Notornis, 2010, Vol. 57: 75-80

Bioacoustic monitoring of New Zealand birds

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Abstract New bioacoustic technologies offer novel ways to monitor bird populations in the field. Bioacoustic techniques can greatly enhance effective field time, enhance survey site coverage, and increase quantification of key time periods such as crepuscular and nocturnal hours. Moreover, digital files provide searchable, independently verifiable records. Historical impediments to the use of bioacoustics have diminished with unit costs declining and data storage capacities increasing. Recent software developments enable rapid extraction of targeted bird calls and facilitate ease of data analysis. This paper details the recent application of bioacoustic technology at a proposed wind farm site in the upper North I, New Zealand. In this case, bioacoustics were employed as a supplement to on-site field observations and as a complement to avian radar technology. Results illustrate the utility of bioacoustic methods, highlighting the range and scale of potential data outputs. In addition to the detection of flight calls and song, audible wing flap noise may provide a further means of identification for some species. Targeted monitoring of migrant birds, cryptic marshbirds, and rare seabirds are identified as potential future applications.

Steer, J. 2010. Bioacoustic monitoring of New Zealand birds. *Notornis 57(2):* 75-80.

Keywords Bioacoustics; New Zealand; birds; monitoring; radar; spectrogram; technology

INTRODUCTION

One of the distinguishing characteristics of birds is their extraordinary diversity of vocalisations. Many amateur and professional ornithologists are able to identify the majority of species in the field by sound alone, and most cryptic species are identified primarily by this means (e.g. spotless crake, *Porzana tabuensis*, and marsh crake, *P. pusilla*; Kaufmann 1987). The recording of such biotic sounds for the purposes of species identification, comparison or analysis comprises the science of bioacoustics. Here I describe the use of new bioacoustic technology to monitor bird populations in the upper North Island, New Zealand.

While bioacoustic techniques for studying bird vocalisations have been used since at least the 1950s, the discipline has grown considerably in the last 20-30 years. Much of this research has focused on fine-scale differences in inter- and intraspecific song characteristics using hand-held directional microphones. However, a number of new bioacoustic recording and analysis technologies and techniques have been developed recently. These are starting to revolutionise the way birds can be monitored in the field. For example, recordings and detailed analyses of contact calls have been used to greatly enhance the detection and subsequent quantification of migrant bird movements in the United States (Evans & O'Brien 2002). While the use of recordings for biodiversity monitoring or species-specific tracking seems an intuitive application of bioacoustic technology, bioacoustics have remained largely restricted to academia. Instead, most field ornithologists continue to rely on call identification via direct listening, and visual observations using traditional optical technologies such as binoculars and telescopes.

Bioacoustic techniques have a number of advantages over traditional approaches to fieldwork (Laiolo 2010). First, they have the potential to greatly enhance effective field time without

Received 11 Dec 2009; accepted 17 Jun 2010
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Fig. 1. A bioacoustic unit situated in rank grass. The 2 containers in the foreground house the laptop (left) and batteries (right). The microphone element is housed within the ceramic pot placed behind.

increasing labour inputs. Powered by solar panels or batteries, remotely placed units can be operated 24-hours a day for as long as necessary. Second, multiple units can be deployed to enhance the coverage of a site. The number of units deployed is limited only by budgetary constraints and time required to analyse recordings. Third, recordings are able to be verified by qualified third parties (Dawson & Efford 2009). Typically, detections of rare or unusual species rely on the credibility of the eyewitness. This person has to identify a call on the spot based on as little as a single vocalisation, greatly enhancing the probability of errors. Fourth, a site can be thoroughly surveyed day *and/or* night and irrespective of visibility. Although daytime surveys may be effective at detecting resident species, the majority of migratory behaviour over many sites may occur at night (Evans & Mellinger 1999). Moreover, peak activity periods generally occur at dawn and dusk; periods which are often logistically more difficult to survey.

