Active Listening IoT Device for Little Tern Conservation Projects

Emran Yasser Moustafa
School of Informatics
University of Edinburgh
Edinburgh, UK
e.y.moustafa@ed.ac.uk

Abstract— The Little Tern is a declining migratory shorebird that breeds along the coasts of the UK and Ireland. Its continued persistence is threatened by several pressures: loss of breeding habitat to coastal development, increased predation, and human disturbance from recreational beach use. Volunteer-led conservation efforts, such as the Little Tern Project, aim to protect the species by monitoring colony disturbances, warding off predatory threats like foxes and gulls, and engaging beachgoers to reduce accidental disturbance. However, many such projects are heavily understaffed, making it difficult to vigilantly cover long stretches of coastline. In this project, we propose a low-cost IoT device that acoustically monitors Little Tern nesting areas, deployable as an array along the colony perimeter to localise disturbance events. The device can be paired with other IoT devices, such as the smartphones of beach wardens, to alert them in real time to potential nest disturbances, enabling them to respond faster and more consistently to disturbances they would otherwise miss.

I. Introduction / Background

The Little Tern is one of the UK's rarest breeding seabirds, migrating from West Africa each spring to nest on the coasts of the UK and Ireland. Unlike most other tern species in these islands, it nests directly on mainland sand and shingle beaches, leaving it acutely vulnerable to recreational disturbance, predators, and tidal flooding. In Ireland, breeding is now restricted to a handful of east coast sites — principally Baltray (Co. Louth), Kilcoole (Co. Wicklow), and Wexford Harbour — with several historic colonies abandoned due to recreational pressure.

Survival therefore depends on active in-person conservation. The UK Little Tern Project coordinates work across more than 20 sites; in Ireland, Baltray and Kilcoole are wardened by Louth Nature Trust and BirdWatch Ireland. Volunteers erect fencing before the breeding season, then patrol throughout summer, monitoring nests, redirecting beachgoers, and deterring predators. Any disturbance flushes incubating adults from the nest, exposing eggs and chicks to overheating, cooling, and predation; repeated disturbances can drive colonies into abandonment.

Volunteer numbers are limited, and the stretches of coastline to monitor are often vast. In this project, we propose a low-cost IoT device that supplements coverage by acoustically monitoring Little Tern nesting areas and alerting wardens in real time. Deployed as an array, such devices could also localise disturbances across the beach, reducing the proportion of events that go undetected and contributing to the conservation of Little Terns and other breeding seabirds.

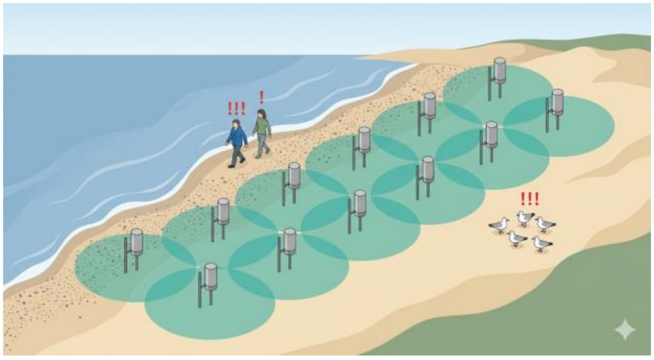

Figure [1]: AI Generated concept for listening device for Little Tern disturbances.

II. Related Work

Little Tern Disturbances

McManus [2], studying the Kilcoole colony in County Wicklow, found that Little Tern parents with higher nest attendance produced more hatchlings than their conspecifics, primarily because unattended eggs cool below sustainable temperatures (and are also vulnerable to predation). Time on the nest is therefore directly linked to reproductive output and colony persistence.

Disturbances are damaging precisely because they break this attendance: incubating adults flush from the nest, exposing eggs and chicks for the duration of the flight. Briel et al. [1] quantified this effect at a colony in the Algarve, finding that joggers elicited the strongest response and walkers in conversation as the weakest. Other recorded sources of disturbance included heat stress (the single largest cause), groups of walkers, gulls, sole walkers, dog walkers, and off-leash dogs. Volunteers are responsible for reducing the frequency and severity of these disturbances, but this is difficult given limited staff numbers and the large areas they must cover.

IoT Devices for Habitat Monitoring

Low-cost open-hardware IoT platforms have become established for biodiversity monitoring. Hill et al. [3] present a low-energy open-source acoustic detector built around a MEMS microphone and programmable microcontroller, widely adopted for monitoring wildlife vocalisations and anthropogenic noise.

Such systems can also drive real-time alerts to field staff. Zualkernan et al. [4] present an architecture combining an edge device (e.g. Raspberry Pi or Nvidia Jetson) with a quantised CNN for animal species detection, with results forwarded via LoRaWAN. However, this approach depends on relatively expensive edge hardware per node, which may not be viable for voluntary projects, which motivates a design that offload inference to the cloud and keep per-node cost low.

