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# ACOUSTIC MONITORING OF FOREST PESTS *HYLURGUS LIGNIPERDA* FABRICIUS AND BUPRESTIDAE IN *PINUS THUNBERGII* PARL.

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**Abstract:** This study aims to investigate the feasibility of acoustic monitoring for distinguishing species and behavioral activities of wood-boring pests, specifically the bark beetle *Hylurgus ligniperda* Fabricius and jewel beetles (Buprestidae), to provide technical support for early non-destructive monitoring of cryptic pests. Under controlled conditions (temperature 25 ± 1°C, humidity 45 ± 5%), acoustic signals generated during feeding and crawling activities of the two pests on the bark of Japanese black pine (*Pinus thunbergii* Parl.) were collected using self-made soundproof equipment and an acoustic acquisition system. Parameters including pulse count, peak amplitude (dB), and peak frequency (Hz) were extracted through acoustic processing software and statistically compared via one-way ANOVA. Results showed significant differences in acoustic parameters between *H. ligniperda* and Buprestidae during feeding ($p < 0.001$). *H. ligniperda* exhibited higher pulse count (27.00 ± 22.31), peak amplitude (-37.34 ± 3.40 dB), and peak frequency (3208.25 ± 783.62 Hz) compared to Buprestidae (pulse count 2.25 ± 2.20; peak amplitude -25.11 ± 4.73 dB; peak frequency 1291.40 ± 1154.58 Hz). Significant differences were also observed between feeding and crawling behaviors of *H. ligniperda* ($p < 0.01$): feeding yielded fewer pulses (27.00 ± 22.31) but higher peak frequency (3208.25 ± 783.62 Hz), while crawling produced more pulses (91.75 ± 29.66) and higher amplitude (-31.59 ± 5.58 dB). Acoustic parameters effectively distinguished both species and their behavioral patterns, confirming the potential of acoustic monitoring for early detection of wood-boring pests. Further field validation is required to enhance practical applicability.
**Keywords:** Acoustic monitoring; Wood-boring pests; Bark beetle; Buprestidae; Acoustic parameters

## 1 INTRODUCTION

Bark beetles and jewel beetles are two common groups of wood-boring forest pests. Both adults and larvae bore into host plants, facilitate dispersal through timber transportation, and hold significant economic importance. Their infestations are often cryptic and difficult to detect at early stages. *Hylurgus ligniperda* Fabricius, recently identified as an invasive species in Shandong, China, infests *Pinus thunbergii* Parl. [1–2]. When *H. ligniperda* and Buprestidae co-infest *P. thunbergii*, distinguishing the causative pest is challenging, complicating monitoring efforts [3–4].

Current techniques for early pest detection include image recognition, acoustic signal analysis, odor sensing, and near-infrared spectroscopy [5–8]. Among these, acoustic monitoring employs sensors to amplify and filter sounds produced by pest activities, enabling non-destructive, real-time detection. Unlike other methods, acoustic analysis identifies unique features of target sounds—such as time-domain and frequency-domain characteristics—distinguishing them from environmental noise or other pests [9–11].

This study focuses on analyzing acoustic features of *H. ligniperda* and Buprestidae to explore the application of acoustic methods in monitoring and identifying these two pest groups. The findings aim to support early detection of *H. ligniperda* invasions and provide a basis for acoustic-based pest surveillance.

## 2 MATERIALS AND METHODS

### 2.1 Materials

The insects used in the experiment were the invasive alien pest *H. ligniperda* and a native wood-boring pest, Buprestidae. All test insects were collected from infested areas in Shandong Province, China. Following collection, they were reared and studied under laboratory conditions maintained at a temperature of 25 ± 1°C and relative humidity of 45 ± 5%. The rearing substrate consisted of host materials, namely wood segments or bark from *P. thunbergii* Parl.

The equipment used was an insect acoustic monitoring device independently developed by the laboratory. Acoustic recordings were made using a SONY ICD-PX470 digital voice recorder. During monitoring and recording, a soundproof box was employed to absorb external vibrations and noise, thereby preventing their capture by the monitoring equipment.

### 2.2 Acoustic Acquisition Method

The test insects were grouped according to different quantities and placed in plastic boxes containing bark from the host plant, *Pinus thunbergii* Parl., for rearing. Acoustic monitoring commenced after at least 12 hours of acclimatization.

