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Bioacoustic monitoring of New Zealand birds

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[illegible]

Abstract [illegible]
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 [illegible]
complement to avian radar technology. Results illustrate the utility of bioacoustic methods, highlighting the range and [illegible]

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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 [illegible]
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 [illegible]
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 [illegible]
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 [illegible]
detailed analyses of contact calls have been used to greatly enhance the detection and subsequent [illegible]
United States (Evans & O'Brien 2002). While the use of recordings for biodiversity monitoring or species-[illegible]
bioacoustic technology, bioacoustics have remained [illegible]
via direct listening, and visual observations using traditional optical technologies such as binoculars and telescopes.

Bioacoustic techniques have a number of [illegible]

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Fig. 1. A bioacoustic unit situated in rank grass. The 2 containers in the foreground house the laptop (left) and [illegible] the ceramic pot placed behind.

[illegible]
[illegible]
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 [illegible] [illegible] rare or unusual species rely on the credibility of the eyewitness. This person has to identify a call on [illegible] [illegible] a site can be thoroughly surveyed day *and/or* night and irrespective of visibility. Although daytime [illegible] 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 [illegible]

[illegible] bioacoustics for biodiversity monitoring the technology has not been widely adopted in New Zealand, largely due to: (1) expense of recording [illegible] personal computers; and (3) protracted length of [illegible] 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 [illegible] of external storage space has reduced dramatically; and while still providing some impediment to amateurs, recent software developments enable [illegible] 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 [illegible] [illegible] 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; [illegible] *et al.* 2004). In this case, bioacoustics were employed both to verify radar trails and to [illegible]

Six bioacoustic devices, known as pressure zone microphones, were deployed at the study [illegible] [illegible] 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 [illegible] frequency calls within the 6-10 kHz range the cone of detection was reduced to a volume of approximately [illegible] 2005). Units were constructed from rudimentary components: the microphone circuits comprised [illegible] [illegible] circuit board, and a Knowles EK3029c microphone [illegible] (see Evans & Mellinger 1999). Microphone housing [illegible] (approximately 35 cm diameter) insulated with bedding underlay. Recordings were made directly [illegible] Easy Hi-Q Recorder software.

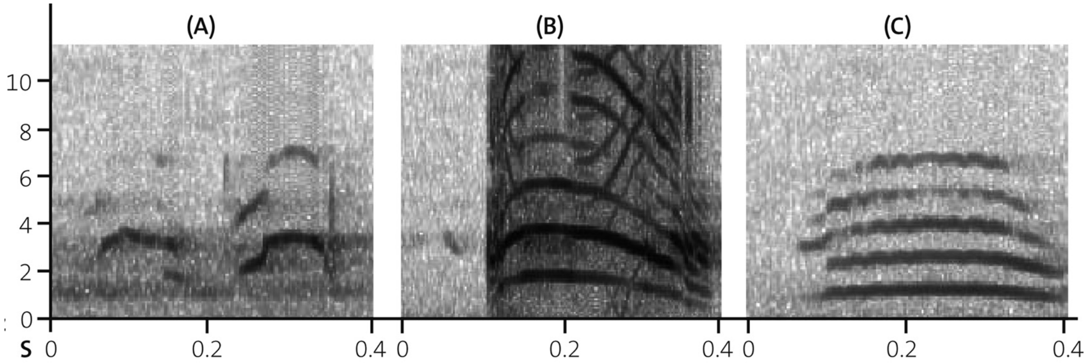

Fig. 2. Vocalisations of (A) pied oystercatcher (*Haematopus ostralegus* [illegible] *Circus approximans* [illegible] *Ninox novaseelandiae*; song). The harrier call was within close proximity to the microphone, hence the striking harmonics.

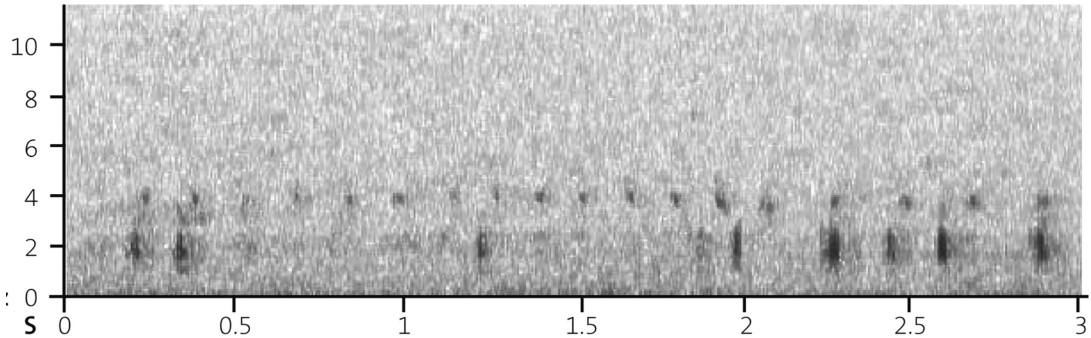

Fig. 3. [illegible]

