

Listening to Rivers: Engaging communities in freshwater conservation through real-time audio and locative media

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Abstract

River Listening is an interdisciplinary project established in 2014 that presents an innovative approach to freshwater conservation. This paper reflects on a decade of research with particular focus on the creative outcomes that have leveraged real-time audio and locative media for public engagement and ecological awareness. This interdisciplinary project works at the intersection of art and science and has deployed hydrophones in global river systems making the artistic and scientific possibilities of listening to rivers accessible to global audiences through real-time audio streaming and interactive sound walks. River Listening embodies the concept of Everywhen by interweaving the past, present, and future narratives of freshwater ecosystems through sound. This approach not only amplifies the project's scientific contributions but also extends its reach and impact on public engagement. The project stands as a testament to the transformative potential of art, science, and technology in facilitating an empathetic connection and care for rivers at a time when it is increasingly important to listen.

Keywords

Sound art, locative media, freshwater ecoacoustics, conservation, hydrophones, real-time audio, augmented reality.

Introduction

River Listening is an interdisciplinary research project exploring the possibilities of freshwater ecoacoustics in the conservation and management of global river systems. The project works at the intersection of art and science by investigating the cultural and biological diversity of freshwater ecosystems through real-time listening and underwater recording used for biodiversity monitoring and public engagement (Barclay et al. 2020). The effects of ecological changes are often readily visible in terrestrial environments, but conservation is challenging in aquatic ecosystems when we cannot see beneath the surface. Conventional environmental monitoring in freshwater ecosystems remains problematic because it is highly invasive, expensive, and constrained to restricted areas and manual processing of observations by specialists (Linke et al. 2018).

In an era where the Everywhen concept — emphasising the coexistence of past, present, and future — is crucial for understanding our rapidly changing world, River Listening is an innovative exploration into the cultural and biological diversity of rivers and the spatial and temporal complexities of freshwater ecosystems. By employing non-invasive hydrophone technologies for acoustic monitoring, River Listening offers a unique lens to perceive and engage with the often-unseen life below the surface of freshwater ecosystems, highlighting the urgency of their conservation. The project contributes to the scientific understanding of aquatic biodiversity and pioneers' new methods in fostering community engagement through creative practice. Live streaming hydrophones and mobile sound walks are central to the creative outcomes that are transforming the way communities interact with and perceive their local waterways. This paper reflects on a decade of research and outlines the current challenges and opportunities for interdisciplinary approaches to freshwater ecoacoustics moving into the future.



Figure 1: River Listening Hydrophone Recording.

Freshwater Conservation

Freshwater is a resource fundamental to all life forms and carries a diversity of ecological, cultural, and socio-economic values. Despite covering less than 1% of the Earth's surface, freshwater systems support an estimated 10% of all known species. Global freshwater ecosystems are currently facing unprecedented threats due to factors like climate change, pollution, over-extraction, and habitat destruction. The evidence suggests that there are persistent challenges and emerging threats to freshwater biodiversity conservation internationally (Reid et al., 2018). Efforts to set global conservation priorities have largely ignored freshwater

diversity, excluding some of the world's most threatened, and valuable taxa (Abell et al. 2010). Recent projects, such as the 30 × 30 initiative provides an opportunity to refocus and reposition global conservation efforts to benefit freshwater systems and the habitats they support (Moravek et al. 2023). Additionally, there is a global agenda for advancing freshwater biodiversity research that identifies fifteen pressing global needs to support informed global freshwater biodiversity stewardship (Maasri et al. 2021).

The urgency to protect these vital ecosystems is more pressing than ever in the context of the Everywhen, where we recognise the cultural value of river systems and the interconnectedness of past, present, and future environmental actions and consequences. In this research, the responsibility for freshwater conservation extends beyond river custodians, environmental scientists and policymakers to include artists, technologists, and community stakeholders. By listening to a river, we tap into a form of ecological engagement that resonates with the Everywhen, intertwining narratives of place, time, and the continuous flow of life that rivers embody. This project not only contributes to the scientific understanding of aquatic biodiversity but also serves as a conduit for public engagement and environmental advocacy with a core focus in advancing the field of freshwater ecoacoustics through creative engagement.