Prior to monitoring the insects, a blank recording was made to serve as a control for noise cancellation during subsequent analysis. For monitoring, the rearing box containing insects was placed inside the soundproof box and allowed to stabilize for 10 minutes before recording began (Figure 1). Each recording of insect acoustic signals lasted for at least 5 minutes to ensure the reliability and validity of the experimental results.

**Figure 1** Rearing Setup within the Plastic Box

### 2.3 Insect Sound Extraction

The insect acoustic files in WAV format were imported into acoustic processing software. The collected acoustic waves were then analyzed and processed using this software to extract valid insect acoustic signals.

### 2.4 Insect Acoustic Parameter Extraction

Each biological acoustic signal of the insects is a collection of pulses, and the process of analyzing the pulse signals constitutes a time-domain analysis. Based on the filtered waveform graphs, the total pulse counts of the acoustic waves generated by *H. ligniperda* and Buprestidae during their activities in the bark were statistically analyzed to examine the differences in the number of sound emissions during their activities. The duration of each pulse was measured, reflecting the length of time the pests emitted sound per event. Using the software, waveform statistical analysis was performed on the filtered recordings to read the peak amplitude of the insect sounds, analyzing the difference in the maximum loudness of the activity sounds between *H. ligniperda* and Buprestidae.

Frequency represents the intensity of an event occurring within a specific time frame, and the process of analyzing frequency-related parameters constitutes a frequency-domain analysis. The recordings were subjected to Fast Fourier Transform (FFT) using the software. Spectrograms were plotted with time (s) as the x-axis and frequency (Hz) as the y-axis to analyze the variation patterns of the sound frequency. Using the software's spectrum analyzer, power spectrum graphs were plotted with frequency (Hz) as the x-axis and amplitude (dB) as the y-axis. The peak frequency was analyzed and statistically determined to examine the difference in the highest frequency of the activity sounds between *H. ligniperda* and Buprestidae.

### 2.5 Statistical Analysis

The acoustic parameters were subjected to one-way analysis of variance (One-way ANOVA) using statistical analysis software [12].

## 3 RESULTS AND ANALYSIS

### 3.1 Comparative Analysis of Insect Activity Acoustic Graphs

The recorded acoustic waves were filtered using the sound processing software Cool Edit PRO to compare differences in the waveform graphs. Visual comparison of the filtered sound waveform graphs (Figure 2) and the single-pulse waveform graphs (Figure 3) allowed for intuitive observation of differences in acoustic characteristics among different insects and different behaviors.

Comparing the crawling behavior (Figure 2A) with the feeding behavior (Figure 2B) within the same species (*H. ligniperda*), the crawling waveform exhibited a higher amplitude, suggesting that feeding activities might produce stronger acoustic signals. Between the two species, the waveform of *H. ligniperda* during feeding (Figure 2B) showed lower amplitude and sparse pulse distribution, whereas the waveform graph of Buprestidae feeding (Figure 2C) displayed higher amplitude and dense pulses.

