MASTS TECHNOLOGY, PLATFORMS & SENSORS FORUM

Project Report - Small Grant

Building and evaluating recorders for seabird vocalisations at nesting sites with human disturbance

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Rationale and project background Populations of nesting seabirds have been declining for many species, for several reasons, e.g. decreasing prey densities. There is concern from the National Trust for Scotland (NTS) and other organizations that tourists may impose additional stress to frequently visited seabird colonies, affecting their behaviour, and possibly also nesting success. St Abb's Head at the Scottish Borders coast has one of the largest onshore breeding seabird colonies in the UK, and was designated an SPA in 1997 (extended in 2009 to include a 1km zone offshore). The site is visited by > 20,000 clifftop visitors during the breeding season. Likewise, the coves underneath the cliffs are popular boating destinations and frequently visited, e.g. by divers. Many dive boats at St Abbs operate relatively noisy elevators to help the diver in and out of the water. To investigate whether the seabirds are suffering from "anthropogenic coastal squeeze" at St Abb's Head, which would call for mitigation through improved visitor management, a longer-term study was started in 2015, in collaboration with the National Trust for Scotland (Liza Cole) and with funding from the AEB Trust. The success of Kittiwake (*Rissa tridactyla*) nests in response to clifftop and water-based visitors is assessed annually by Edinburgh Napier University (ENU) MSc students, at 9 plots with differing degree of human encroachment (~25 nests monitored per plot). Since 2017, the effect of boats on the loafing behaviour guillemots (*Uria aalge*) is additionally observed.

The small grant from the MASTS Technology and Sensors Forum allowed us to build/obtain two devices to record and analyse airborne ambient sound and seabird vocalization (ongoing since 2016), complementing above mentioned projects. This grant report gives a brief description of the recorders and their deployment in the field and presents some of the so far developed methods (no off-the-shelf analysis tool was available) along with some preliminary results. The work was conducted by French placement student Anne Sainpol (University Lyon) in collaboration with Diele, and with additional advice from Johnson. Anne was hosted at ENU between May and August 2017.

Technical details, performance and deployment of the recorders The weatherproof recorders (Fig. 1), built by Mark Johnson, were connected via USB cable to a laptop and deployed using the software Soundtrap Host V2.08 (http://www.oceaninstruments.co.nz/downloads-beta/). Default settings were *High Pass Filter* – off; *PreAmp Gain* – high; *Sample Rate* - 96 kHz; *Detector* – none; *Logging Interval*: 10 sec. The devices were able to record continuously for up to 12 days. Audio wav. files (each 3 hrs long, 2.93 GB) were downloaded overnight using the software Soundtrap Host V2.08 (http://www.oceaninstruments.co.nz/downloads-beta/), whilst the recorders were simultaneously charged. They performed reliably, without failure.

Fig. 1. Continuous sound recorder used for recordings of airborne sound at St Abb's Head, Berwickshire.

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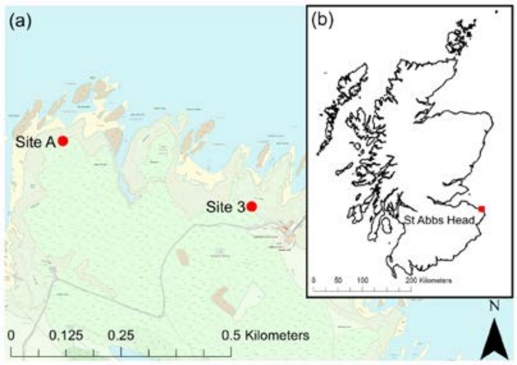

Fig. 2. Map of St Abb's Head, with (a) approximate locations of the two sites where the recorders were deployed and (b) the location of St Abb's Head in Scotland. (Edina Digimap); Clough, A. 2017.

The recorders were installed at two plots with reported high boating frequency at St Abb's Head, during the seabird breeding season (May - August) in 2016 and 2017. They were hidden under small rocks, with microphones facing towards the coves, and secured in the ground with tent pegs. Data were downloaded once per week.

Method development A MATLAB script written by Mark Johnson was used to translate the audio wav.files into a matrix of noise levels (dB), a vector of the frequencies (Hz) and a vector of the time (seconds), basically translating the files into numbers for further analysis. The script allowed to analyse 12 hrs (= four 3hr audio wav.files) in one run. Additional MATLAB functions (MATLAB v9.2) for automatized analyses of the audio wav.files were programmed, e.g. to detect, count and measure durations of "noise events" in a given file. Firstly, however, frequencies and detection limits had to be defined. Recordings with knowingly high boat presence during the breeding season were selected (as known from observational field data), listened to, and the timestamp of boating (and other) auditory events noted. Respective short file sequences were then extracted using the freeware VLC, and plotted in MATLAB. To remove unwanted background noise, filters using the software Audacity were tested, but the idea was discarded since e.g. elevator noise (which is varying in noise level) was partly masked and/or no longer distinguishable from lower frequency guillemot vocalization, when applying the filters, and bird calls were loud enough without filters.

dB

Noise spectra were separated into categories (fmin, fmax) characterizing boat motors, boat elevators, guillemot and kittiwake calls (Table 1), by visually inspecting the MATLAB spectrograms. Overlapping frequencies (such as between elevators (1000- 1500Hz) and guillemots (1000- 2500 Hz), or Kittiwakes (1500– 5000 Hz)) were excluded from further analyses, to generate frequency ranges that best represented the respective categories for automatic detection.

