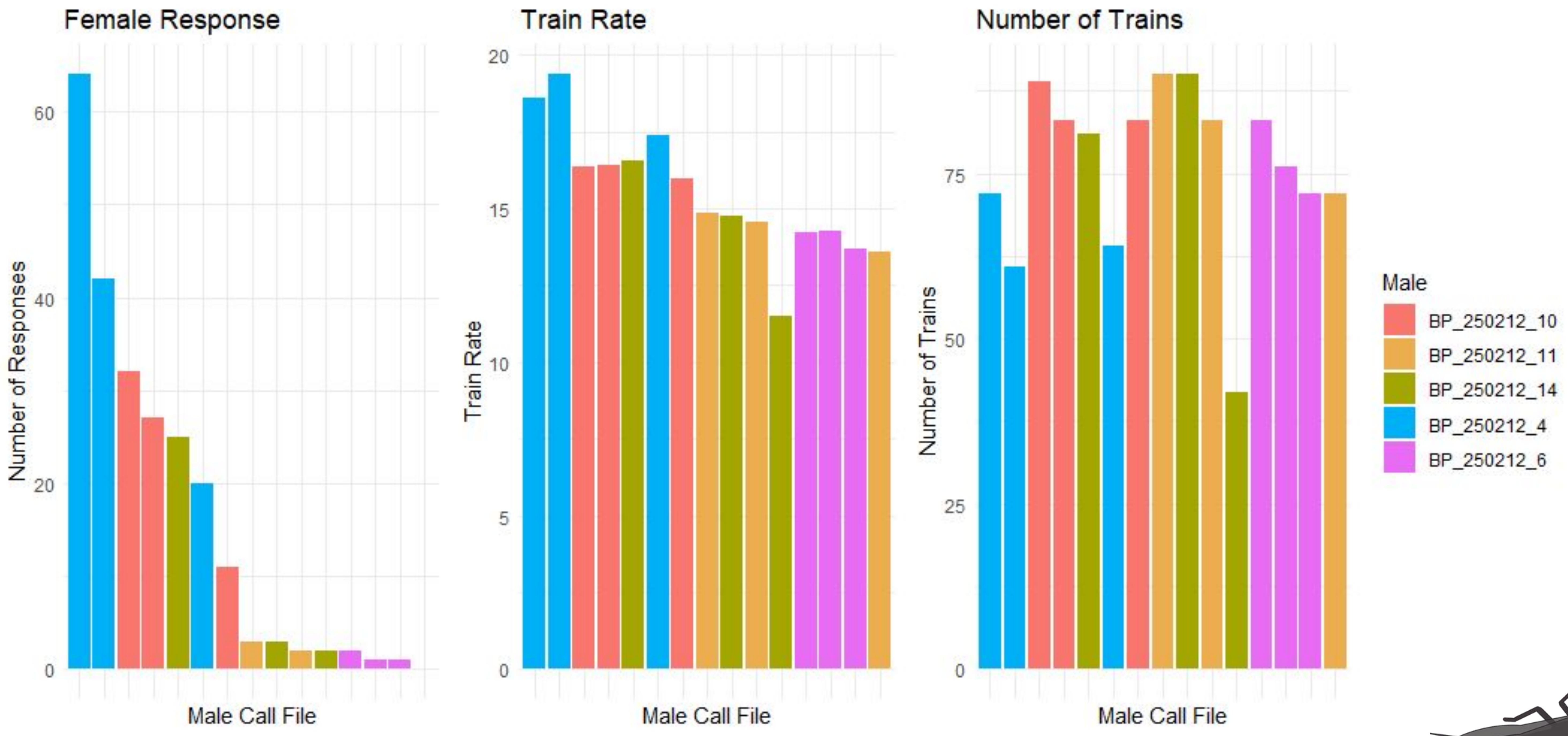
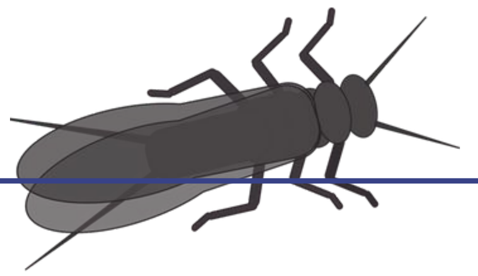


Figure 10: Number of *Brachyptera putata* female responses to three recording of male drumming from five different males (each colour represents a different male). Also shown is the train rate and number of trains for each male drumming event.