Despite the potential benefits of using bioacoustics for biodiversity monitoring the technology has not been widely adopted in New Zealand, largely due to: (1) expense of recording equipment; (2) the use of sound files too large for personal computers; and (3) protracted length of time and difficulty in the analysis of calls. However, recent developments have reduced these obstacles. The cost of recording equipment has decreased while the range of models has increased, and there are now several commercial and voluntary organisations manufacturing reasonably priced bioacoustic units or the key parts for custom constructions. Memory storage on personal computers has also increased such that a standard home computer can now store many weeks of field recordings. In addition, the cost of external storage space has reduced dramatically; and while still providing some impediment to amateurs, recent software developments enable the bird call component of sound files to be rapidly extracted for analysis.

METHODS AND ANALYSES

The following example illustrates the utility of bioacoustic technology in the ecological assessment of a proposed wind farm in the Kaipara District, Northland, New Zealand. Assessment of the potential effects on threatened birds are common components of such surveys (see Powlesland 2009). Internationally, the use of radar technology is an established method of monitoring bird movements at potential wind farms (Harmata *et al.* 1999). Consequently, a DeTect © Advanced Avian Radar System was deployed at the study site (DeTect 2008). The radar system monitors the passage of birds across a site in both the horizontal and vertical planes; thus researchers can track both the direction *and* height of selected targets. However, radar trails are not able to verify species identity without assistance from on-site observers or bioacoustics (Black 1996; Evans 2000; Larkin *et al.* 2002; Farnsworth *et al.* 2004). In this case, bioacoustics were employed both to verify radar trails and to provide a supplement to on-site field observations.

Six bioacoustic devices, known as pressure zone microphones, were deployed at the study site in Mar 2009 (Fig. 1). These microphones were designed specifically to monitor the flight calls of birds, being directed upward and laterally insulated to reduce recordings of ambient song and other noises. Each unit had an inverted cone of detection of approximately 600 m high by 1,000 m wide for low frequency calls in the 2-5 kHz range. For high frequency calls within the 6-10 kHz range the cone of detection was reduced to a volume of approximately 300 m high by 250 m wide (Farnsworth & Russell 2005). Units were constructed from rudimentary components: the microphone circuits comprised a 9V battery and connectors, a capacitor, a carbon film resistor, audio cabling, XLR connectors, a circuit board, and a Knowles EK3029c microphone element attached to a sound-conducting plastic plate (see Evans & Mellinger 1999). Microphone housing principally consisted of a large ceramic flower pot (approximately 35 cm diameter) insulated with bedding underlay. Recordings were made directly onto an HP 2140 Mini note laptop computer using Easy Hi-Q Recorder software.

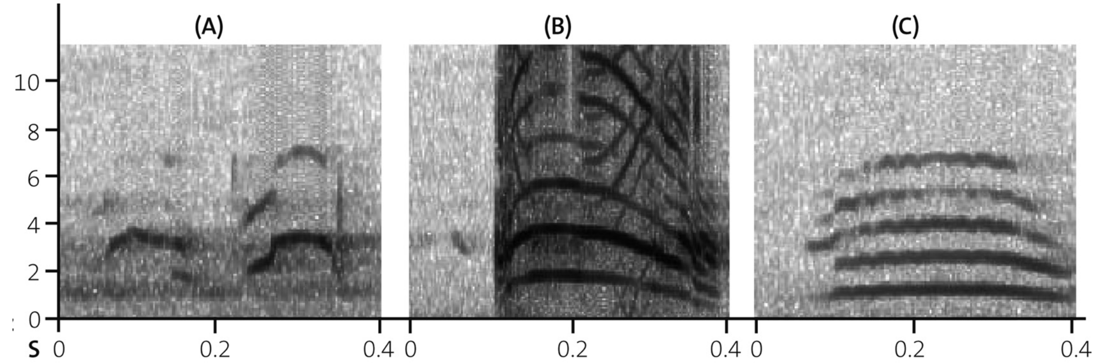

Fig. 2. Vocalisations of (A) pied oystercatcher (*Haematopus ostralegus*; flight call), (B) Australasian harrier (*Circus approximans*; flight call) and (C) morepork (*Ninox novaseelandiae*; song). The harrier call was within close proximity to the microphone, hence the striking harmonics.