Table 1. Frequency ranges defined for the different sound source categories (excluding frequency overlaps) identified in the recordings of airborne sound at St Abb's Head.

Sound category	Boat motor	Elevator	Guillemots	Kittiwakes
Frequency Range	50-300 Hz	1000-1050 Hz	1200-1300 Hz	3000-5000 Hz

Using the minimum and maximum values of the range of frequency of each sound category, a MATLAB function was created to calculate the sum of sound pressure of each frequency range, and then to generate respective sound curves (e.g. for boat motor noise all sound pressures between 50 Hz and 300 Hz were summed up). This was done by defining/using limits of noise levels for each category – i.e. when the curve of the range of the frequencies of a given category was exceeding certain noise level limits (i.e. limits 1,2,3), this was considered as noise of this category being present. For example, Limit 1 corresponds to the minimum noise level where the noise of a given category is audible.

Preliminary results

Objective 1: Detection of cumulative time of audible boats A script to automatically detect/ calculate the time that audible boats are present at the two studied plots was developed using respective frequency ranges and limits. The data were compared with observational data obtained during a MSc project (Clough 2017). In 10 out of 14 cases, the MATLAB detected times were shorter than those noted by the observer. One reason could be that the observer termed a boat presence as audible while it may only have been noisy upon its arrival and departure (i.e. when driving) whereas motors of boats waiting for surfacing divers are typically a lot less noisy (albeit audible by the human ear) since in idle. The percentage of boat motor time detected by MATLAB was found to vary strongly at high wind speeds of 16- 18 mph. At lower wind speeds, detection was around 50% compared to on-site observations, with a large error, again probably due to motors being in idle. At high wind speeds motors may have been on, but masked by the elevated background noise.

Further analyses run with the developed MATLAB code revealed that the coves at plot A and 3 were less frequented by dive boats on days with high wind speeds and rain, corroborated by observational data. Water-based activities were highest on weekends, compared to Fridays for example, again a good reflection of the divers' behavioural patterns.

The pattern of mean dB level of the frequency band corresponding to boat motor noise in function of time of day differed between weekends and weekdays. At weekends, the noisiest time in the boat motor frequency range was between 9 and 12 am, whilst during the week it was noisier in the later afternoons. This corresponds well with observed diver behaviour. It is interesting to note that the distribution of noise differed throughout the day, but in total the average sound level through the day was the same for both weekends (42.46 dB) and weekdays (42.51 dB). Future analyses will incorporate wind, tide and sea state.

Objective 2: Detection of elevator noise and the birds' vocal responses Several analyses were performed attempting to detect elevator noises by a respective MATLAB code. Since the frequency of the elevator noise is very similar to the lower frequencies of guillemot calls, it was not possible to produce trustable results due to the detection of false positives. In the future, we plan to analyse the noise level of the harmonics of the elevator noise. If a pattern of the noise level of the harmonics of the elevator noise compared to the noise level of its fundamental frequency (f0) can be found, it may be possible to detect the elevator noises in the audio files, and to disentangle between the two sound sources.

Objective 3: Detection of the bird colonies' nocturnal resting phase Noise levels of the frequencies formerly identified for guillemot and kittiwake vocalization were plotted in function of time and visually analysed. A recording from April 2017, before the arrival of the birds, reveals environmental background noise (most likely tide-related noise) within the same frequency as that of kittiwake and guillemot vocalization (Fig. 3), which needs to be considered for future analyses. Fig. 4 presents an example when the birds were already on site, revealing their nocturnal resting pattern using vocalization as a proxy. It was influenced by sunset and sunrise, roughly lasting 7 hrs. Tide related background noise has not been filtered out here, yet is unlikely to be the sole factor having caused the pronounced dip of the curve (e.g. no similar decrease in noise with progressing ebb tide in the morning). Future analyses will consider cloud cover, moon phases and tides, compare nights in different months, and attempt to filter out any background noise (audacity software).