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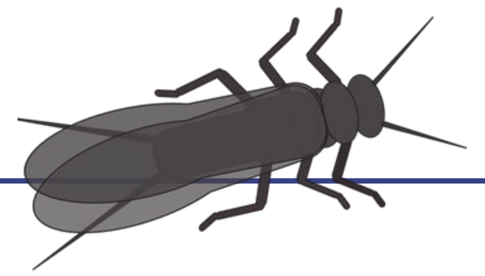
Next steps

- Describe the structure of female drumming response for all three species.
- More detailed analysis of male drumming.
- Playback experiments with *Perlodes mortoni* and *Perla carlukiana* females to test how call structure affects female response to males of both species.
  - Will play three drumming events from five individuals from both species to test how response to both heterospecifics and conspecifics is affected by train rate, number of trains, and temperature.
- First investigation of the effect of noise pollution from road traffic on stonefly male drumming calls and female response.



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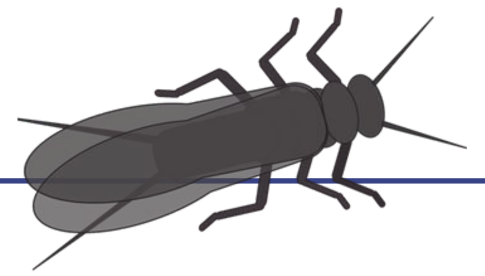
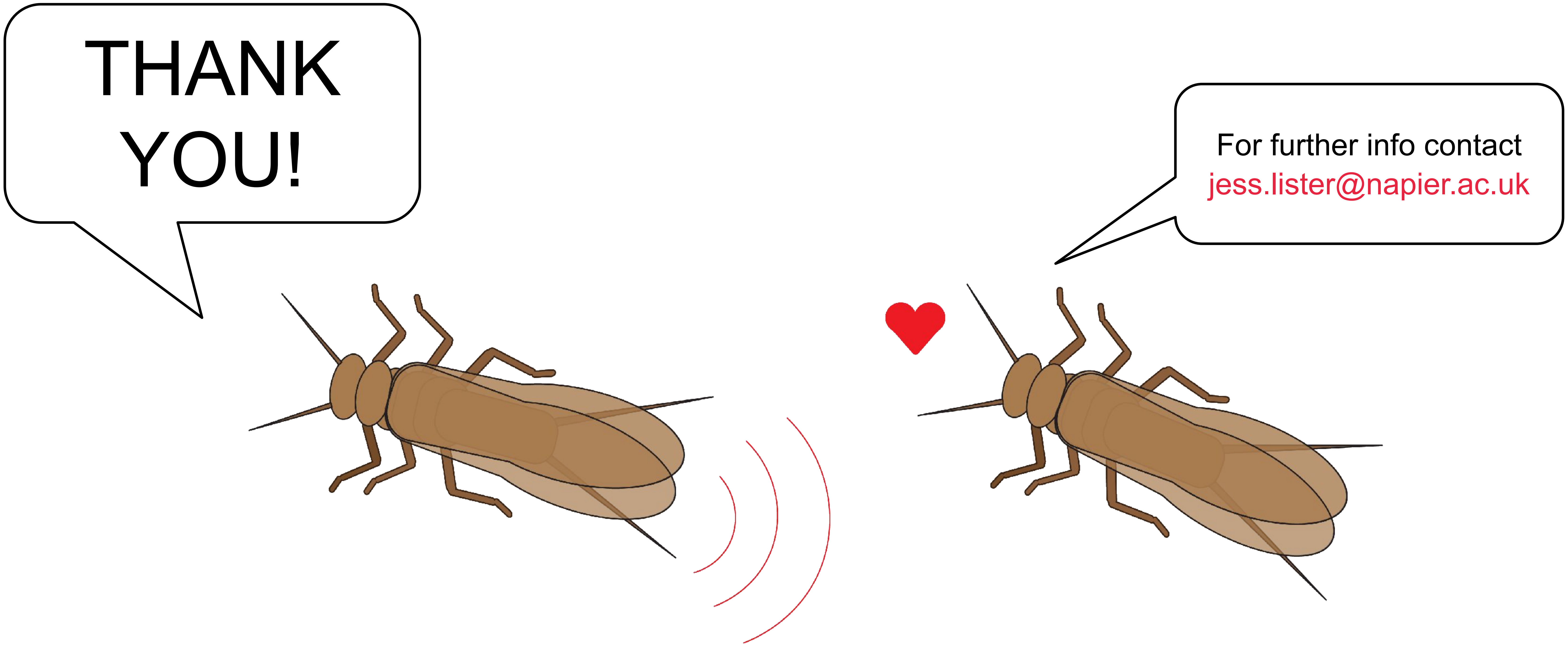
Conclusion

- Substrate-borne vibrations for a vital component of stonefly mating behaviour, but their study has been limited by cost and technical barriers.
- The BEATBOX provides a **cheap, standardised, portable, and effective method** for recording and playback of stonefly drumming.
- With it, I’ve been able to capture the drumming signals of all three British endemic species.
- There are limitations of this methodology, but it makes vibrational communication research more accessible, hopefully enabling further research in this field.




THANK YOU!
For further info contact
jess.lister@napier.ac.uk