Freshwater Ecoacoustics

Freshwater ecoacoustics is an emerging interdisciplinary field that explores the ecological role of sound in freshwater ecosystems. This discipline revolves around the study of soundscapes within freshwater environments, including rivers, lakes, and wetlands. Ecoacoustics approaches are being increasingly used in terrestrial systems, particularly for bird populations (Farina and Gage 2017), tropical coastal habitats for fish monitoring (Staaterman et al. 2017), and marine realms for cetacean monitoring (Tavolga 2012). However, the use of ecoacoustics in freshwater environments is still underdeveloped. Recent research has provided the foundations to advance the field of freshwater ecoacoustics, including detailed characterisations and taxonomic distinction of sounds that can offer the basis for automatic detection algorithms. For example, multi-taxon characterisation by Gottesman et al. (2018) and Desjonquères et al. (2015) catalogued insect and physicochemical sounds. Other studies have characterised calls by piranhas in Peru (Rountree and Juanes 2018). Freshwater ecoacoustic methods have shown differences in freshwater soundscapes across different types of sites and environmental gradients (Abrahams et al., 2021) along with a diversity of recent work that demonstrates the potential of ecoacoustics as a tool for continuous ecosystem monitoring in freshwater environments (Linke et al., 2018).

The acoustic signals in freshwater environments emanate from a diverse range of sources. Bioacoustic activities, such as the vocalisations of fish and the movements of macro-invertebrates, reveal the presence and behaviours of various

species. Geophysical sounds, including the flow of water over substrates and the movement of sediments, offer insight into the physical state and processes of aquatic habitats. These sounds also serve as indicators of environmental changes, such as shifts in water flow or the introduction of pollutants, making them essential tools for monitoring ecosystem health. The application of ecoacoustics in freshwater ecosystems has the potential to detect ecosystem responses to environmental water allocations, offering a promising tool for monitoring restoration and the general health of freshwater ecosystems (Linke & Deretic, 2019). However, despite the vast amount of recent research, applications of ecoacoustics in freshwater environments have been lagging, highlighting the need for further research, engagement and operationalisation of freshwater ecoacoustic monitoring (Linke et al., 2019).

River Listening Foundations

River Listening has been a catalyst for the interdisciplinary possibilities of freshwater ecoacoustics. Rapid advancements in digital technology have provided opportunities for non-invasive acoustic monitoring that is now accessible, affordable, and viable (Barclay et al. 2020). The integrated nature of ecoacoustics calls for greater collaboration with other disciplines, including electronics, remote sensing, data science, humanities, and social sciences (Sueur and Farina 2015). In addition to advancing science, listening to rivers can help human communities understand freshwater biodiversity in accessible and engaging ways (Barclay 2016, 2018). Mobile applications and interactive experiences that augment real acoustic data with creative responses and community voices have the capacity to encourage public engagement. By deploying hydrophones — underwater microphones — in various riverine environments, the project amplifies the often-unheard voices of aquatic life and the impacts of human activities on these delicate ecosystems. These soundscapes provide not only scientific insights into the health and biodiversity of rivers but also create immersive auditory experiences that connect the public with the unseen world beneath the surface of a river.

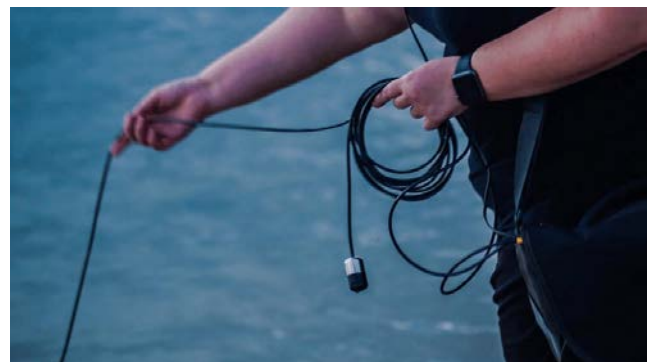


Figure 2: River Listening Hydrophones (Aquarian Audio H2a).

