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Seasonal and environmental effects on morepork (*Ninox n. novaeseelandiae*) vocalisations in two forests in Northland, New Zealand

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Abstract To investigate factors that might influence calling rates of morepork (ruru, *Ninox n. novaeseelandiae*), Song Meter SM2+ acoustic recorders were deployed for 12 months recording every night at Hodges Bush (a remnant forest) and Trounson Kauri Park (TKP) in Northland, New Zealand. Three call types were recorded: the classic 'morepork' hoot, the 'wheel' and 'wok'. There was no strong seasonal variation in 'morepork' hoots from Hodges Bush, although there were fewer hoots from February to March. At TKP, the number of hoots declined from June to August, but the number of 'wheel' and 'wok' calls remained constant. At dusk, 'Morepork' hoots gradually increased until they were at their greatest frequency 3 hours after sunset at both sites. Thereafter, the number of calls reduced through the night at TKP, but remain constant at Hodges Bush until a second peak 2 hours before dawn, after which numbers drop off markedly. The other two call types were constant throughout the night at both localities, but with a pre-dawn peak at Hodges Bush. There was no significant correlation between calls and moon phase at either site. We suggest that it is possible to use vocal activity as a means of monitoring morepork population changes, but more studies are needed to determine variations between sites and different population densities.

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Keywords morepork; ruru; *Ninox novaeseelandiae*; owls; bioacoustics

INTRODUCTION

The morepork (ruru, *Ninox n. novaeseelandiae*) is a small native nocturnal owl that is widespread throughout New Zealand. It is New Zealand's only indigenous owl (following the extinction of the laughing owl in the early 1900s (Heather & Robertson 2015)) and is very closely related to Australia's boobook owl (*Ninox n. boobook*).

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Owls are top predators in the food chain, so healthy owl populations can be indicators of healthy ecosystems (Olsen *et al*. 2002). However, as top predators they are also susceptible to secondary poisoning and can concentrate toxic substances through eating contaminated prey (Sheffield 1997). This is especially relevant in areas that undergo regular poison bait operations to control introduced mammalian predators. Morepork have been killed during rodent eradication programmes using the anticoagulant poison brodifacoum (Empson & Miskelly 1999) and poisoning is more

prevalent when mice are targeted (Stephenson *et al*. 1999). Conversely, Fraser & Hauber (2008) found higher morepork calling rates in an area regularly poisoned with brodifacoum compared with call rates from an unmanaged control site, indicating that morepork probably benefitted from the rodent control operations.

Traditional methods for assessing owl populations (e.g. regular call monitoring using observers and survival monitoring of radio-tagged individuals) are expensive and labour intensive. More recently, automated acoustic recording methods have proven to be efficient for determining the presence of vocal nocturnal species such as owls and, potentially, can be used to help infer population fluctuations (Goyette *et al.* 2011). Pryde & Greene (2015) have investigated the optimal spacings of acoustic recorders needed for monitoring morepork.

All owl monitoring methods require a good understanding of both the types of call the birds make and when they call. However, only a few papers have been published on morepork vocalisations in New Zealand. In regards to the number of vocalisations, Stephenson (1998) described 7 different morepork calls on Mokoia Island (Lake Rotorua), while Brighten (2015) reported 11 morepork vocalisations on Ponui Island (Hauraki Gulf). Olsen *et al*.'s (2002) study of the boobook owl in Canberra identified 10 vocalisations made by adults. While female boobooks have been reported as having have deeper voices than males (Fleay 1968; Debus 1996; Olsen & Trost 1997), Stephenson (1998) and Brighten (2015) could not distinguish calls of radio-tagged morepork.