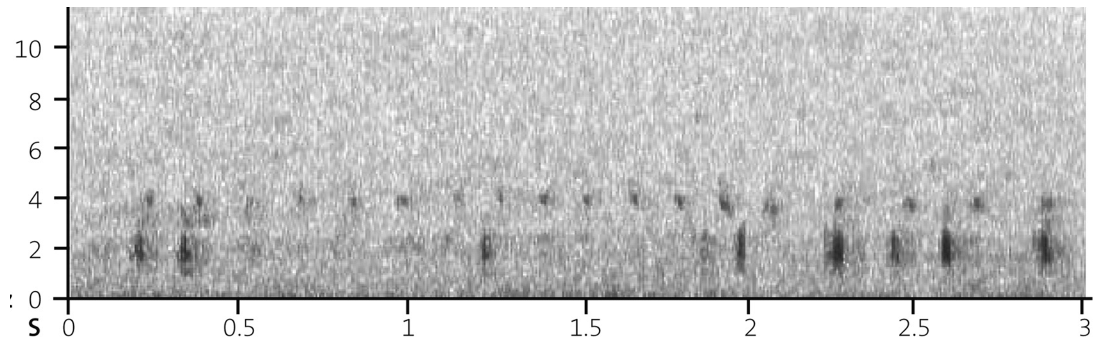

Fig. 3. Duck wing flap noise represented by small regular dots at approximately 4 kHz. Intermittent vertical lines below are flight calls.

The units were run continuously at the study site from deployment in Mar 2009 until the time of publication (units are scheduled for removal in Dec 2010). Each unit's laptop was powered by a bank of 2 R155 deep cycle batteries and a single A12-18 battery to run an attached Rolls MP13 preamp. The batteries were replaced for recharging on a weekly basis in conjunction with downloading each week's recording data. The bioacoustic units were cost-effective, with the total cost of recording equipment for each unit being approximately $360 NZ. Additional costs included the requirement of laptop computers and batteries to power these remotely.

In the present study, bioacoustic data sorting was conducted entirely off-site using the GlassOFire software package (see Farnsworth *et al.* 2004). Each recording was run through 2 initial call extraction programs, Tseep and Thrush. These programs extract calls within the 6-10 kHz and 2.8-5.0 kHz range, respectively. The selected frequencies cover the range of calls exhibited by most North American bird species. However, the cut-off frequencies for the software are not precise and indicate the beginning of a roll-off or lessening of detector sensitivity. Therefore, the software effectively covers the whole range from mid- to high frequencies. Although some species give very low calls below the range of the Thrush detector, such species are still frequently detected with this software. GlassOFire is used to manually distinguish and catalogue call types and eliminate false detections. Each detection is plotted on a graph displaying frequency on the *y*-axis and time on the *x*-axis. The software allows multiple graphs to be displayed on the same screen for rapid processing and species identification. Calls are classified on the basis of their audible characteristics and by comparison of spectrograms (see Fig. 2).

SURVEY RESULTS

For illustrative purposes, a raw analysis of data from 4 bioacoustic units was carried out on a sample of recordings from 20 Mar to 4 Apr 2009. A total of