The foundations for River Listening emerged out of Leah Barclay's artistic practice as a composer and sound artist, now spanning over 20 years of collaboration with river communities across the world. Barclay's creative work began with compositions inspired by rivers and shifted into participatory sound experiences, site-specific live performances, and immersive installations designed to bring attention and awareness to rivers as the lifeblood of communities. In 2014, Barclay was awarded an ANAT Synapse residency to work with the Australian Rivers Institute at Griffith University to develop River Listening and explore the creative possibilities of freshwater ecoacoustics. The residency involved working in collaboration with computational programmer and designer Dr Toby Gifford and freshwater ecologist Dr Simon Linke, who is now a Senior Research Scientist and Freshwater Ecologist at CSIRO in Australia.



Figure 3: Dr Simon Linke listening to the Mary River.

The first phase of River Listening was designed to explore the artistic and scientific possibilities of hydrophone recording and inspire community engagement through interactive workshops, recording expeditions, and audio installations designed to draw attention to the sounds beneath the surface of the river. The project explored ways we could use acoustics to understand aquatic biodiversity and involved extensive experimentation with recording techniques, new technologies, and community collaborations to compare aquatic soundscapes and the most effective methods for recording in freshwater ecosystems.

River Listening was designed as an inherently interdisciplinary project, with an equal balance between artistic and scientific methods throughout the fieldwork and resulting outcomes. By transforming scientific data into immersive media art, the project invites a broad audience to experience and reflect on the ecological value of freshwater ecosystems. This approach not only raises awareness about freshwater conservation but also stimulates a dialogue about the role of art and technology in environmental activism and education. River Listening evolved to work at the intersection of art and science by investigating the cultural and biological diversity of freshwater ecosystems through real-time listening and underwater recording used for biodiversity monitoring and public engagement. As there was such limited research around freshwater ecoacoustics at the start of the project, the research team were developing methods in the field, designing and developing new technologies for recording, and developing new processes that were deeply

informed by both scientific and artistic approaches. The community engagement approaches, and emerging models of reciprocity were the core of the fieldwork, this involved developing strong relationships with Traditional Owners along the river systems, community groups, landholders, and local farmers who had deep knowledge about the rivers.

The creative outputs of River Listening are not simply presentations of ecoacoustic data; they shape new ways to engage with rivers and facilitate a sensory experience that fosters a deeper connection with freshwater ecosystems. The central tools for public engagement around River Listening have been the creative outcomes, including site-specific performances and installations that have toured internationally. The most effective tool for public engagement has been the River Listening Sound Walks, which require audiences to visit their river to experience the work. The sound walks involve a custom-built mobile application that transforms the listener's phone into a sonic compass to guide them along the riverbank and explore the cultural and biological diversity of the river through sound (Barclay 2017). The installation triggers geo-located soundscapes that are accompanied by images and text identifying the sounds that are drawn from a local database of hydrophone recordings.

Live Streaming Hydrophones

Live streaming hydrophones have been a core focus of experimentation in River Listening since the conception of the project. Live hydrophones, submerged in river systems, enable real-time auditory access to the dynamic soundscapes beneath the surface of a river.

On World Water Day 2014, the research team established the first live stream in the Brisbane River in Australia and connected with a node in New York City along the Hudson River to initiate a discussion about the value of aquatic acoustic ecology as part of the World Water Day Symposium in New York (hosted on Waterwheel). The soundscapes of the Brisbane River were broadcast globally in real-time, diffused live in a surround sound environment in New York by Leah Barclay, and became the subject of a discussion about the value of listening to rivers.



Figure 4: First River Listening Live Stream in 2014.

The initial phase of River Listening in Australia involved community streaming workshops across Queensland, and the project launched on the iconic River Thames in London during the 25th anniversary of the EVA London International Conference in June 2014. This involved hosting a seven-day live stream with hydrophones installed on the HMS Belfast, permanently moored on the river Thames. The intensity of the Thames stream, reminiscent of a busy highway, was compared to the database of river recordings in Australia and demonstrated the diversity of freshwater soundscapes globally. The team used social media, particularly Twitter, to facilitate an online conversation around the stream, and the project became a valuable learning experience to design the ongoing project.