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 [illegible] weekly basis in conjunction with downloading each week's recording data. The bioacoustic units [illegible] equipment for each unit being approximately $360 NZ. Additional costs included the requirement [illegible] remotely.

In the present study, bioacoustic data [illegible] *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, [illegible] lessening of detector sensitivity. Therefore, the [illegible] mid- to high frequencies. Although some species give very low calls below the range of the Thrush detector, such species are still frequently detected [illegible] distinguish and catalogue call types and eliminate [illegible] 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 [illegible] the basis of their audible characteristics and by [illegible]

SURVEY RESULTS

[illegible] from 4 bioacoustic units was carried out on a sample of recordings from 20 Mar to 4 Apr 2009. A total of

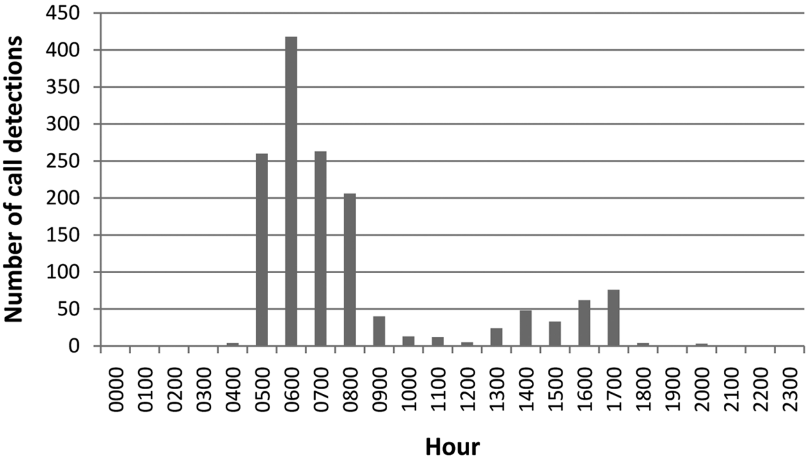

Fig. 4. Number of call detections per hour from a 24 hour sub-sample recorded over 4-5 Apr 2009.

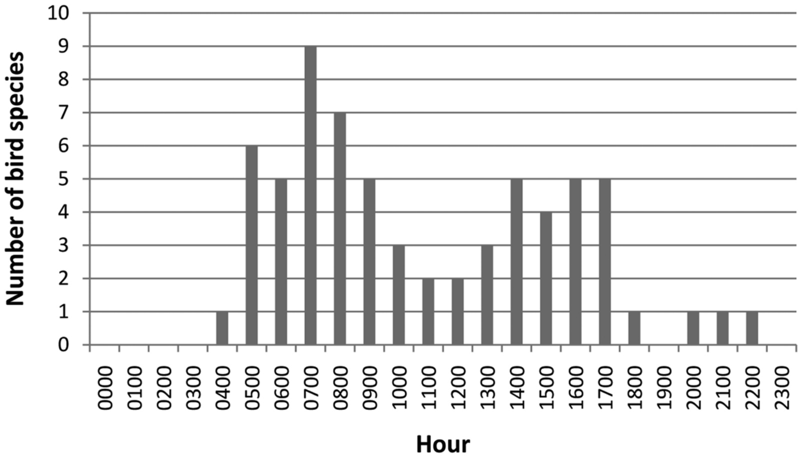

Fig. 5. Number of species recorded per hour from a 24 hour sub-sample recorded over 4-5 Apr 2009.

111,063 detections were extracted from the sound [illegible] calls or song, an average of approximately 1.4 calls [illegible] were in the 6-10 kHz range, while the remaining [illegible] to reliably fall into only one of these frequency [illegible] in the 2.8-5 kHz range. It is not known if similar [illegible] However, the calls of New Zealand species have been observed in both frequency ranges.

Non-target detections were principally other [illegible] 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 [illegible] will commonly exceed the horizontal range of the recorder within any 15 second period.