In terms of seasonal variability, Brighten (2015) recorded low calling rates of morepork on Ponui Island in winter months compared with summer months, with the highest call rates in the late spring to mid-summer period from November to January. O'Donnell (1980) undertook monthly counts of morepork at Nelson and recorded calling peaks in April (autumn) and August (winter), while Gibb (2000) recorded morepork counts in the Western Hutt Hills (Wellington) as peaking in March (early autumn). It is likely that the seasonality of morepork calling is related to the breeding cycle. In New Zealand, the breeding season begins with an increase in calling activity, usually in the second half of August (Imboden 1975), and the first mating has been recorded on 1 September.

The time of day when morepork call also appears to be somewhat variable within the constraints associated with the birds' nocturnal lifestyle. Most surveys of morepork calls in New Zealand take place in the hours around nightfall (Stephenson *et al*. 1999) and it has been suggested that the peak calling time is in the hour following sunset (Heather & Robertson 1996). However, Brighten (2015) found that call rates in the first 2 hours after sunset were significantly lower than during the rest of the night. Debus (1997) reported that boobooks in New South Wales called throughout the night, with calls peaking in the first half of the night.

With respect to weather conditions, Olsen *et al.* (2002) reported that boobook calling frequency did not vary with moon visibility, rain or wind. Kavanagh & Peake (1993) found that boobooks called more often on calm nights with no moon and clear skies. Debus (1997) reported that moon visibility and cloud cover did not affect calling rates for boobooks in New South Wales, but rain and wind did.

This current study set out to gain a better understanding of the types of calls morepork make and when they are most vocal as a first step towards designing the best possible monitoring programmes the species, especially to detect any positive or negative effects from predator control operations.

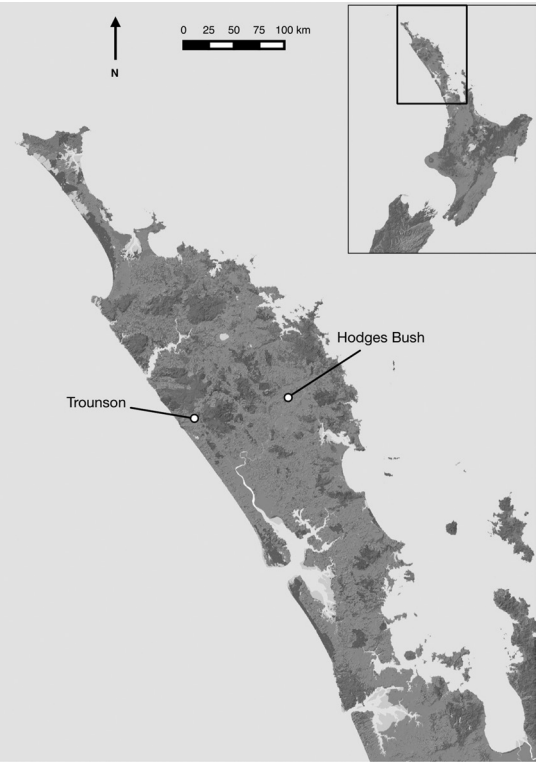

Fig. 1. Map showing locations of 2 morepork study sites in Northland (Basemap is from Koordinates.com).

MATERIALS AND METHODS

Study sites

Hodges Bush (Fig. 1), located 17 km northwest of the city of Whangarei (Northland, New Zealand) is a privately owned 35 ha forest remnant adjoining a 15 ha of pine (*Pinus radiata*) plantation. The largely taraire (*Beilschmiedia tarairi*) and tōtara (*Podocarpus totara*) forest is surrounded by pastoral grasslands. A listening site (35°38′22′′ S, 174°8′10′′ E) was positioned to hear over an area of approximately 30 ha. of native forest.

Trounson Kauri Park (TKP) (Fig. 1), located 40 km north of Dargaville (Northland), comprises 586 ha of mature kauri (*Agathis australis*) forest. A listening site (35°43′19′′ S, 173°38′2′′ E), located approximately 150 m within the northern boundary of the forest, was positioned to monitor an area of approximately 90 ha of forest.