Many of the performances and installations resulting from River Listening over the last decade have incorporated live streams established by the research team, but in all cases, these have been temporary streams running for periods varying from several days to three weeks. The infrastructure required for permanent streams can be cost prohibitive in many research projects, particularly streaming from remote locations in Australia where the data requirements alone can be extremely expensive. As an example, a basic Mp3 encoded stereo hydrophone stream running at 320 kbps will use 144 megabytes per hour, 3.5 gigabytes per day, over 100 gigabytes per month and at least 1.3 terabytes per year. The most affordable 4G mobile broadband in Australia for regional areas can be calculated at \$50 per 25 gigabytes, meaning the data costs for the stream can be approximately \$160-\$200 per month depending on the network provider. The various technical challenges and global opportunities for live streaming audio have resulted in a culture of collaboration emerging through artistic and scientific networks working in this area. This was the foundation for River Listening collaborations with Sound Camp, a London-based organisation coordinated by Grant Smith, Maria Papadomanolaki and Dawn Scarfe.

The technological implementation of live streaming hydrophones merges acoustic engineering with digital innovation, experimentation and media art. These hydrophones streaming kits are designed to withstand the harsh and variable conditions of aquatic environments, streaming high-quality audio with limited impact on the surrounding environment. The live stream technology is configured to transmit the audio to a live sound map and the River Listening website, making the experience accessible to a global audience. This technological setup requires robust data transmission capabilities, often challenging in remote areas. Despite these challenges, the project has successfully established live streams in various locations, demonstrating the adaptability and resilience of this approach.

The logistical aspects of deploying and maintaining live streaming hydrophones are complex. First and foremost, the project seeks permission and collaboration with Traditional Owners along the river system. The process then involves

careful site selection to ensure ecological relevance, securing permits and permissions from local stakeholders, and ensuring minimal disturbance to the aquatic habitats. Regular maintenance and monitoring are crucial to ensure the continuous operation of these streams. The project navigates these logistical challenges through collaborative efforts with local communities, scientists, and environmental organisations, fostering a sense of shared responsibility, care, and collaboration.

Artistically, live streaming hydrophones serve as a conduit for creative exploration, experimentation, and public engagement. The real-time nature of these audio streams creates a compelling sense of immediacy and connection, drawing listeners into the present moment of the river. These shifting temporalities engage listeners through the unpredictability and immediacy, the stream can often be fragile, pending the location, and the listening experience becomes very compelling if the stream is volatile and only active for a short period of time. River Listening harnesses these live streams in various artistic formats, including sound installations and performances, where the live sounds of the river become the foundations for a composition and the work becomes a collaboration with live soundscapes of a river system. These explorations not only enrich the artistic experience but also provides a powerful way for conveying the ecological and conservation focus inherent in the project, and the value of listening to rivers.



Figure 5: Building River Listening Live Stream Kits.

The River Listening live streams enable a highly accessible form of engagement, where audiences, regardless of their physical location, can connect with the soundscapes of a distant river ecosystems. This real-time connection fosters a community of listening and creates a shared experience of global freshwater soundscapes. The accessibility and engagement with the live streams have been most effective through mobile technologies, particularly the River Listening sound walks.

Mobile Sound Walks and Locative Media

River Listening sound walks are designed to engage audiences with the invisible world beneath the surface of their river and shift how communities interact with and perceive their surrounding aquatic environments, fostering a unique blend of place, acoustic ecology, mobility, technology, and ecological awareness.



Figure 6: Leah Barclay testing River Listening sound walks.

The mobile sound walks are immersive audio tours that guide participants along riverbanks. Utilising GPS technology, these walks trigger location-specific soundscapes through a mobile application. The sounds, derived from the project's hydrophone recordings, soundscape compositions and community contributions, are carefully curated to create a narrative that reflects the ecological and cultural significance of each location. The development process involves extensive fieldwork to record and map the acoustic environment of the rivers, followed by consultation, collaboration, and composition to ensure that each soundscape offers an engaging and informative experience.

In River Listening, locative media serves as a critical way to connect the experiences to place and ensure audiences are physically engaging with the river. As participants walk along the riverbank, they encounter the live audio streams, offering real-time engagement interweaving with different soundscapes that reveal hidden aspects of the river's ecology, culture, and history. The integration of the live streaming hydrophones in these experiences not only enhances the sensory experience of the walk but also encourages participants to explore and interact with their environment in new ways. Participants are not passive audiences in this experience; they become active explorers, composing their own soundscapes based on how they walk and engaging in a dialogue with the environment. This engagement is particularly aligned with the Everywhen, as it allows participants to experience the temporal and spatial dimensions of river ecosystems in a deeply personal and embodied way.