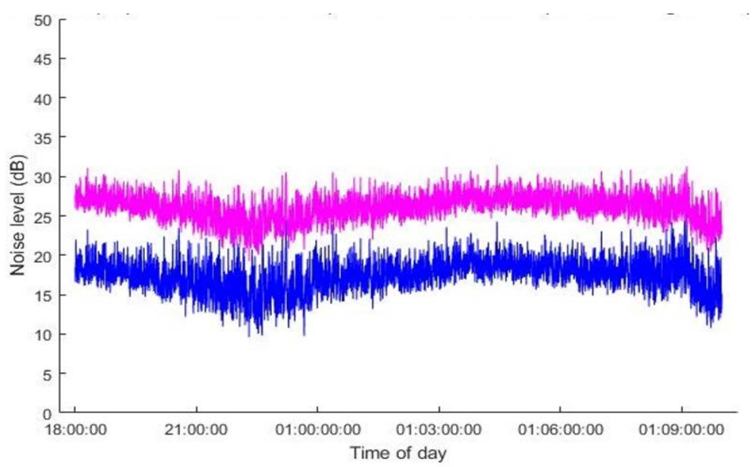

Fig. 3. Preliminary analysis of airborne sound recordings from environmental background noise at St Abbs's Head, 12/04/2017. Blue curve: Noise levels corresponding to frequency ranges of guillemot (red) and kittiwake (blue) vocalization. Low Tide 12/04/2017 - 22:32; High tide 13/04/2017 - 04:35; Low tide 13/04/2017 - 10:38.

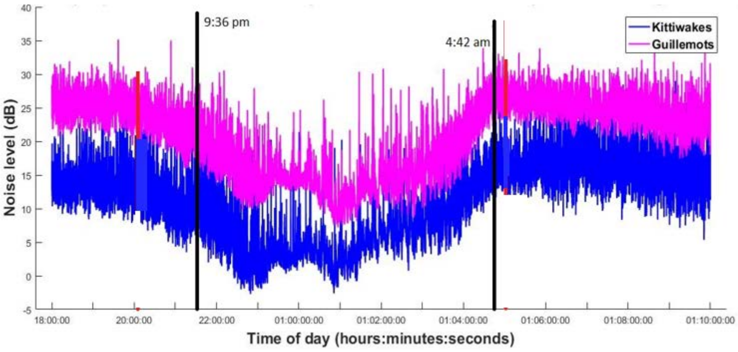

Fig. 4. Preliminary analysis of airborne sound recordings at St Abbs's Head, 25/26/05/2017, Plot A. Black vertical lines: Times of sunset and sunrise. High tide 25/05 - 20:26; Low tide 25/05/2017 - 21:17; High tide 26/05/2017 - 03:24, Low tide 26/05/2017 - 9:39 (Berwick tide table).

Objective 4: Analysis of the birds' vocal responses to boat noise To investigate whether the seabirds call louder in response to boat noise, a MATLAB script was written, considering the fact that the intensity of bird calls varies naturally. The aim was to compare the number of "loud bird call events" of times with and without boat motor noise, and the average frequency of the calls. Three noise limits each were defined for kittiwake and guillemot calls (limit 1, 2 3 - corresponding to high noise level calls in increasing intensity). The average noise levels of the calls were analysed for 26 different days. Kittiwakes and guillemots seem to vocalize differently in response to boat noise: Kittiwake vocalization was generally louder when boat motor noise was absent, whereas the opposite was true for guillemots. However, since the frequency of the calls of the latter are closer to the frequency of boat motor noise, further analysis (and field observation) is needed to avoid false positives. We further assessed the average proportion of boat motor noise events (boat noise level limit 3) that was followed by noisy bird vocalization (above noise level limit 1 of the respective species). The birds reacted to 1 out of 5 loud motor events (19.1% and 21.3% for kittiwakes and guillemots, respectively, 26 analysed days).

Preliminary Conclusion and outlook The preliminary data analyses with the methods developed so far have yielded some interesting first results regarding automatized detection of cumulative boat time, the duration of the birds nocturnal resting phase, and their vocal responses to loud boat noise. Further analyses need to better incorporate weather and tide data to help develop methods omitting unwanted ambient background noise which can produce false negatives (masking) or false positives. We plan to install a weather station at St Abb's Head in 2018 to get continuous wind (and other) weather data, permitting a more nuanced data analysis. We will also analyse a larger set of data, including data from different dates, months, years, to test whether the identified trends hold true across time. We will further try to develop an automatized method to better assess the effects of the very sudden elevator noise of varying frequency. Finally, it is important to consider that we are not be able to determine the number of total boats present at any time (including e.g. silent kayaks, idling or moored boats) through analysis of sound recorded by the current devices. However, with increasing boat number, visual disturbance increases (e.g. through people on board), which may affect the birds' behaviour and vocal responses. Disentangling the effects of auditory and visual cues when analysing the impacts of anthropogenic encroachment on the birds' behaviour and fitness is a remaining challenge.