Field recordings and analysis

A single Song Meter SM2+ acoustic recorder from Wildlife Acoustics Inc. (Concorde, MA, USA) was deployed at each of the 2 study sites. At Hodges Bush the Song Meter recorded 358 nights, starting on 1 January 2012 and finishing on 1 January 2013. At TKP the Song Meter recorded 365 nights starting on 1 January 2012 and finishing on 1 January 2013.

The Song Meters were positioned on ridges to gain the maximum listening coverage and positioned away from the most direct wind to minimise weather interference. They were set at 1.5 m above the ground, screwed onto trees that were no more than 20 cm in diameter at that height and away from forest epiphytes that could cause rustling noise in the wind.

The recorders operated from sunset to sunrise, every night, for a year. The Song Meter automatically calculated sunrise and sunset at each site from the input coordinates. The recordings were made at a 16 kHz sampling rate in stereo, and recording in compressed wave (WAC) format. From the WAC files, all data was decompressed into WAV format and viewed as spectrograms using Raven Pro 1.4 (Cornell Laboratory of Ornithology, Ithaca, NY, USA).

Given the difficulty in separating out whether vocalisations were from 1 or more individuals, we recorded morepork as either present or absent within 10-minute sampling periods rather than counting the number of sounds recorded. The probability of calls is indicated by the proportion of 10 minute blocks containing morepork calls per night.

The relationship between probability of calling and time of night was analysed by dividing each night into 10 periods of equal length, to account for changing night length during the year (the day length at Whangarei, nearest city to the study sites, is 9.42 hours in mid-winter and 14.32 hours in mid-summer, a difference of 4.9 hours (LINZ astronomical information www.linz.govt.nz)). Thus, time of night was given as a percentage, with each time period ('bin') covering 10% of the night.

As well as recording the presence of morepork, we also recorded information on background noise. The main noises were wind (a scale of 0–3: 0 = no wind, 1 = light wind, 2 = moderate to strong wind, 3 = severe) and rain (a scale of 0–3: 0 = no rain, 1 = light rain, 2 = moderate to heavy rain, 3 = torrential downpour). These environmental variables were estimated for each 10-minute file from listening to the sound file and inspecting the background noise levels in the spectrogram. The noise on the spectrogram was due to energy produced by the wind and rain and hence the darker the shading the stronger the wind and rain effect.

For each time period ('bin') we noted if morepork were heard or not heard, environmental variables were taken from the value for the file containing the time period, and moon phase and altitude were calculated for the middle of each time period ('bin') using package moonsun (Komsta 2010) in R (version 3.01; (R Core Team, 2013)).

Localised regression (LOESS) curves, with 95% confidence intervals, were added to the graphs produced to show smoothed relationships.

We did not attempt to sex the morepork calls given that previous studies have not been able to determine sex (Stephenson 1998; Brighten 2015).

RESULTS

The total number of 10 minute recordings at Hodges Bush and TKP were 23,902 and 25,876 respectively. The percentage of these recordings with the different types of calls present are given in Table 1.

All vocalisations recorded were of the 3 main types (the 'morepork' hoot, the 'wheel' call and the 'wok' call; Fig. 2). There was no strong seasonal variation in 'morepork' hoots from Hodges Bush (Fig. 3), although there was lower calling from February to March. 'Wheel' and 'wok' calls were

Table 1. Percentage of 10-minute periods with calls present.

Type of call	Hodges Bush	Trounson Kauri Park
'Morepork' hoot	40.8%	32.7%
'Wheel'	9.7%	7.2%
'Wok'	6.6%	4.4%

