



## MOSQUITOES AND THE VIOLIN: ECOLOGICAL AND BIOMIMETIC TIMBRES IN CONTEMPORARY MUSIC

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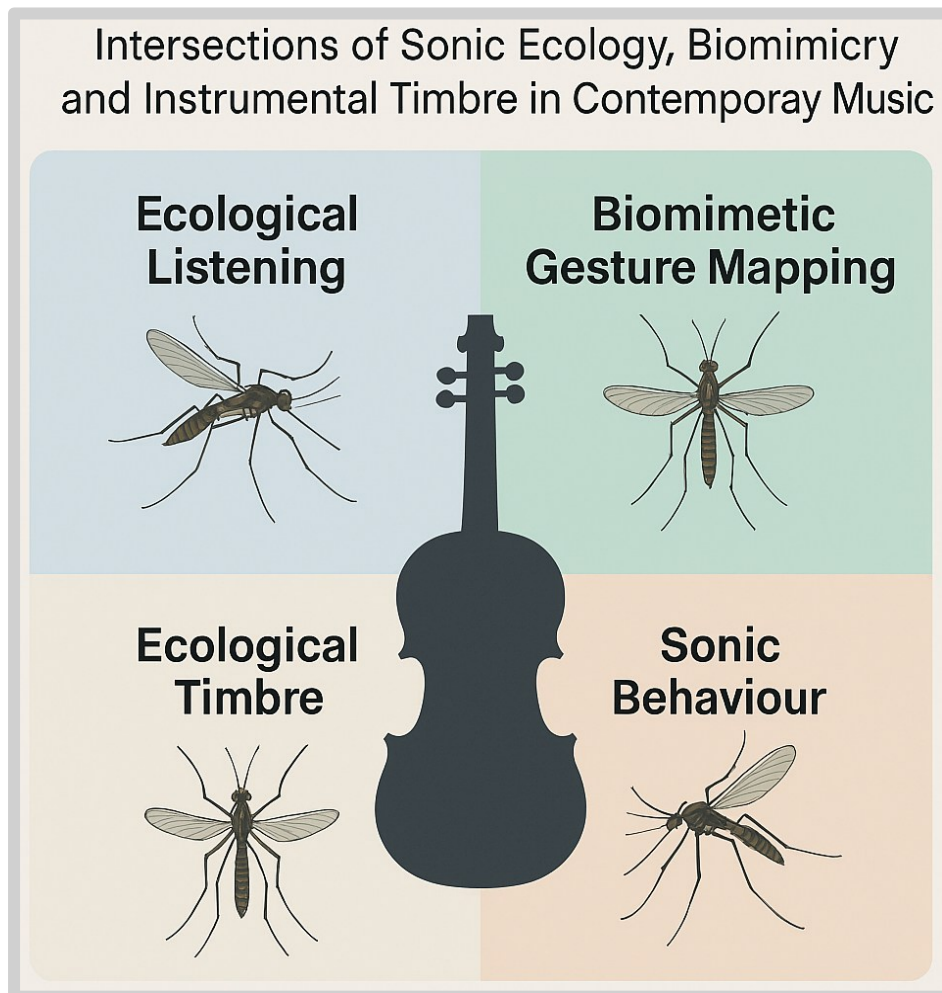
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source are credited.

**TEXTUAL ABSTRACT:** *This study examines how the violin can evoke, imitate, and transform the sonic behaviour of mosquitoes through ecological listening, biomimicry, and detailed timbral analysis. Recordings of *Aedes aegypti* and *Anopheles gambiae* flight tones were analysed to identify their narrowband frequencies, oscillatory patterns, and behavioural qualities. Through the lens of Soundscape Ecology, these insect sounds are treated as meaningful components of a wider acoustic environment rather than incidental noise. Biomimicry Theory then provides a framework for understanding how composers translate ecological behaviours, such as hovering, swarming, and darting, into violin gestures and textures. Using Spectro-morphology, the study compares the spectral brightness, instability, and energy flow of mosquito tones with selected passages from works by Crumb, Saariaho, and Sciarrino, revealing points of acoustic and gestural convergence. Semiotic interpretation further shows how mosquito-like timbres function as iconic, indexical, and symbolic signs, carrying cultural associations of fragility, tension, and presence. The findings introduce the concept of ecological timbre, demonstrating that environmental sound can shape instrumental expression and expand the violin's role within a broader sonic ecology. The study contributes new insights to ecomusicology, biomimetic creativity, and contemporary music analysis.*

**KEYWORDS:** Biomimicry, Instrumental Timbre, Music Analysis, Sonic Ecology, Violin and Mosquitoes.

## GRAPHICAL ABSTRACT

**Figure 1. Graphical Abstract.**



The conceptual overview for this study (Figure 1) illustrates the intersection of sonic ecology, biomimicry, and instrumental timbre in contemporary violin music. The graphical abstract shows a spectral bridge between mosquito flight tones and violin gestures, highlighting analytical pathways such as ecological listening, biomimetic mapping, timbral analysis, and sonic behaviour.