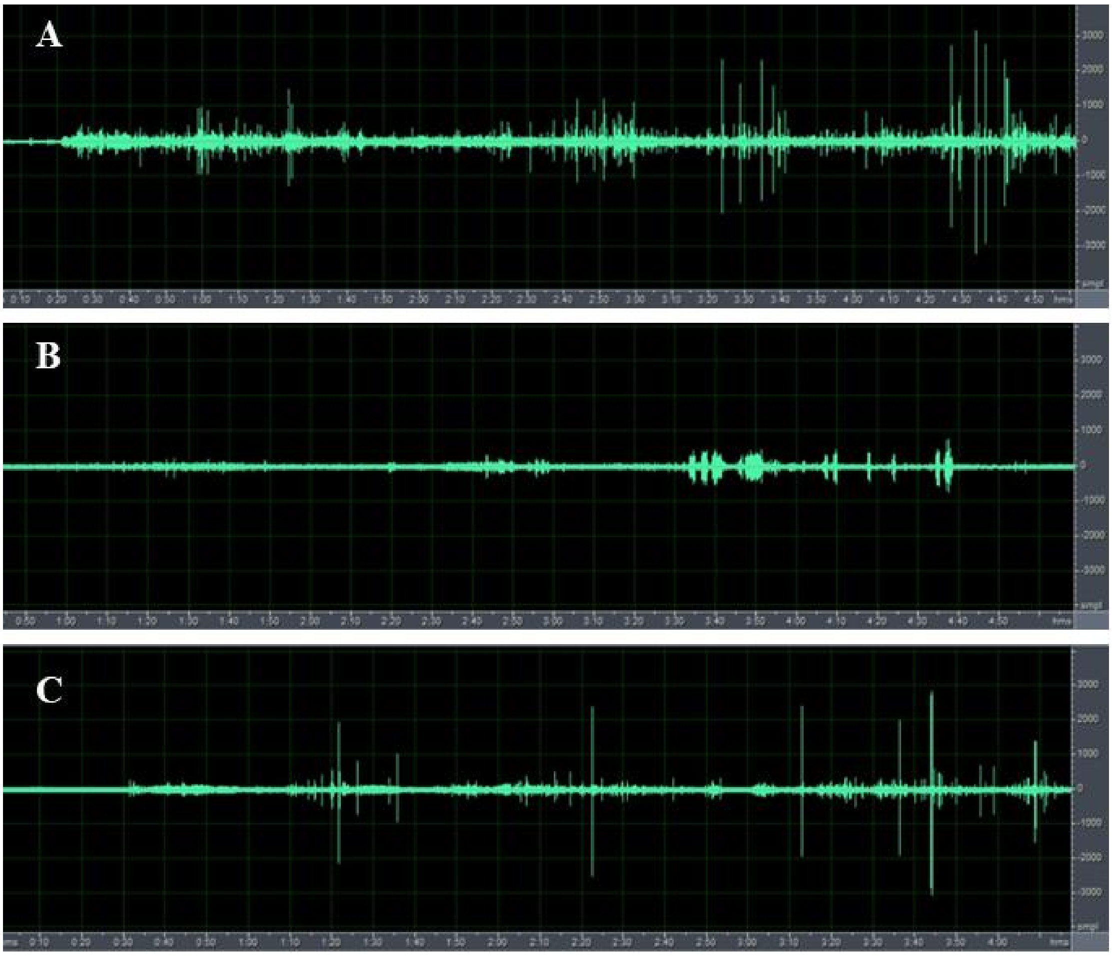


**Figure 2** Waveform Graphs of Feeding and Crawling Activities of *Hylurgus ligniperda* and Buprestidae (A. Waveform of *Hylurgus ligniperda* crawling; B. Waveform of *Hylurgus ligniperda* feeding; C. Waveform of Buprestidae feeding)

The single-pulse waveform graphs (Figure 3) revealed that the single pulse associated with crawling behavior (Figure 3A) exhibited a multi-peak pattern, potentially correlated with the multi-stage nature of limb movement. The single pulse of *H. ligniperda* during feeding (Figure 3B) was characterized by a shorter duration and a relatively smooth amplitude, whereas the single pulse of Buprestidae during feeding (Figure 3C) showed a longer duration and a prominent amplitude peak. These graphical differences provided a visual basis for the subsequent quantitative parameter analysis.