III. Imagined or existing prototype sketches/drawings/photos

Device Outline and Vision

Below is an overview of elements of a possible design for such a device. I have not developed a prototype or generated detailed 3D renders, but I have sketched up concepts that I would hope to develop further throughout the summer school.

The device is envisioned as a small, self-contained sensor unit deployed in or near a Little Tern breeding area (a cordoned-off section of shingle beach), operating autonomously throughout the breeding season (May to July/August) and forwarding alerts to wardens via their smartphones. The intended user is a volunteer warden patrolling a long stretch of coastline, who cannot directly observe every part of the colony at once and who needs timely notice of disturbances occurring within a specified distance of the devices and breeding areas.

In our concept, each device would act as a low-cost acoustic sensor, streaming flagged audio segments to a cloud-based service for classification of disturbance type. Deployed as an array across the breeding area, these nodes could also enable time-difference-of-arrival processing to localise disturbances on the beach.

Sensing

The primary sensing modality for this device is audio. Relevant disturbances of Little Tern nests, such as human voices, footfall on shingle, dog barks, gulls, and tern alarm calls themselves, have distinct acoustic signatures, making a microphone a potentially useful and orders-of-magnitude-cheaper sensor modality for this application, particularly in comparison to camera-based systems. A MEMS microphone (e.g. Knowles SPH0645, ~£5) feeding a low-cost microcontroller such as an ESP32-S3 (~£8) could provide a workable node at well under £20 in parts, broadly following the design pattern established by AudioMoth [3].

Communication

Each device may send data to the cloud over 4G/LTE-M cellular, which appears to be the simplest option given that continuous audio streaming exceeds LoRaWAN's payload budget. Quantisation of the audio signal may also be possible using an embedded DSP on the ESP32 to reduce bandwidth. A SIM-equipped module such as the Sixfab Cellular IoT HAT attached to the ESP32 may be sufficient.

Figure [2]: ESP32 Microcontroller

Compute

To keep per-node cost low, classification would be offloaded to the cloud, leaving on-device compute to audio sampling, filtering, and uplinking flagged segments to the cloud. Specifics about the cloud service and classification approach are out of scope here. An Espressif ESP32-S3 (~£8) appears to be well-suited for our application: dual-core 240 MHz, native I²S for MEMS microphone input, SIMD instructions for audio feature extraction, on-chip wireless, and Espressif's ESP-SR library covering VAD and noise suppression.

Form and Use

Each device would be housed in a small enclosure mounted on a short stake, positioned along the beach in the nesting areas at intervals with overlapping acoustic coverage suitable for time-difference-of-arrival localisation. Power would be supplied with a small lithium battery, which I believe should provide enough energy through the breeding season (May to July/August). Units would be deployed by wardens at the start of the season alongside the existing fencing work, and retrieved at the end, requiring no on-site maintenance beyond occasional checks.

IV. Responsible innovation

There is a clear link between this device and the potential for societal impact. The Little Tern is just one example of seabirds with a declining population and birth rates due to increased coastal development. Moreover, this is likely a trend we will see continuing into the future, as available building space continues to encroach on land previously used by local wildlife.

Unfortunately, initiatives similar to those for Little Terns are often underfunded and understaffed. Devices like the one presented in this paper would support conservation teams at a reasonable cost, extending their ability to respond to disturbances in habitats sensitive to human and predatory disturbances areas, improving breeding of such animals and hopefully recovering once endangered populations.

V. Author bio(s) / experiences

I am a first year PhD student at the School of Informatics at the University of Edinburgh. My work takes place in the Centre for AI in Assistive Autonomy, where I research assistive technology for driving. In particular, I am working on building a shared autonomy framework for assistive driving, with my work touching on topics of interactive planning, statistical human modelling, and control systems.

I have a background in engineering, holding a BEng and MEng in electronic and computer engineering, graduating with first-class honours. During my studies I have worked on a handful of hands-on embedded systems and signal processing projects. I was also the lead of our university's Formula Student AI team, where we were continuously required to develop sensors rigs for our vehicle, calibration, and systems integration. That being said, I am drawn to the summer school as my knowledge and experience of independently building embedded systems projects is fairly low. I would like to learn how to effectively prototype and test these devices, particularly at scale and for manufacturing.

Unrelated to my PhD research, I am interested in Little Tern conservation. Many of my hometown friends and I have taken part voluntarily in the Little Tern colony in Baltray, Co Louth, part of Louth Nature Trust. I know first-hand how wonderful these birds are, as well as the serious lack of volunteer staff to support initiatives like the Little Tern Project.

VI. Acknowledgements

I would like to thank my supervisor, Prof. Subramanian Ramamoorthy, for allowing me to apply and hopefully take part in this summer school.

I would also like to thank my hometown friends Ivan and Liam for our conversations about Little Tern conservation, as well as their feedback on this project proposal.

VII. Refernces

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