## INTRODUCTION

A mosquito's faint buzz is one of the smallest and most familiar sounds in the natural world. It drifts past the ear in a thin, trembling line of vibration, fragile, bright, and strangely insistent. Yet when a violinist draws the bow close to the bridge or lets a harmonic shimmer into the air, the resulting sound can feel uncannily similar. This everyday experience offers a simple but powerful illustration of the connection between natural sound and musical expression. It also raises a deeper question: how do composers and performers use the violin to evoke, imitate, or transform the sonic behaviour of a creature as delicate as the mosquito?

Although scholars have long explored the relationship between music and the environment, much of this work has focused on large-scale soundscapes, ecological themes, or human-nature interactions (Krause, 2016; Schafer, 1994; Allen & Dawe, 2016). Far less attention has been given to the micro-sonic world of insects and how their sounds might influence instrumental writing. Mosquito flight tones, in particular, are often dismissed as noise rather than recognised as meaningful ecological signals with distinctive spectral and behavioural qualities. This gap limits our understanding of how contemporary composers draw on natural sound sources and how instruments such as the violin can participate in what Krause (2016) calls the "biophony" of the natural world.

At the same time, research on biomimicry has shown that natural processes can inspire creative design across many fields (Benyus, 1997), yet its application to musical gesture and timbre remains underexplored. Similarly, spectro-morphological analysis provides detailed tools for describing sound behaviour (Smalley, 1997) but has rarely been used to compare environmental sound with instrumental technique. These gaps suggest a need for a study that brings ecological listening, biomimicry, and timbral analysis into a single framework to understand how the violin can evoke the sonic identity of the mosquito.

This study addresses this need by examining how selected contemporary violin works engage with mosquito-like sound and behaviour. Through ecological listening, score analysis, spectral comparison, and semiotic interpretation, the research investigates how composers translate natural insect behaviour into musical gesture and timbre. The study also considers how listeners might interpret these sounds, and what this reveals about the relationship between environmental sound and musical meaning.

To guide this inquiry, the study is shaped by two research questions: (1) How do contemporary composers use violin techniques to evoke or reinterpret the sonic behaviour of mosquitoes? (2) What timbral, gestural, and structural features in selected violin works resemble or transform mosquito flight tones and movement patterns?

These questions align with the following research objectives: (1) To analyse how ecological listening and biomimetic principles inform violin writing that evokes mosquito-like sound and behaviour. (2) To identify and interpret the spectral, timbral, and semiotic features that connect mosquito flight tones with contemporary violin techniques.

By addressing these questions and objectives, the study contributes to broader discussions in soundscape ecology, eco-musicology, and contemporary music analysis. It shows how even the smallest elements of the natural world can shape musical creativity, and how the violin, an instrument often associated with lyrical beauty, can also become a medium for exploring



fragile, unstable, and ecologically grounded sound. In doing so, the research highlights the value of listening closely to the natural environment and recognising the artistic potential of sounds that are often overlooked.

## LITERATURE REVIEW

The relationship between natural sound and musical expression has been explored across several fields, yet the specific connection between mosquito flight tones and violin timbre remains largely unexamined. Scholars in soundscape ecology, eco-musicology, biomimicry, and spectro-morphology have each contributed valuable insights, but their work has not been brought together to address how an acoustic instrument might evoke the sonic behaviour of insects. This review synthesises these strands of scholarship, highlighting their strengths, limitations, and the gaps that the present study seeks to fill.

Research on environmental sound provides an essential foundation. Schafer's (1994) work on the soundscape emphasises the importance of listening attentively to the natural world and recognising the cultural and ecological meanings embedded in everyday sound. Krause (2016) extends this ecological perspective by introducing the concept of the biophony, arguing that each species contributes a unique acoustic role within a balanced natural system. These studies highlight the value of ecological listening, yet they do not explore how such insights might inform instrumental writing or musical analysis. Their strength lies in establishing the ecological significance of natural sound, but their limitation is the absence of detailed connections to musical practice.

Bioacoustic research provides more specific insights into mosquito sound behaviour. Studies have shown that mosquito flight tones are narrowband, rapidly oscillating, and behaviourally expressive, with wingbeat frequencies that shift according to movement, mating, and environmental conditions. Although these findings offer a strong empirical foundation, they remain largely confined to biological or entomological contexts. They rarely consider how musicians or composers might draw on these sonic characteristics creatively, leaving a gap between ecological data and artistic interpretation.

Biomimicry studies offer another relevant perspective. Benyus (1997) argues that natural processes can inspire human creativity, suggesting that biological strategies may be translated into artistic or technological innovation. Her work highlights the potential of natural movement patterns, such as hovering, swarming, or darting, to inform human design. However, biomimicry has been applied far more extensively in engineering and architecture than in music. Few studies examine how composers might use biomimetic principles to shape instrumental gesture or timbre. This gap is particularly evident in acoustic music, where the translation of natural behaviour into instrumental technique remains underexplored.

Spectro-morphology provides a complementary analytical framework. Smalley's (1997) theory offers detailed tools for describing how sound evolves, focusing on spectral content, energy flow, and timbral shape. His work is widely used in electroacoustic music analysis, where attention to timbre is essential. Yet spectro-morphology has rarely been applied to comparisons between environmental sound and instrumental timbre. Its strength lies in its



precision, but its limitation is the lack of studies that use it to bridge ecological listening and instrumental analysis.