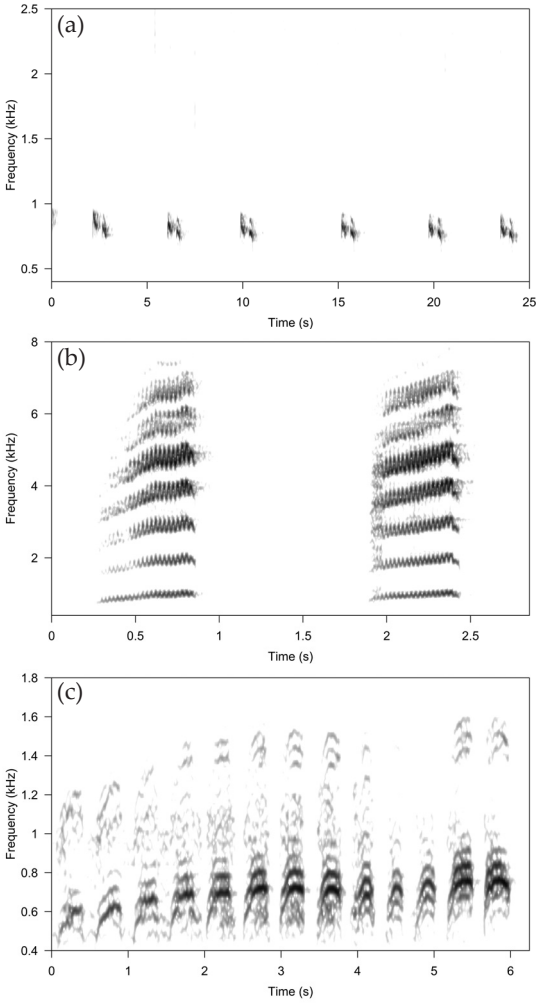

Fig. 2. Spectrograph of the 3 main morepork calls: (a) typical double syllable 'morepork' territorial/contact hoot; (b) 'Wheel' call; (c) 'Wok' call that can continue non-stop for minutes.

spread evenly over time, although 'wheel' calls were more likely in the first half of year, and 'wok' calls in October to November. At TKP, 'morepork' calls had a different seasonal pattern from Hodges Bush, with calling frequency declining from June to August. However, the 'wheel' and 'wok' calls remained more-or-less constant throughout the year (Fig. 4).

Both sites showed constant calling for most of the night with an increase just before dawn at TKP. Peak calling started after 20% of the night at Hodges Bush and after 30% of the night at TKP (Fig. 5a and Fig. 5b).

There was no correlation between moon phase and likelihood of calling at either Hodges Bush or TKP (Fig. 6 and Fig. 7).

Increasingly heavy rain tended to result in reduced call rates at all sites, as did increasing wind speed (Fig. 8).

DISCUSSION

We recorded only 3 of the 7 types of calls identified by Stephenson (1998); those 4 not recorded were agitated alarm calls, alarm calls, chick alarm calls and chick begging. The last 2 types were related to nesting behaviour and fledgling vocals; it is possible that our recorders were not close enough to nests to detect such calls. The other alarm calls are high pitched and may not have been loud enough or close enough to be picked up by the microphones. Likewise, Brighten (2015) had further sounds associated with nesting, such as copulations heard following birds with radio transmitters and chick alarm calls. The 'hoot' call, on the other hand, is very low frequency (Fig. 2) and has been hypothesised to function for territorial advertising (Stephenson 1998). Low frequency sound can be carried and heard over much longer distances than high frequency sounds, so what the acoustic recorders detect may not give a true indication of the proportion of the vocalisations made by morepork.

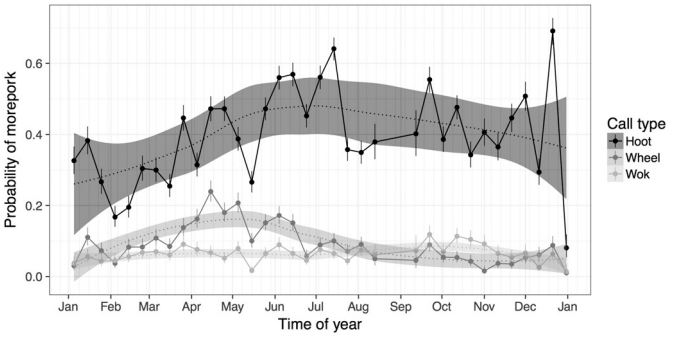

Fig. 3. Seasonal variation in morepork calling (by type) at Hodges Bush, January 2012 to January 2013. The probability of calls is indicated by the proportion of 10 minute blocks containing morepork calls per night. Dotted lines show localised regression (LOESS) curves to smooth the results, with 95% confidence intervals of these indicated by shading.