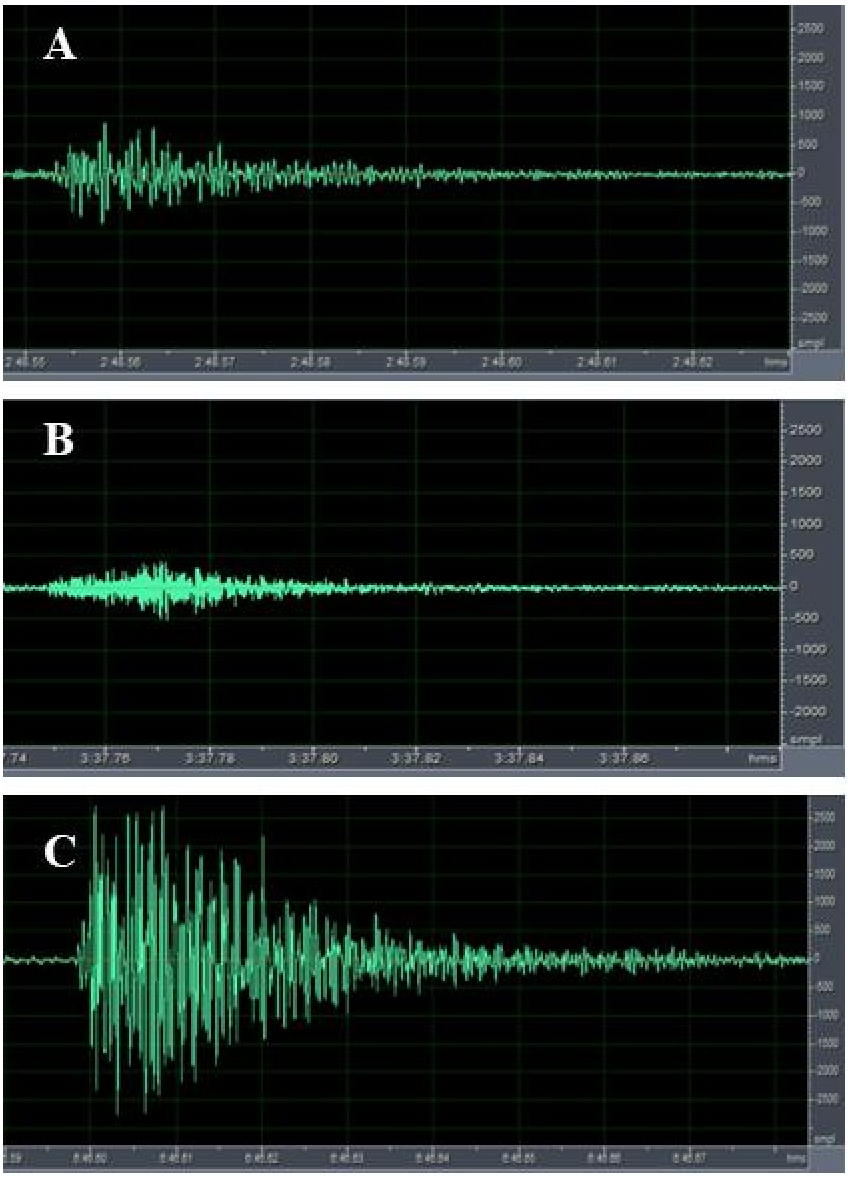


**Figure 3** Single-pulse Waveform Graphs of Feeding and Crawling Activities of *Hylurgus ligniperda* and Buprestidae (A. Single-pulse waveform of *Hylurgus ligniperda* crawling; B. Single-pulse waveform of *Hylurgus ligniperda* feeding; C. Single-pulse waveform of Buprestidae feeding)

### 3.2 Comparison of Acoustic Parameters between Two Insect Species During Feeding

Statistical analysis was performed on the acoustic parameters of feeding sounds produced by *H. ligniperda* and Buprestidae (Table 1). Analysis based on species revealed significant differences ($P < 0.05$) between *H. ligniperda* and Buprestidae in the number of pulses ($F(1,38) = 24.38$, $p < .001$), peak amplitude of insect sounds ($F(1,38) = 88.07$, $p < .001$), and peak frequency ($F(1,38) = 21.15$, $p < .001$). During feeding, the pulse count of *H. ligniperda* was significantly higher than that of Buprestidae (approximately 12 times greater), indicating more frequent or continuous feeding activity by *H. ligniperda*. The peak amplitude of *H. ligniperda* was lower (a more negative dB value indicates higher relative sound intensity), suggesting that its feeding sounds were more intense. The peak frequency was higher, reflecting that its acoustic signals were concentrated in a higher frequency range. This combination of parameters can effectively distinguish between the two pest species; for instance, signals with a pulse count >20 and a peak frequency >3000 Hz are more likely to originate from *H. ligniperda*. Figure 4 intuitively displays the intergroup differences in the three parameters through bar charts, further validating the visual consistency of the statistical results.