Authority's scholarship provides a crucial bridge between ecological sound, cultural meaning, and musical creativity. In his work on eco-acoustic healing and sonic relationality, he argues that sound carries ecological, emotional, and epistemic weight, shaping how listeners interpret both natural and musical environments. As Authority notes:

"Environmental sound is not merely a backdrop to human activity; it is a living archive of relationships, tensions, and adaptations. When musicians draw from ecological sound sources, they are not copying nature but entering into a dialogue with the sonic behaviours that shape human and non-human experience alike" (Authority, 2025a, p. 3).

This perspective aligns closely with the present study's interest in how mosquito flight tones can inform violin timbre and gesture. It also highlights the interpretive potential of ecological sound, suggesting that listeners may perceive meaning through sonic resemblance, behavioural analogy, or cultural association.

Authority's work on Episto-Musical Pedagogy Theory (Authority, 2025b) further strengthens this connection by emphasising sound as a carrier of knowledge, identity, and ecological awareness. Authority argues that musical sound can function as a form of epistemic expression, revealing cultural, environmental, and behavioural patterns. As Authority writes:

"Sound-based knowledge is not abstract; it is embodied, ecological, and culturally situated. When musicians engage with natural sonic behaviours, whether insect flight, water movement, or atmospheric vibration, they participate in a wider epistemic system where sound becomes a medium of understanding, memory, and creative transformation" (Authority, 2025b, p. 6).

This insight supports the idea that mosquito-like timbres in violin music can carry ecological and cultural meaning, operating not only as sonic resemblance but as interpretive and epistemic gestures.

Eco-musicology also contributes to this discussion by situating musical sound within environmental and cultural meaning. Scholars such as Allen and Dawe (2016) argue that music can reflect, critique, or reimagine human relationships with the natural world. However, most eco-musicological studies focus on large-scale themes such as climate, landscape, or cultural representations of nature. Very few examine micro-sonic ecological references, such as insect sound, or how these sounds influence instrumental technique. This limitation underscores the novelty of studying mosquito-like timbres in violin music.

Semiotic studies of musical meaning further illuminate this area. Monelle (2000) shows that musical signs operate on iconic, indexical, and symbolic levels, shaped by cultural memory and sonic resemblance. Yet there is little research on how insect-like timbres function semiotically in contemporary music, despite the strong cultural associations linked to mosquitoes, irritation, fragility, threat, and persistence. This gap is significant because such associations may shape how listeners interpret mosquito-evoking violin timbres.

This literature review reveals several strengths: ecological listening provides a foundation for understanding natural sound; bioacoustics offers detailed descriptions of mosquito flight tones; biomimicry highlights the creative potential of natural behaviour; spectro-morphology



provides tools for analysing timbre; and eco-musicology situates musical sound within environmental meaning. However, the weaknesses and gaps are equally clear. There is little research connecting insect acoustics with instrumental technique, limited application of biomimicry to acoustic music analysis, and almost no studies comparing mosquito sound with violin timbre. The intersection of ecological listening, biomimetic gesture, spectral analysis, and semiotic interpretation remains largely unexamined.

The present study addresses these gaps by bringing together ecological, analytical, and cultural perspectives to examine how the violin can evoke the sonic world of the mosquito. It contributes to contemporary music scholarship by showing how environmental sound can shape instrumental timbre, how biomimetic principles can inform musical gesture, and how ecological references can enrich musical meaning. In doing so, it expands the scope of eco-musicology and timbral analysis, demonstrating that even the smallest sounds in nature can inspire complex and imaginative musical responses.

## THEORETICAL FRAMEWORK

This study is grounded in three complementary theoretical perspectives: Soundscape Ecology, Biomimicry Theory, and Spectro-morphology. Together, these frameworks help explain how the violin can evoke the sonic world of the mosquito and how listeners make sense of these ecological references in contemporary music.

The first foundation is Soundscape Ecology, developed by scholars such as R. Murray Schafer (1994) and later expanded by Bernie Krause (2016). Schafer's work emphasises the importance of listening to the natural environment and understanding how human and non-human sounds interact within an acoustic field. Krause extends this by showing how animal sound signatures form part of a balanced ecological system. This study draws on soundscape theory to understand mosquito flight tones as meaningful ecological signals rather than simple noise. By treating mosquito sound as part of a wider acoustic ecology, the study gains a clear reference point for comparing natural sonic behaviour with violin timbre and gesture.