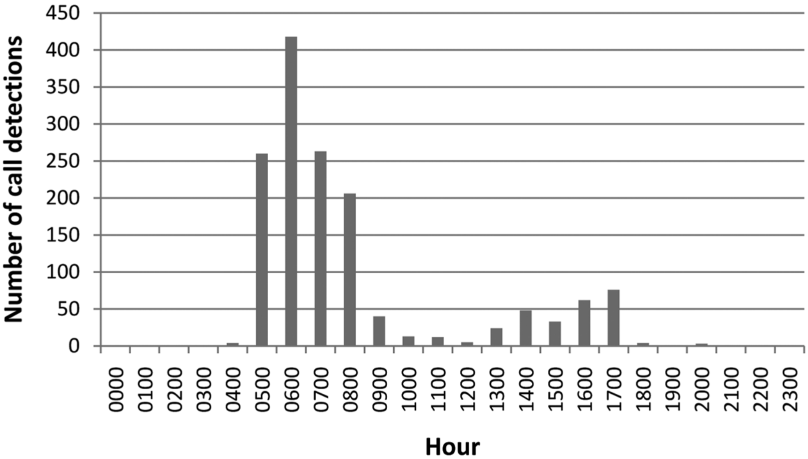

Fig. 4. Number of call detections per hour from a 24 hour sub-sample recorded over 4-5 Apr 2009.

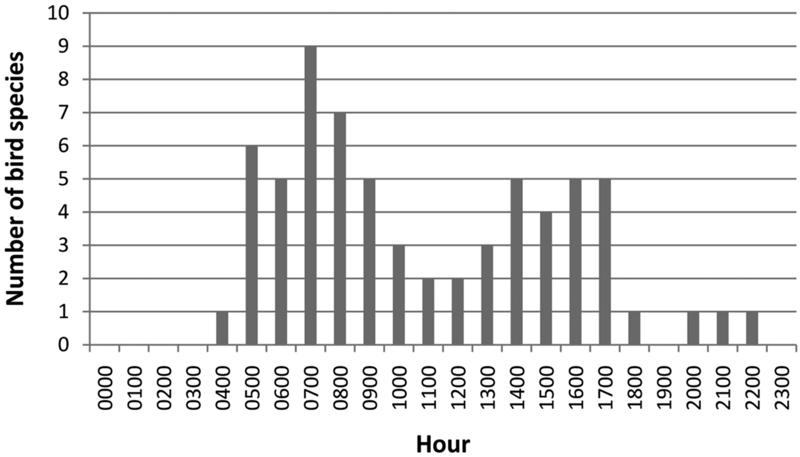

Fig. 5. Number of species recorded per hour from a 24 hour sub-sample recorded over 4-5 Apr 2009.

111,063 detections were extracted from the sound files using Tseep and Thrush. Of these, 19,975 (18%) were manually identified using GlassOFire as bird calls or song, an average of approximately 1.4 calls per minute per unit. Of the detected calls, 65% were in the 6-10 kHz range, while the remaining 35% were in the lower 2.8-5 kHz range. In North America, the flight calls of a particular taxa tend to reliably fall into only one of these frequency ranges. For example, most warbler and sparrow (Family Passeridae) calls fall in the 6-10 kHz range, whereas thrushes (Family Turdidae) tend to call in the 2.8-5 kHz range. It is not known if similar patterns occur among New Zealand species. However, the calls of New Zealand species have been observed in both frequency ranges.

Non-target detections were principally other biotic noises such as crickets, flies and possums. Abiotic noises were also detected and were mainly caused by occasional wind gusts and rain. Call extraction programs have an automatic shutdown mode that is triggered when 15 or more detections occur within 15 seconds. This prevents many false detections otherwise caused by rain, continuous song from insects and frogs, or mechanical noises. Operation resumes as soon as the program registers that detections have fallen below 15 in 20 seconds. Thus, the extraction software maximises the likelihood of bird call detection while minimising the time spent sorting through erroneous noises. This operation does not appear to reduce the likelihood of detecting large flocks that call at a high rate. This may be because airborne flocks will commonly exceed the horizontal range of the recorder within any 15 second period.