**Table 1** Comparison of Feeding Acoustic Parameters between the Two Insect Species

| Experimental specimen | Number of pulses | Peak of insect sounds (dB) | Peak of frequency (Hz) |
|---|---|---|---|
| *Hylurgus ligniperda* | 27.00+22.31 | -37.34+3.40 | 3208.25+783.62 |
| Buprestidae | 2.25+2.20 | -25.11+4.73 | 1291.40+1154.58 |

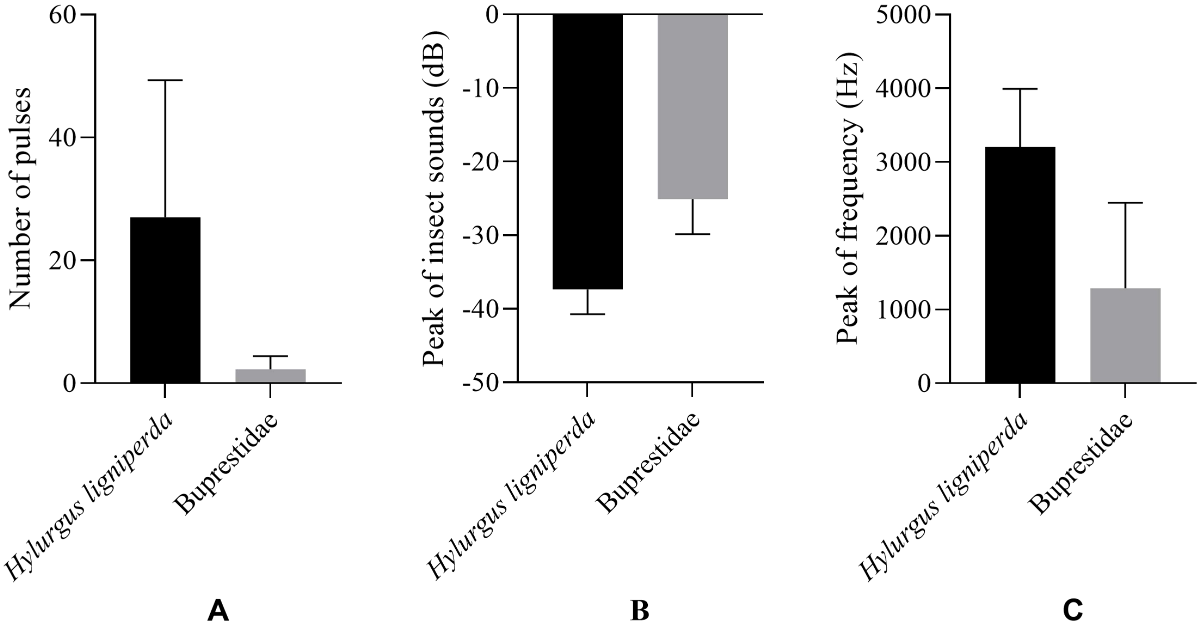


**Figure 4** Difference of Sound Parameters Produced by the Feeding of *Hylurgus Ligniperda* and Buprestidae

### 3.3 Comparison of Acoustic Parameters between Feeding and Crawling Activities in *Hylurgus ligniperda*

Statistical analysis was performed on the acoustic parameters of feeding and crawling activities produced by *H. ligniperda*(Table 2). Analysis based on different behaviors revealed significant differences ($P < 0.05$) between feeding and crawling activities in the number of pulses ($F(1,38) = 60.88$, $p < .001$), peak amplitude ($F(1,38) = 15.52$, $p < .001$), and peak frequency ($F(1,38) = 9.89$, $p < 0.01$). For *H. ligniperda*, the number of acoustic pulses during Feeding was significantly lower than during Crawling within the same time frame. Feeding also exhibited a lower peak amplitude but a significantly higher peak frequency compared to Crawling. Further analysis indicated that the pulse count of crawling behavior was substantially higher than that of feeding (approximately 3.4 times greater), which may be attributed to the continuous limb movements during crawling generating more acoustic events. In contrast, feeding was characterized by a lower peak amplitude and a higher peak frequency, suggesting that the interaction between mouthparts and wood during feeding produces acoustic signals of lower intensity but higher frequency. This distinction aids in differentiating the types of pest activities during monitoring; for instance, high-frequency signals (>3000 Hz) might preferentially indicate feeding behavior. Figure 5 emphasizes the stability of the differences between behaviors by comparing the parameter distributions of feeding and crawling, providing a basis for behavioral identification.