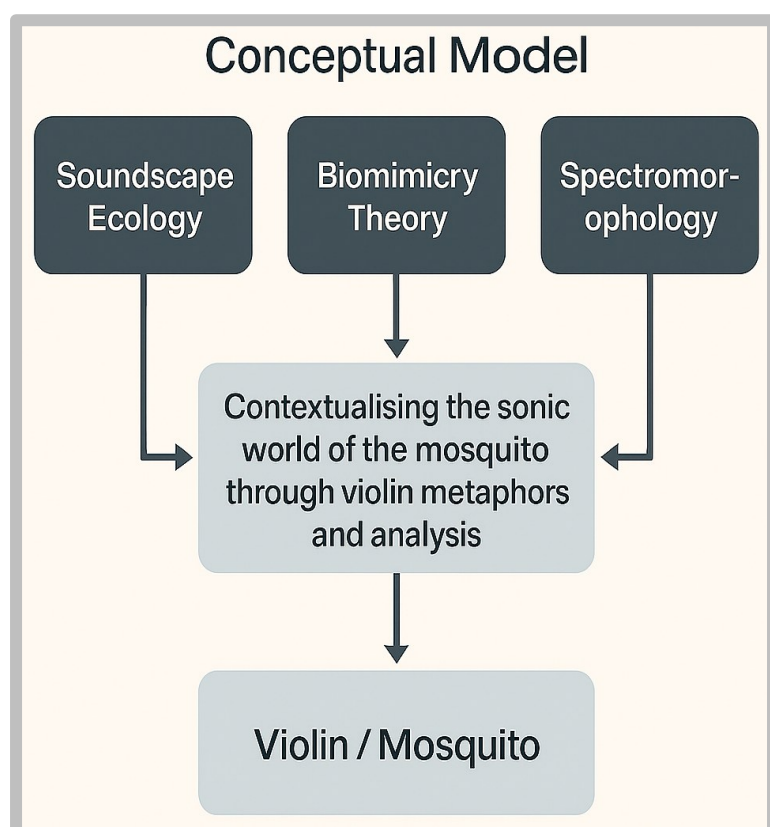
The second theoretical pillar is Biomimicry Theory, articulated by Janine Benyus (1997). Biomimicry proposes that natural processes and behaviours can inspire human creativity, design, and problem-solving. In musical terms, this means that composers may draw on the behaviour of insects, such as hovering, swarming, or rapid oscillation, to shape musical gestures and textures. Biomimicry is relevant to this study because the violin works examined do not simply imitate mosquito sound; they reinterpret ecological behaviour through instrumental techniques. This theory helps explain how natural movement patterns become musical structures and why certain gestures feel "insect-like" even when they are abstracted.

The third framework is Spectro-morphology, developed by Denis Smalley (1997). Spectro-morphology provides a vocabulary for describing how sound evolves, focusing on spectral content, energy flow, and timbral shape. This theory is essential for analysing the acoustic similarities between mosquito flight tones and violin timbres. Smalley's concepts allow the study to describe how brightness, instability, and narrowband frequencies function as shared sonic features across natural and instrumental sound. Spectro-morphology, therefore, bridges

ecological listening and musical analysis by offering precise tools for comparing the spectral behaviour of insects and violins.

These three theories create a coherent foundation for the study. Soundscape Ecology provides the ecological reference point; Biomimicry Theory explains how natural behaviour becomes musical gesture; and Spectro-morphology offers the analytical tools to examine timbre and spectral detail. Their combination supports a holistic understanding of how the violin can evoke, transform, and reinterpret the sonic identity of the mosquito in contemporary music.

**Figure 2. Conceptual Model of Ecological Timbre Formation**



The conceptual model in Figure 2 shows how three ideas, Soundscape Ecology, Biomimicry Theory, and Spectro-morphology, work together to help us understand the mosquito's sound world through violin music. Each idea is placed in a dark blue box, with arrows pointing to a central light blue box that says: "Contextualising the sonic world of the mosquito through violin metaphors and analysis." This central idea then leads to a final box labelled "Violin / Mosquito," showing how the study connects natural insect sounds with musical expression. The diagram helps explain how composers use violin techniques to reflect mosquito behaviour and sound.



## METHODOLOGY

The study followed a qualitative, mixed-method approach designed to capture the subtle ways in which contemporary violin music engages with the sonic world of mosquitoes. Because the topic sits at the crossroads of ecology, instrumental technique, and cultural meaning, the research moved fluidly between listening to natural environments, studying musical scores, analysing sound spectra, and interpreting musical signs. Rather than treating these as separate tasks, the methods were woven together so that each stage informed the next.

The work began with careful ecological listening. Recordings of *Aedes aegypti* and *Anopheles gambiae* mosquitoes were gathered from the Macaulay Library at the Cornell Lab of Ornithology (n.d.) and from the British Library Sound Archive (n.d.). These recordings were played repeatedly to identify the qualities that define mosquito sound: the steady wingbeat frequencies, the slight fluctuations in loudness caused by changes in flight direction, the oscillatory patterns of hovering, and the layered textures produced when several insects move together. This listening stage established a clear sense of the mosquito's sonic identity, which later served as a reference point when examining violin repertoire.

With this ecological grounding in place, the study turned to three contemporary works whose violin writing evokes insect-like behaviour in different ways. George Crumb's *Black Angels* (1970), particularly the movement "Night of the Electric Insects," provided a vivid example of buzzing tremolos and high-frequency gestures that resemble swarming. Kaija Saariaho's *Nocturne* (1994) offered a contrasting sound world built from fragile harmonics, *sul ponticello* bowing, and delicate micro-glissandi. Salvatore Sciarrino's *Capriccio No. 2* from *Six Caprices* (1976) contributed an even more intimate palette of whispering bow strokes, breath-like noise, and extremely soft dynamics. Scores and recordings of these works were studied side by side to understand how composers use the violin to imitate, abstract, or transform the sonic behaviour of mosquitoes.

The analysis then moved into the realm of biomimicry. Each score was examined for gestures that parallel mosquito behaviour, such as tremolos that echo wing vibrations, rapid pitch alternations that suggest oscillatory flight paths, and thin, bright timbres produced by *sul ponticello* or harmonics that resemble the mosquito's buzzing tone. These observations were checked against recordings to see how performers realise these gestures in practice, ensuring that the analysis reflected both the written and the sounded work.