The sound walks have proven to be powerful tools for community engagement. They provide an accessible and novel way for people of all ages and backgrounds to connect with their local waterways. By participating in these walks, community members develop a stronger sense of place and a deeper understanding of the ecological and cultural importance of rivers. This connection fosters a sense of responsibility towards these environments and provides education about the value of freshwater ecoacoustics. These experiences also explore new paradigms for environmental engagement, they offer a form of experiential connection that is difficult to facilitate in traditional conservation approaches.

The audio content published in the River Listening sound walks is always developed in consultation with the local community. Creative and scientific field recording approaches can differ in the field, but critical considerations for the River Listening team have always been around consent, collaboration, and permission. All the River Listening locations have evolved through relationships within the local community, deep listening onsite, invitations to record, and collaborations in the outcomes. River Listening became a model to look at more ethical ways of recording in the field, and sharing the resulting recordings, with reciprocity, collaboration, and co-design at the core of how those models evolved. An important part of this project was also ensuring the creation and installation of River Listening sound walks was accessible to young people and the project has always been committed to creating accessible pathways for youth to engage with art-science practice, which has had very positive outcomes. As an example, a River Listening workshop in Hull in the UK, pictured below on a freezing cold day with torrential rain, yet the team still had groups of enthusiastic children enthralled by hydrophones and all asking their parents for hydrophones for Christmas.



Figure 7: River Listening workshops, Hull, UK.

River Listening ISEA2024 Creative Work

At ISEA2024, the River Listening project returns to the 2014 foundations of the project with a live streaming hydrophone in the Brisbane River. The impacts of climate change, often less perceptible in aquatic environments compared to

terrestrial ones, will be brought to the forefront through this immersive auditory experience, through the addition of community voices within the soundscapes. The work explores the interdisciplinary nature of River Listening, bridging art and science to explore the cultural and biological diversity of freshwater ecosystems. The extensive database of Brisbane River hydrophone recordings, collected over a decade, are mixed with the live streaming hydrophone, and available live through a new customised design mobile application and website launching for ISEA2024. In this context, global audiences can experience the work live online, while local audiences can experience immersive sound walks and guided dusk kayak tours along the Brisbane River, integrating live mixes of underwater soundscapes. This provides a unique sensory experience with the Brisbane River and a deep reflection on the foundations of the River Listening project. The live soundscapes form a 24-hour composition every day across ISEA, a blend of historical recordings and real-time hydrophones, creating a generative audio environment that immerses listeners in the unseen world beneath the Brisbane River's surface. This experience not only connects the audience with a local place-based experience, but also resonates deeply with the ISEA theme by exploring time and space and the past, present and future of the Brisbane River.



Figure 8: River Listening sound walks on Brisbane River.

The new mobile application, launching in 2024, represents a significant advancement in locative media with the integration of live hydrophones. The app is designed in response to the experiences of delivering River Listening locative media walks across the world over the last decade. As a new feature, the app introduces a live, generative sound mix of the Brisbane River, that will respond to environmental conditions and will be accessible throughout the duration of ISEA2024. Its design includes geolocated points along the river, connecting ISEA venues and enabling users to experience the river's soundscapes as they move through different locations. This innovative use of augmented reality and GPS-triggered audio exemplifies the project's commitment to using technology creatively for accessible environmental engagement. This work offers a compelling way for audiences to engage with the Everywhen theme and by

combining scientific research with media art, the project not only raises awareness about the urgent need for freshwater conservation, but also inspires a deeper embodied connection with place.

River Listening Next Steps

As the project reflects on a decade of development, the research team are actively designing the future directions of the project. These next steps are envisioned to further technological advancements, deepen the integration of art and science, and expand the community engagement and education pathways.