Unexpected detections included the audible wing flaps from waterfowl such as mallards (*Anas platyrhynchos*) and scaup (*Aythya novaseelandiae*). Different species, or species groups, appear to exhibit different wing flap intensities. Such detections present a distinctive spectrogram pattern that may provide the potential for some level of

Scientific name	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	Total
Carduelis carduelis	0	0	0	0	0	22	42	101	40	22	8	7	1	17	32	25	45	12	0	0	0	0	0	0	374
Zosterops lateralis	0	0	0	0	0	67	130	71	6	3	3	0	0	6	4	4	5	0	0	0	0	0	0	0	299
Fringilla coelebs	0	0	0	0	0	45	233	0	0	0	0	0	0	0	3	3	3	0	0	0	0	0	0	0	287
Halcyon sancta	0	0	0	0	0	0	9	9	146	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	171
Turdus merula	0	0	0	0	0	108	0	21	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	132
Gymnorhina tibicen	0	0	0	0	0	3	0	40	3	35	2	0	3	0	7	1	0	4	0	0	0	0	0	0	98
Rhipidura fuliginosa	0	0	0	0	0	0	0	3	0	0	0	0	0	1	2	0	6	54	0	0	0	0	0	0	66
Emberiza citrinella	0	0	0	0	0	15	4	0	5	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	27
Acridotheres tristis	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
Ninox novaseelandiae	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	3	1	1	0	13
Alauda arvensis	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	3	0	0	0	0	0	0	0	7
Gerygone igata	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5
Passer domesticus	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Vanellus miles	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
TOTAL	0	0	0	0	4	260	418	263	206	70	13	12	4	24	48	33	62	76	4	0	3	1	1	0	1502

identification without actual vocalisations (see Fig. 3). Nevertheless, categorical identification of calls or other noise is still dependant on comparison with reference sounds. Those who are not confident with the classification of bird noise will require assistance from skilled field ornithologists and/or require reference to existing private call libraries such as the McPherson Natural History Unit Sound Archive.

A further sub-sample from one bioacoustic unit was more fully analysed to illustrate call patterns over a typical day. This recording covers a 24-hour period from 4-5 Apr 2009 and was extracted from a unit located in an area of rank grassland between neighbouring pine (*Pinus radiata*) forest and native kanuka (*Kunzea ericoides*) forest. Results from this sub-sample are presented in Table 1.

As expected, there was a clear daily pattern of vocalisation intensity with call frequency and species diversity peaking at dawn and, to a lesser extent, at dusk (Figs. 4 and 5). Of 1,502 call detections, most (99.1%) were made between 0500 and 1800 h. Calls outside this range were of morepork. In addition, 23 scaup wing flap detections were made between 1908 and 1924 h. The frequencies of species recorded with bioacoustics appear to broadly correspond with the recorded frequencies of these species from field observations at this site. However, species that call regularly (e.g. blackbirds, *Turdus merula*, and silvereyes, *Zosterops lateralis*) or irregularly (e.g. harriers, *Circus approximans*) may be over- or under represented in results. Although 15 bird species were recorded (including scaup) in this sub-sample, the 3 most common species – goldfinch (*Carduelis carduelis*), silvereye and chaffinch (*Fringilla coelebs*) - comprised over half (63.9%) of all call detections.

CONCLUSIONS

The results of my study suggest bioacoustic technology can provide a novel and robust method for monitoring bird populations and movements. However, there are a few potential drawbacks to the method. First, remote 24 hr recordings necessitate battery changes on a weekly basis. Depending on the location, this can be labour-intensive, and future 24 hr applications should aim to power remote units via solar panels. Alternatively, units could be programmed to sample key time periods only, which would reduce power output and the frequency of battery changes. Second, construction of acoustic recording equipment, though straightforward, still requires basic

Table 1. Number of call detections per hour for each species from a 24 hour sub-sample recorded over 4-5 Apr 2009.

electronic skills. During this study, many of the electronic components suffered degradation due to the exposed location of units and the protracted duration of surveying. Therefore, ongoing monitoring and maintenance of equipment is necessary. This may be reduced in future by use of more robust, weatherproof bioacoustic units such as the SongMeter SM2 © (Wildlife Acoustics 2009).