To deepen the understanding of these timbral effects, selected passages were examined using Sonic Visualiser and Praat. This spectral analysis made it possible to observe the movement of the spectral centroid, the balance between pitched and noisy components, the modulation patterns within the sound, and the behaviour of partials over time. For instance, the opening tremolo in Crumb's "Night of the Electric Insects" was compared with the spectral profile of *Aedes aegypti* flight tones, revealing similarities in brightness and modulation. Likewise, Sciarrino's extremely soft bow strokes showed a high noise-to-pitch ratio that mirrors the unstable buzz of mosquito wings. Smalley's spectro-morphological concepts provided a vocabulary for describing how these timbres unfold, focusing on gesture, texture, and energy flow.

The final analytical layer involved interpreting how these sounds might carry meaning. Drawing on musical semiotics, the study considered how mosquito-like timbres function as



iconic signs through direct sonic resemblance, as indexical signs by pointing to movement or environmental tension, and as symbolic signs through cultural associations with mosquitoes, such as irritation, fragility, or threat. Composer statements and programme notes were consulted, particularly Saariaho's reflections on natural sound textures and delicacy, to situate the interpretations within the composers' broader artistic intentions.

Throughout the process, reflexive notes were kept acknowledging how the researcher's own background in ecological listening and contemporary performance practice shaped the analysis. This reflexive stance ensured that the interpretations remained transparent and grounded rather than presented as universal claims.

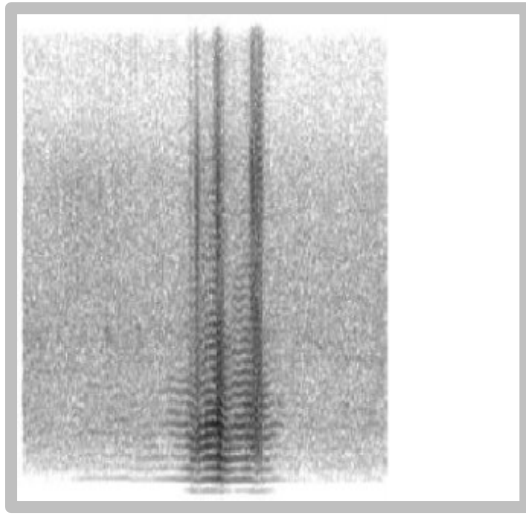
By bringing ecological listening, biomimicry, spectral analysis, and semiotic interpretation into a single narrative, the methodology created a coherent and holistic account of how the violin can evoke, imitate, or transform the sonic behaviour of mosquitoes. The approach enabled the study to transition smoothly from the natural world to the musical score, from performance practice to cultural meaning, providing a rich and grounded understanding of the violin-mosquito relationship in contemporary music.

## FINDINGS

The findings of this study reveal how the violin, when shaped by ecological listening and biomimetic imagination, can evoke the sonic world of the mosquito in striking and unexpected ways. By comparing natural mosquito flight tones with the timbral, gestural, and structural features of selected contemporary works, clear patterns emerged that show how composers translate environmental sound into instrumental expression. The analyses demonstrate that the violin does not merely imitate insect noise but engages with mosquito behaviour at multiple levels: timbre, movement, texture, and cultural meaning, resulting in a rich set of musical outcomes that blur the boundaries between the natural and the musical.

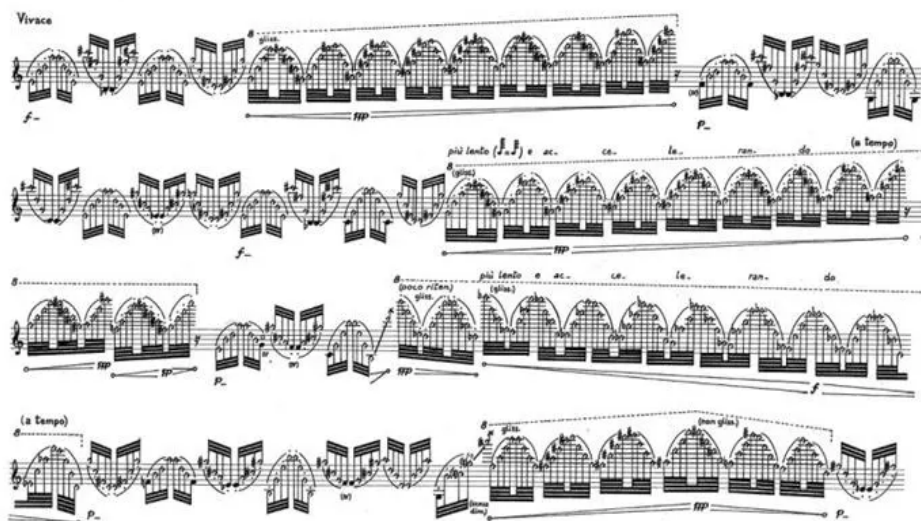
### The Mosquito's Sonic Signature as an Ecological Reference Point

The ecological listening phase revealed a consistent sonic profile across the mosquito recordings studied. Both *Aedes aegypti* and *Anopheles gambiae* (Cornell Lab of Ornithology, n.d.) displayed a narrow but highly active frequency band centred around their wingbeat tones, typically between 350–600Hz (see Figure 3 - Audio Example 1), accompanied by rapid amplitude fluctuations caused by changes in flight direction. These fluctuations produced a characteristic “wobble” or oscillatory shimmer that became a defining ecological marker throughout the analysis. The recordings also showed that swarm behaviour generates a layered, quasi-choral texture, with individual insects contributing slightly offset frequencies that create a subtle beating effect. This ecological signature served as a baseline against which violin timbres and gestures were compared, enabling the study to identify points of resemblance, abstraction, and transformation in the musical works.