**Table 2** Comparison of Acoustic Parameters between Feeding and Crawling Activities in *Hylurgus Ligniperda*

| Experimental specimen | Number of pulses | Peak of insect sounds (dB) | Peak of frequency (Hz) |
|---|---|---|---|
| Feeding | 27.00+22.31 | -37.34+3.40 | 3208.25+783.62 |
| Crawling | 91.75+29.66 | -31.59+5.58 | 2451.306+738.64 |

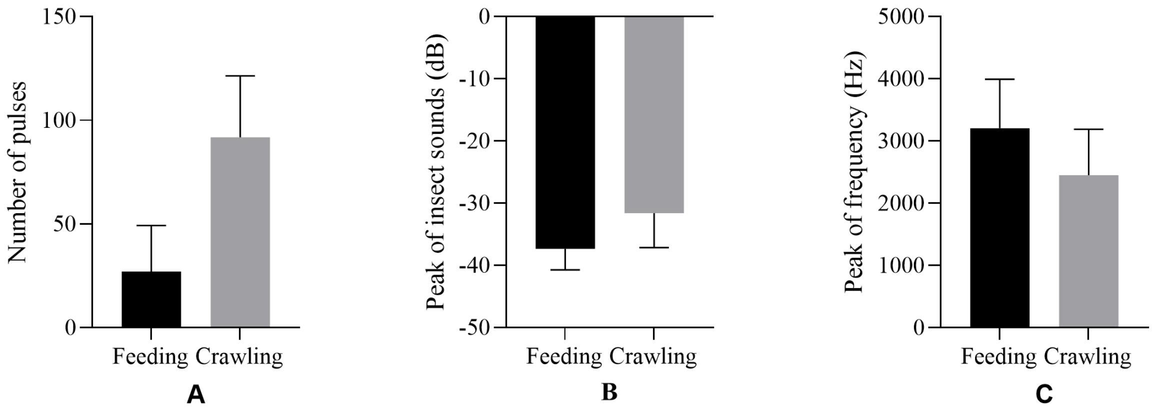

**Figure 5** Difference of Sound Parameters Produced by the Feeding and Crawling of *Hylurgus ligniperda*

## 4 CONCLUSIONS AND DISCUSSION

*H. ligniperda* and Buprestidae cause severe damage to trees. Their harmful activities are concealed beneath the bark, posing significant challenges for monitoring infested trees. Acoustic monitoring offers a non-destructive method to detect these hidden pests; however, related research on applying acoustic methods for their monitoring remains limited. Therefore, this study utilized self-developed soundproof equipment and a custom insect acoustic monitoring device to investigate the acoustic waves generated by *H. ligniperda* and Buprestidae during feeding and movement activities in the bark. The results demonstrate that the number of pulses, peak amplitude, and peak frequency of the acoustic parameters during feeding can distinguish between the two insect species. Furthermore, these acoustic parameters (number of pulses, peak amplitude, peak frequency) can also differentiate between feeding and crawling behaviors within *H. ligniperda*. The significantly higher acoustic parameter values observed in *H. ligniperda* compared to Buprestidae may be related to its stronger feeding intensity or differences in mouthpart structure (e.g., higher drilling efficiency typical of bark beetles). The parameter differences between behaviors reflect distinct physiological mechanisms between feeding (characterized by higher frequency and intensity) and crawling (characterized by high pulse count but lower intensity), which is consistent with the findings of Fleurat-Lessard et al. regarding the correlation between insect behaviors and acoustic signals [10].

This study confirms the significant potential of acoustic monitoring methods for the early detection and monitoring of different wood-boring pests (bark beetles and Buprestidae) and their different activities (feeding and crawling), providing data support for subsequent research and application of acoustic monitoring for various forest pests. A current limitation is that the experiments were conducted under controlled laboratory conditions; environmental noise in field settings may affect parameter accuracy, necessitating further field validation.

Acoustic monitoring is a method based on receiving and identifying the acoustic signals generated by pest feeding and movement. The analysis of acoustic parameters can provide valuable information about insect behavioral characteristics, enabling early pest detection and identification through acoustic monitoring. In the future, with the development of more sensitive acoustic sensors and intelligent acoustic analysis methods, non-destructive monitoring and identification of different hidden insect species and their various activities could be achieved not only in trees but also in other hosts such as stored grains and fruits [13-15].

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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