One of the primary future directions involves embracing emerging technologies to enhance ecoacoustic monitoring. This includes the integration of advanced machine learning and artificial intelligence algorithms to analyse the vast amounts of acoustic data more efficiently and accurately. Such technology could transform the field, indicating ecological shifts or environmental threats, and bring a wider attention and awareness to the field of freshwater ecoacoustics. Additionally, there is potential to develop more sophisticated and resilient live hydrophone systems that can provide higher quality recordings and operate in a wider range of environmental conditions for longer durations. The current focus of the project is exploring a series of new approaches working towards a network of permanent live hydrophones in Australian rivers that will inform the development of a live public sound map of Australia's freshwater ecosystems. The use of augmented reality and virtual reality technologies also presents an exciting avenue to create more immersive and interactive soundwalk experiences that focus on the emerging possibilities of spatial audio. These experiences will be explored as an engagement and wellbeing tool through the next stage of the River Listening project.

Community engagement remains a central focus of River Listening, with plans to expand its reach to more communities and river systems globally. This includes conducting more participatory workshops, educational programs, and public events that bring local communities closer to their waterways. A significant focus will be on involving and empowering underrepresented communities and being led by Indigenous knowledge and perspectives throughout the project development. By doing so, River Listening aims to foster a more inclusive and diverse dialogue around freshwater conservation and highlight the critical value and importance of First Nations knowledge in river management.

River Listening also aims to influence environmental policy and advocacy. The goal is to see ecoacoustic monitoring recognised as a valuable tool in environmental assessment and decision-making processes, which is slowly coming to fruition. The project's innovative use of hydrophone technology and ecoacoustics has contributed to our understanding of freshwater ecosystems. This work is critical in an era where rivers face increasing threats from pollution,

climate change, and human interference. The field of ecoacoustics has been enriched by the methodologies and findings of River Listening, the project has pushed the boundaries of this emerging discipline, demonstrating the potential of sound as a tool for ecological monitoring and research. It has shown that the acoustic signatures of rivers can be powerful indicators of their ecological state, providing a non-invasive and cost-effective means of studying aquatic biodiversity. Through live streaming hydrophones, sound walks, locative media, and public installations, the project has made the science of ecoacoustics accessible and engaging to a diverse audience. These initiatives have not only educated the public about the importance of river conservation but have also inspired a sense of wonder and connection with global river systems. The project has successfully fostered a global community of listeners and advocates, united by a shared interest in the health and future of our rivers.

River Listening contributes to a broader understanding and appreciation of freshwater ecosystems and aligns with the Everywhen, exploring the past, present and future of rivers as temporal and spatial tapestries rich with sound, biodiversity, culture, and stories. This project continues to explore the value of interdisciplinary collaboration and the impact that creative approaches can have in environmental science and conservation. River Listening is part of a network of interdisciplinary and interconnected projects are designed with a sense of optimism about the future and a commitment to reciprocity within the research. This work has a focus on facilitating connections between art, science, and technology to mobilise local and global communities to listen, connect, collaborate, and care.

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Author Biographies

Dr Leah Barclay is a sound artist, designer, and researcher who works at the intersection of art, science, and technology. Leah's research and creative work investigates new methods in ecoacoustics, exploring the soundscapes of terrestrial and aquatic ecosystems to inform conservation, scientific research, and public engagement. She has been the recipient of numerous awards, and her work has been commissioned, performed, and exhibited to wide acclaim internationally by organisations including the Smithsonian Museum, UNESCO, Ear to the Earth, Streaming Museum, Al Gore's Climate Reality, and the IUCN. Leah leads several research projects including Biosphere Soundscapes and River Listening, which focus on advancing the field of ecoacoustics. The design of these interdisciplinary projects is responsive to collaborating communities and involves the development of new technologies, including remote sensing devices for the rainforest canopy and hydrophone recording arrays in aquatic ecosystems. Leah is the Discipline Lead of Design at the University of the Sunshine Coast, where she is also co-leading the Creative Ecologies Research Cluster.

Dr Toby Gifford is a designer, creative coder, and interdisciplinary media arts practitioner, with a particular interest in virtual/augmented reality and immersive installation. He has worked across industry and academia at the intersection of art and technology, with extensive professional experience in software programming and systems design. His research spans a broad range of areas including: application of artificial intelligence to the creative industries; environmental sensing for ecosystem health monitoring; and modelling and data visualisation to aid design. Toby is a Lecturer in Design at the University of the Sunshine Coast, where he is also co-leading the Creative Ecologies Research Cluster.