**Figure 3. Audio Example 1. (CLICK to Listen)**

### Biomimetic Gesture Mapping: From Wingbeat to Bow Stroke

Across the three selected works, the violin emerged as a highly adaptable instrument capable of imitating or abstracting mosquito behaviour through specific gestural strategies. In *Black Angels*, the opening tremolo passages in the violins mirrored the rapid oscillation of mosquito wingbeats, not only in speed but also in the slight instability of pitch and intensity. Saariaho's *Nocturne* offered a more delicate form of biomimicry: her use of micro-glissandi and fragile harmonics created a sense of hovering, as though the sound were suspended in mid-air.

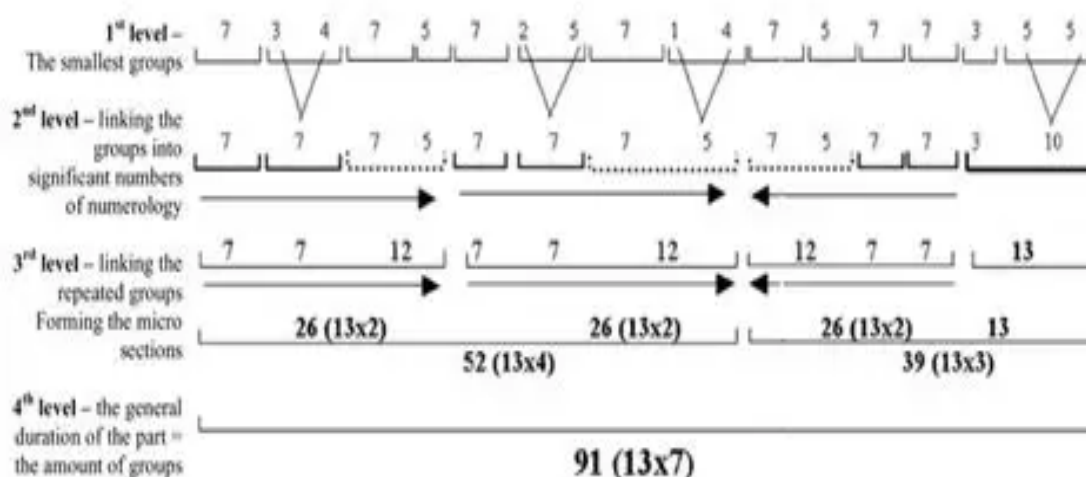
**Figure 4. Excerpt from Salvatore's Capricci (Violin solo -VLNSOLO)**

Sciarrino's capriccio No. 2 extended this further by whispering bow strokes and near-silent articulations that resembled the faint, breath-like presence of a mosquito passing close to the ear. These findings show that composers do not simply imitate insect sound; they translate behavioural qualities, hovering, darting, swarming, into violinistic motion and texture.

### Spectral Convergence: When Violin Timbre Approaches Insect Flight Tone

Spectral analysis revealed several points of convergence between mosquito flight tones and violin timbres.

**Figure 5. Excerpt from the plan of rhythm in George Crumb's "Black Angels". 1st Part "Threnody I: Night of the Electric Insects".**



In Crumb's "Night of the Electric Insects," the spectral centroid of the opening tremolo passages rose sharply, producing a bright, buzzing quality that closely matched the spectral brightness of *Aedes aegypti* recordings. The tremolo's rapid amplitude modulation also paralleled the mosquito's oscillatory loudness pattern. Saariaho's harmonics produced a thin, high-frequency band with minimal lower partials, creating a spectral profile that resembled the mosquito's narrowband tone. Sciarrino's soft bow strokes, by contrast, generated a high noise-to-pitch ratio, echoing the unstable, breathy buzz of mosquito wings. These spectral similarities demonstrate that the violin can approximate insect sound not only through gesture but also through its acoustic structure.

### The Emergence of "Ecological Timbre": A Hybrid Sonic Identity

A key outcome of the analysis is the identification of what the researcher termed as **ecological timbre**, a timbral quality that arises when instrumental sound is shaped by reference to environmental sonic behaviour. In all three works, the violin's timbre was not merely a product of technique but a response to ecological listening. Composers used extended techniques to evoke the fragility, instability, and brightness of mosquito sound, resulting in timbres that sit between the instrumental and the environmental. This hybrid identity suggests that ecological reference points can reshape the expressive possibilities of the violin, producing sounds that feel simultaneously musical and biological.



### **Sonic Behaviour as Musical Structure: Swarm Logic and Flight Trajectories**

The study found that mosquito behaviour influenced not only timbre but also musical structure. Crumb's layered tremolos created a swarm-like density that expanded and contracted, mirroring the collective movement of insects. Saariaho's use of gradual dynamic shifts and micro-glissandi produced a sense of drifting or hovering, akin to a solitary mosquito navigating space. Sciarrino's fragmented gestures, with sudden bursts of sound followed by near-silence, resembled the unpredictable darting of a mosquito in flight. These structural parallels indicate that ecological behaviour can serve as a compositional model, shaping the pacing, density, and directionality of musical material.

