Acknowledgements

Paul Roe
Mike Towsey
Why detect species?

• We may want to
  • identify presence/absence, abundance or activity of individual species — study organism, rare, threatened
  • quantify numbers of species in an area in relation to habitat, anthropogenic disturbance — grazing, fire, urbanisation, etc.
• Determine effects on ecosystem “health” — climate change, logging, agriculture, changes in land use etc.
Traditional Monitoring

• Fauna & vegetation surveys
Traditional Audio Monitoring
Traditional Monitoring

Advantages:
— Provide highly accurate information on species presence/absence, activity & richness

Limitations:
— Highly spatially & very highly temporally restricted
— Expensive & time consuming to get a lot of data
— Limited to expertise that is present
— Observer bias
Autonomous Recording Units — Record Sound \textit{in situ}

Advantages —

• Non-invasive
• Relatively cheap
• Collect extensive audio data
• Permanent record
• Limited only by storage capacity — which continues to increase rapidly
Autonomous Recording Units — Record Sound *in situ*

Disadvantages —

• Restricted to species that make some kind of noise
  • Birds, frogs, insects, some fish, some reptiles, many mammals

• There is so much data analysing it becomes a problem!
Species Detection – Individual Species

• Humans listen & recognise calls – subsampling in time

• Songscope-type recognisers

• Human-in-the-loop combinations
What’s better – ARUs or traditional methods?

• Autonomous Recording Units (ARUs) versus point counts to quantify species richness and composition of birds in temperate interior forests.

• Short-term monitoring, point counts may probably perform better than ARUs, especially to find rare or quiet species.

• Long-term (seasonal or annual monitoring) ARUs a viable alternative to standard point-count methods

What’s better – ARUs or traditional methods?

- This study used ARUs almost exactly like point counts.
- Human observers at exactly the same time & place as recorders perform better – distant calls & difficult to hear calls, visual recognition.
- Used Songscope™ to ID calls.
- Even using this method – ARUs larger samples over time produced better samples than human visits.

Species Detection – Individual Species

- Humans listen & recognise calls – subsampling in time
- Songscope-type recognisers
- Human-in-the-loop combinations
Species Detection – Individual Species

Songscape-type automated “recognisers”

• possible based on several different kinds of algorithms: fuzzy logic, dynamic time or Hidden Markov models, oscillation detection, event or syntactic pattern recognition

• Speech recognition models are not very successful on environmental recordings because of their need for limited background noise

• Animal calls vary more than human speech

• Variable success dependent on type of background noise

• Need to be trained for call & environment
Species Detection – Individual Species

• Human-in-the-loop combinations
  – best outcomes at the moment
Indices of Ecosystem Health

Ecoacoustics, Soundscape Ecology

— Use Acoustic Indices

— Characterise animal acoustic communities, habitats, overall ecological state
Acoustic Signatures

• Natural soundscapes should be habitat specific.

• Ambient sound in **different types of forest** was recorded

• Used digital signal techniques and machine learning algorithms

• *Even fairly similar habitat types have specific acoustic signatures distinguishable by machine*
Acoustic Complexity Index

- ACI highlights and quantifies complex biotic noise (i.e., bird calls) while reducing effects of low-variability human noise (i.e., airplane engines) Sueur et al. 2014. Acta Acustica 100:772-81.

Fig. 3. Spectrogram representing a typical scene of the airplane noise overlapping the natural soundscape.
Can soundscape reflect landscape condition?

- Soundscape patterns vary with landscape configuration and condition
- 19 forest sites in Eastern Australia
- 3 indices soundscape = landscape characteristics, ecological condition, and bird species richness
- acoustic entropy (H), acoustic evenness (AEI), normalized difference soundscape index (NDSI)
- **Anthrophony** was inversely correlated with biophony and ecological condition
- **Biophony** positively correlated with ecological condition

Fuller et al. 2015. Ecological Indicators 58:207-15
Overall Signatures *Not For Species Detection*
Species Richness Applications

• We want to know not only that a system is rich or diverse, or different from other systems, but **which species** are present...
How to bridge the gap?

**BIO-ACOUSTICS**
- Single vocalisations
- Species recognition

**ECO-ACOUSTICS**
- Soundscape ecology
- Ecosystem processes

Time scale = seconds

Time scale = days > months > years
Combination Approaches

• Estimating avian species richness from very long acoustic recordings.
• Used acoustic indices to summarise the acoustic energy information in the recording.
• Randomly sampled 1 minute segments of 24 hour recordings - achieved a 53% increase in species recognised over traditional field surveys.
• Combinations of acoustic indices to direct the sampling - achieved an 87% increase in species recognized over traditional field surveys.

Sampling?

- Different sampling protocols listening to 1 minute samples of a 5-day real sound sample - Towsey et al. 2014. Ecological Informatics 21: 110-119.
Many Indices

- Average signal amplitude
- Background noise
- Signal-to-noise ratio (SNR)
- ACI
- Acoustic activity
- Count of acoustic events
- Avg duration of acoustic events
- Entropy of signal envelope (temporal entropy = H[t])
- Mid-band activity
- Entropy of average spectrum

(= H[s])
- Entropy of spectral maximum
(= H[m])
- Entropy of spectral variance
(= H[v])
- Spectral diversity
- Spectral persistence

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Visualisation of Large-scale Recordings – Using Indices to Reduce “Noise”

Figure 3: The false-color spectrogram on the right was obtained by combining the ACI, 1-H[t] and CVR spectrograms in red, green and blue colors respectively.
A visual approach to automatic classification from recordings in the wild

- A multi-instance, multi-label framework on bird vocalizations to detect simultaneously vocalizing birds of different species.
- Integrates novel, image-based heterogeneous features designed to capture different aspects of the spectrum.
- Monitor 78 bird species, 8 insects and 1 amphibian (total = 87 species under challenging environmental conditions)
- The classification accuracy assessed by independent observers = 91.3% (note not compared to traditional surveys)

Illustration of Sound Interference
Figure 2. Types of anthropogenic and abiotic interfering sounds.
doi:10.1371/journal.pone.0096936.g002
Figure 3. Spectrogram corresponding to a recording with 3 partially overlapping bird species (trainfile005 in NIPS20134B database). The lower part of the spectrum is coloured by the sound of running water and strong wind.

doi:10.1371/journal.pone.0096936.g003
Figure 4. Detected spectrogram blobs of Fig. 3. Derivations and enumeration of the masks. Axes are enumerated according to their pixel index.
doi:10.1371/journal.pone.0096936.g004
Conclusions

• ARUs could be extremely valuable to collect a massive amount of data on species presence/absence, richness
• Massive amount of data is a double edged sword
• ARUs are especially good for rare or (acoustically) hard-to-detect species
• There is a great deal of research to be done in how best to analyse this data
One more thing

• Caller-listeners, rather than just listeners may increase the probability that a rare thing will call

• Such an invention increases the probability of calling by rare species

• Increases detectability of rare species, because then we know WHEN to look for their calls in long recordings
Current work: Detecting Invasive Species

• Detecting the arrival of invasive cane toads on Groote
• Listening & Calling for toads
• Working with the Anindilyakwa Land Council
• Hoping not to get an answer!
Monthly Average Spectrogram

• Averaging values of acoustic indices over consecutive days

• More ‘washed out’ appearance due to averaging

• But seasonal changes in acoustic landscape are clearly visible

• Morning chorus strongest during late winter and early spring

• Night-time Orthopteran sounds are minimal during winter months