Technologies such as bird-monitoring radar and bioacoustics should not be seen as monitoring methods in isolation. The need for field-based visual observations will certainly continue, however new technologies are increasing the potential to survey sites more rigorously and particularly at night. Potential future applications for bioacoustic devices include further monitoring of migrant birds such as waders, waterfowl and cuckoos, surveying of cryptic marshbirds such as crake and rails (see Dawson & Efford 2009), and detection of rare seabirds on offshore islands. Furthermore, bioacoustic applications need not be restricted to professional ornithologists or large research projects. A common application in North America is for a researcher to place a unit on their home or research station roof and run the software through a desktop computer. As I have demonstrated, the impediments to using bioacoustic techniques to undertake such studies have diminished greatly in recent years and the future for the discipline amongst ornithologists in New Zealand looks bright.

ACKNOWLEDGEMENTS
This project relied on the assistance of numerous people. Firstly, I thank Meridian Energy (Steve Harding, Chris Thomson and Graeme Mills) for their foresight in allowing this bioacoustic application to go ahead. Bill Evans (Oldbird) is responsible for the original design and application of the bioacoustic hardware and software used in this project. His assistance was instrumental. Doug Gerrard (Strident Technology) provided technical assistance with electronic components. The field team (Shane McPherson, Mia Jessen, Carryn Hojem, Emma Crawford and others) stuck with it and kept it going. Lastly to the countless Boffa Miskell staff who have been involved directly and indirectly throughout.

LITERATURE CITED
Black, J.E. 1996. Monitoring nocturnally migrating birds using radar and acoustic microphones. *Birder's Journal* 5: 75-77.

Dawson, D.K.; Efford, M.G. 2009. Bird population density estimated from acoustic signals. *Journal of Applied Ecology* 46: 1201-1209.

DeTect. 2008. *A quantitative methodology for determination of migratory bird mortality at windfarms*. Presented at the American Wind Energy Association, Windpower 2008 Conference, Houston, Texas, USA.

Evans, W.R. 2000. *Applications of acoustic bird monitoring for the wind power industry*. Proceedings of National Avian Wind Power Planning Meeting III, San Diego, California.

Evans, W.R., Mellinger, D.K. 1999. Monitoring grassland birds in nocturnal migration. *Studies in Avian Biology* 19: 219-229.

Evans, W.R.; O'Brien, M. 2002. *Flight calls of migratory birds: Eastern North American landbirds*. Old Bird, New York.

Farnsworth, A.; Gauthreaux, S.A., van Blaricom, D. 2004. A comparison of nocturnal call counts of migrating birds and reflectivity measurements on Doppler radar. *Journal of Avian Biology* 35: 365-369.

Farnsworth, A.; Russell, R.W. 2005. Evaluation of a method for monitoring audible fall migration traffic over platforms. Pg. 247-256 in *Interactions between migrating birds and offshore oil and gas platforms in the northern gulf of Mexico* (Russell, R.W. ed.) Minerals Management Service Publication 2005-009 (Chapter 14).

Harmata, A,R.; Podruzny, K.M.; Zelenak, J.R.; Morrison, M.L. 1999. Using marine surveillance radar to study bird movements and impact assessment. *Wildlife Society Bulletin* 27(1): 44-52.

Kaufmann, G. 1987. Swamp habitat use by spotless crakes and marsh crakes at Pukepuke lagoon. *Notornis* 34: 207-216.

Laiolo, P. 2010. The emerging significance of bioacoustics in animal species conservation. *Biological Conservation* 143(7): 1635-1645.

Larkin, R.P.; Evans, W.R.; Diehl, R.H. 2002. Nocturnal flight calls of Dickcissels and Doppler radar echoes over south Texas in spring. *Journal of Field Ornithology* 73: 2-8.

Powlesland, R.G. 2009. *Bird species of concern at wind farms in New Zealand*. DoC Research and Development Series 317, Wellington.

Wildlife Acoustics. 2009. *Song Meter User Manual – Model SM2*. Wildlife Acoustics Inc, Concord, Massachusetts.