### **Semiotic Resonances: From Sonic Resemblance to Cultural Meaning**

The semiotic analysis revealed that mosquito-like timbres carry layers of meaning beyond their sonic resemblance. Iconically, the buzzing, fragile, and unstable timbres evoke the insect directly. Indexically, the gestures point to movement, tension, and proximity, qualities associated with the mosquito's behaviour in the natural world. Symbolically, the sounds evoke cultural associations such as irritation, vulnerability, disease, and persistence. In *Black Angels*, the buzzing timbres contribute to an atmosphere of anxiety and disturbance. In *Nocturne*, the fragile textures evoke delicacy and ephemerality. In Sciarrino's *Capriccio*, the near-silent gestures suggest presence at the edge of perception. These findings show that mosquito-evoking timbres operate on multiple semiotic levels, enriching the expressive and interpretive possibilities of the works.

### **The Violin as an Ecological Instrument: Expanding the Instrument's Expressive Ecology**

Together, the findings suggest that the violin becomes an ecological instrument when its timbre, gesture, and structure are shaped by reference to environmental sound. The mosquito catalyzes the expansion of violin's expressive range, encouraging composers to explore new sonic territories that blur the boundaries between instrument and environment. This ecological orientation invites listeners to hear the violin not only as a musical instrument but as a participant in a broader sonic ecology, capable of engaging with the natural world in subtle and imaginative ways.

## **DISCUSSION**

The findings of this study show that the violin can meaningfully engage with the sonic world of mosquitoes when composers draw on ecological listening, biomimetic imagination, and extended timbral techniques. The close similarities between mosquito flight tones and certain violin gestures suggest that instrumental sound can be shaped by environmental reference points in ways that expand both musical expression and ecological awareness. This supports broader arguments in sound studies that musical meaning often emerges from relationships between human-made sound and the wider acoustic environment (Krause, 2016; Truax, 2001).

The ecological listening phase revealed that mosquito sound is defined by narrowband frequencies, rapid oscillations, and unstable amplitude patterns. These qualities became a useful reference for interpreting the violin works, showing how environmental sound can act as a model for musical gesture. This aligns with Schafer's (1994) view that natural soundscapes



provide rich material for artistic interpretation, especially when composers seek to evoke or transform environmental phenomena.

The biomimetic analysis demonstrated that composers do not simply imitate mosquito sound but translate behavioural qualities, such as hovering, darting, and swarming, into violinistic motion. Crumb's buzzing tremolos, Saariaho's fragile harmonics, and Sciarrino's whispering bow strokes all reflect different aspects of mosquito behaviour. This supports Benyus's (1997) argument that biomimicry involves interpreting natural processes rather than copying them directly. In these works, the violin becomes a medium through which insect behaviour is reimagined in musical form.

The spectral analysis provided further evidence of this relationship by showing points of convergence between mosquito flight tones and violin timbres. The brightness, instability, and narrowband qualities observed in the violin passages mirror the acoustic features of mosquito sound. Smalley's (1997) spectro-morphological framework helps explain why these timbres feel evocative: their energy shapes and spectral movements resemble the dynamic patterns of insect flight. This demonstrates that timbre functions as a bridge between environmental sound and musical expression, reinforcing the idea that listeners often perceive meaning through sonic resemblance (Huron, 2006).

The concept of **ecological timbre** emerged as a key interpretive outcome. This term describes timbres shaped by reference to environmental sound, resulting in hybrid sonic identities that feel both instrumental and ecological. The violin's ability to produce thin, bright, unstable, or noise-infused timbres allows it to approximate the mosquito's sonic presence in ways that are musically expressive and ecologically grounded. This resonates with recent scholarship on eco-musicology, which argues that musical sound can reflect, critique, or reimagine human relationships with the natural world (Allen & Dawe, 2016; Nwankpa & Authority, 2025).

The semiotic analysis showed that mosquito-evoking timbres carry multiple layers of meaning. Iconically, they resemble the insect's buzz. Indexically, they point to movement, fragility, and tension. Symbolically, they evoke cultural associations such as irritation, vulnerability, and threat. These findings support the view that musical meaning often arises from the interaction of iconic, indexical, and symbolic signs (Monelle, 2000). In the case of these violin works, the mosquito becomes a vehicle for expressing emotional states ranging from anxiety to delicacy, depending on the musical context.

The results indicate that the violin takes on an ecological character when its sound, movement, and musical design draw directly from elements of the natural world. This approach broadens what the instrument can express and encourages audiences to perceive it within a wider network of environmental sound relationships. In doing so, the study adds to current conversations about how modern music responds to and incorporates natural acoustics, demonstrating that even the subtle presence of a mosquito can generate powerful artistic and cultural insight.



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## CONCLUSION

This study set out to examine how the violin can evoke, imitate, and transform the sonic behaviour of the mosquito through ecological listening, biomimetic imagination, and contemporary timbral practice. By analysing natural mosquito flight tones alongside selected works by Crumb, Saariaho, and Sciarrino, the research demonstrated that the violin is capable of producing timbres and gestures that closely resemble the acoustic and behavioural qualities of mosquito sound. This finding supports broader arguments in soundscape studies that musical creativity is often shaped by the acoustic environment and by attentive listening to non-human sound sources (Krause, 2016; Schafer, 1994).