Unexpected detections included the audible [illegible] *Anas platyrhynchos*) and scaup (*Aythya novaseelandiae*). [illegible] that may provide the potential for some level of

2ÊÌÕÛÐ ŗÊÕÊÔÌ	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

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

ÐËÌÕÛÐ ŗÊÈÛÐÖÕ Þ ÐÛ Ï ÖÜÛ ÈÊÛÜÈÓ ÝÖÊÈÓÐÚÈÛÐÖÕÚ φÚ Ì Ì %Î ō ŦĀō - ÌÝÌÙÛ Ï ÌÓÌÚÚ ÊÈÛÌ ÎÖÙÐÊÈÓ ÐËÌÕÛÐ ŗÊÈÛÐÖÕ ÖÍ ÊÈÓÓÚ or other noise is still dependant on comparison ÞÐÛ Ï ÙÌÍÌÙÌÕÊÌ ÚÖÜÕËÚō 3 ÏÖÚÌ Þ ÏÖ ÈÙÌ ÕÖÛ ÊÖÕ ŗËÌÕÛ ÞÐÛ Ï ÛÏ Ì ÊÓÈÚÚÐ ŗÊÈÛÐÖÕ ÖÍ ÉÐÙËÚ ÕÖÐÚÌ Þ ÐÓÓ ÙÌØÜÐÙÌ ÈÚÚÐÚÛÈÕÊÌ ÍÙÖÔ ÚÒÐÓÓÌË ŗ ÌÓË ÖÙÕÐÛ ÏÖÓÖÎ ÐÚÛÚ ÈÕË ÔÈÝ require reference to existing private call libraries ÚÜÊ Ï ÈÚ ÛÏ Ì , Ê / Ï ÌÙÚÖÕ - ÈÛÜÙÈÓ ' ÐÚÛÖÙà 4 ÖÜÕ 2ÖÜÕË Archive.

A further sub-sample from one bioacoustic unit ÞÈÚ ÔÖÙÌ ÍÜÓÓà ÈÕÈÓàÚÌË ÛÖ ÐÓÓÜÚÛÙÈÛÌ ÊÈÓÓ ×ÈÛÛÌÙÕÚ 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.

Ú Ìß×ÌÊÛÌË Û ÏÌÙÌ ÞÈÚ È ÊÓÌÈÙ ËÈÐÓà ×ÈÛÛÌÙÕ of vocalisation intensity with call frequency and species diversity peaking at dawn and, to ÈÓÌÚÚÌÙ ÌßÛÌÕÛ ÈÛ ËÜÚÒ φ%ÐÎÚ Ƙ ÈÕË ƘĀō . ÍhÓƘŲ l ÊÈÓÓ ËÌÛÌÊÛÐÖÕÚ ÔÖÚÛ φŊŊōĥ ŭ Ā Þ ÌÙÌ ÔÈËÌ ÉÌÛ ÞÌÌÕ 0500 and 1800 h. Calls outside this range were ÖÍ ÔÖÙÌ×ÖÙÒō (Õ ÈËËÐÛÐÖÕ l Ŧ ÚÊÈÜ× ÞÐÕÎ ŘÈ× 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 ŗ ÌÓË ÖÉÚÌÙÝÈÛÐÖÕÚ ÈÛ Û ÏÐÚ ÚÐÛÌō ' ÖÞ ÌÝÌÙ Ú×ÌÊÐÌÚ 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 Ŧ ÎÖÓË ŗÕÊ Ï φ*Carduelis carduelis*), silvereye and ÊÏÈ Ś ÕÊ Ï φ*Fringilla coelebs*) - comprised over half φŦōŊ ŭ ĀÖÍ ÈÓÓ ÊÈÓÓ ËÌÛÌÊÛÐÖÕÚō

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 ÔÌÛ ÏÖËō %ÐÚÚÜÌÙÌ ÔÖÛÌ l Ƙ ÏÙÌ ÊÖÙËÐÕÎ ÚÕÌÊÌÚÚÐÛÈ ÉÈŲÌÙà ÊÏÈÕÎÌÚ ÖÕ È ÞÌÌÒÓà ÉÈÚÐÚō # Ì×ÌÕËÐÕÎ 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 ÈÕË ÛÏÌ ÍÙÌØÜÌÕÊà ÖÍ ÉÈŲÌÙà ÊÏÈÕÎÌÚō 2ÌÊÖÕËÓà construction of acoustic recording equipment, though straightforward, still requires basic 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.

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