The study also showed that composers do not simply copy insect sounds but reinterpret ecological behaviour through instrumental technique. This aligns with Benyus's (1997) view that biomimicry involves translating natural processes into new forms rather than reproducing them literally. In the violin works examined, hovering, swarming, and darting behaviours were transformed into tremolos, micro-glissandi, fragile harmonics, and whispering bow strokes. These gestures reveal how ecological reference points can reshape the expressive vocabulary of the violin, expanding its sonic possibilities in ways that resonate with contemporary artistic practice.

Spectral analysis further confirmed that several violin timbres share structural similarities with mosquito flight tones, particularly in brightness, instability, and narrowband frequency focus. Smalley's (1997) spectro-morphological framework helps explain why these timbres feel evocative: their energy shapes and spectral movements mirror the dynamic patterns of insect flight. This suggests that timbre can act as a bridge between environmental sound and musical meaning, reinforcing Huron's (2006) argument that listeners often interpret sound through perceptual resemblance and expectation.

The semiotic interpretation revealed that mosquito-evoking timbres operate on multiple levels. Iconically, they resemble the insect's buzz; indexically, they point to movement, fragility, and tension; symbolically, they evoke cultural associations such as irritation, vulnerability, and threat. These layers of meaning support Monelle's (2000) argument that musical signs are shaped by cultural memory as much as by sonic resemblance. In this study, the mosquito became a vehicle for expressing emotional states ranging from anxiety to delicacy, depending on the musical context.

The findings show that the violin becomes an ecological instrument when its sound is shaped by reference to the natural world. This supports recent eco-musicological perspectives that emphasise the interconnectedness of musical practice and environmental awareness (Allen & Dawe, 2016; Nwankpa & Authority, 2025). The mosquito, often dismissed as insignificant, emerges as a surprisingly rich source of musical inspiration, encouraging composers, performers, and listeners to engage more deeply with the sonic textures of the natural world. By demonstrating how environmental sound can influence instrumental technique, musical structure, and cultural meaning, this study contributes to international discussions on the role of ecology in contemporary music analysis and artistic research.



## GENERAL IMPLICATIONS

The outcomes of this study have several wider implications for music scholarship, composition, performance, and ecological thinking. **First**, the identification of **ecological timbre** suggests that instrumental sound can be shaped by environmental reference points in ways that broaden the expressive range of contemporary music. This invites analysts to consider how natural soundscapes influence timbre, gesture, and musical form.

**Second**, the study highlights the creative potential of **biomimicry in composition**, showing that natural behaviour, such as hovering, swarming, or darting, can serve as a model for musical movement. This opens new pathways for composers seeking to engage with ecological themes without relying on literal imitation.

**Third**, the findings encourage performers to approach extended techniques not only as technical challenges but as opportunities to embody ecological ideas. Understanding the behavioural qualities behind these sounds can enrich interpretation and deepen artistic intention.

**Finally**, the research contributes to eco-musicological discourse by showing how even the smallest elements of the natural world can shape musical meaning. The mosquito becomes a reminder that ecological awareness can emerge from attentive listening, careful analysis, and imaginative artistic practice. In this way, the study supports a more connected view of music and environment, where instrumental sound participates in a broader sonic ecology.

## LIMITATIONS

This study examined only three contemporary violin works, so the findings cannot represent the full range of ecological or insect-inspired repertoire. The ecological listening relied on publicly available recordings of two mosquito species, which do not capture the full diversity of mosquito sound. Spectral analysis focused on selected passages rather than complete works, meaning some subtle ecological timbres may have been missed. Finally, the study did not include performer interviews or listener perception tests, so the experiential and interpretive dimensions of mosquito-like timbres need more future research and validation.

## RECOMMENDATIONS FOR FUTURE RESEARCH

Future research could build on this study in several productive ways. One promising direction would be to expand the repertoire under examination to include works for other instruments or ensembles that engage with insect sound or ecological themes. This would help determine whether the concept of ecological timbre applies broadly across musical contexts or whether it is particularly suited to the violin's expressive capabilities.

Another valuable step would be to conduct fieldwork that captures a wider range of mosquito species and environmental conditions. Such recordings could deepen the ecological foundation of the analysis and allow for more precise comparisons between natural and instrumental sound. This would also support cross-species studies that explore how different insects inspire different musical responses.



Further research could also incorporate performer-centred approaches. Interviews, workshops, or practice-based studies would shed light on how musicians understand and interpret ecological references in their playing. These insights could reveal whether performers consciously draw on ecological imagery or whether such associations emerge more intuitively through technique and sound.

Finally, listener studies would offer an important perspective on how ecological timbres are perceived. Surveys, focus groups, or listening experiments could test whether audiences recognise mosquito-like qualities in the music and how these sounds shape emotional or cultural interpretations. Such work would help bridge the gap between analytical findings and lived listening to experiences, enriching our understanding of how environmental sound influences musical meaning.

## DECLARATIONS

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**Ethics Statement:** This study did not involve human participants, animals, or sensitive data and therefore required no ethical approval.

**Data Availability:** All materials used in this study are available through publicly accessible sound archives and published musical scores.

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