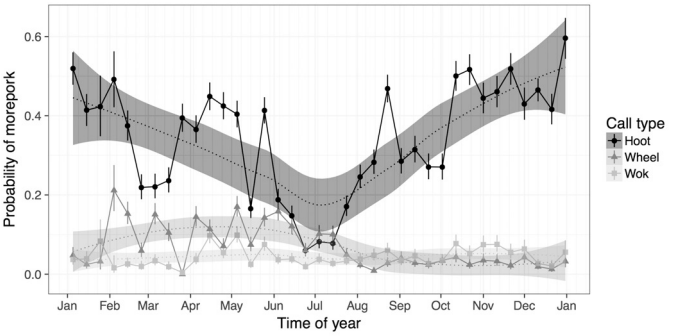

Fig. 4. Seasonal variations in morepork calling (by type) at Trounson Kauri Park, Northland, January 2012 to January 2013. The probability of calls is indicated by the proportion of 10 minute blocks containing morepork calls per night. Dotted lines show localised regression (LOESS) curves to smooth the results, with 95% confidence intervals of these indicated by shading.

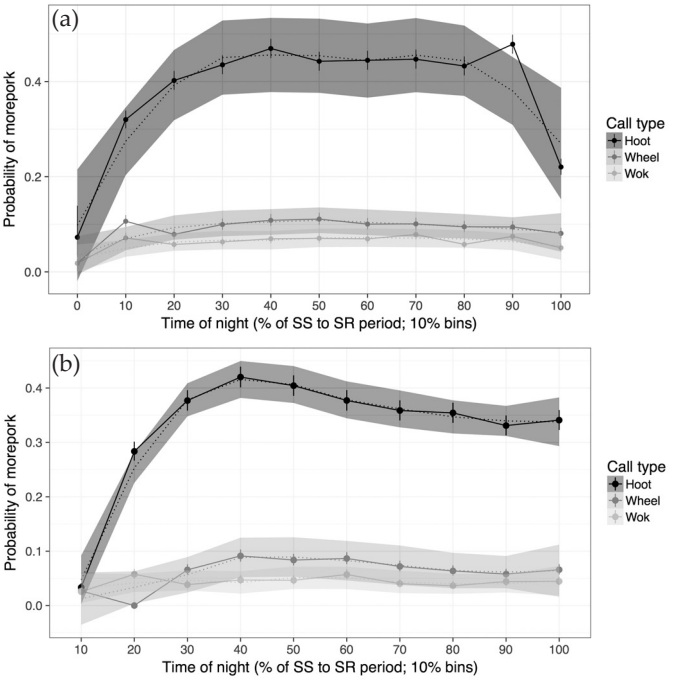

Fig. 5. Probability of morepork calling with time of night at (a) Hodges Bush and (b) Trounson Kauri Park, Jan 2012 to Jan 2013. The time of night is given as a percentage of the sunset (SS) to sunrise (SR) period, with sampling periods ('bins') each comprising 10% of the night (SS to SR) length. Dotted lines show localised regression (LOESS) curves to smooth the results, with 95% confidence intervals of these indicated by shading.

There was no strong seasonal variation in 'morepork' calling rates from Hodges Bush, although they were slightly lower from February to March. At TKP, 'morepork' call rates reduced from June to August, but the 'wheel' and 'wok' calls remained fairly constant. We cannot explain why there was such a decline in 'morepork' calls from June to August at TKP, or why the pattern was different from that at Hodges Bush. However, Olsen & Trost (1997) found that female boobook owls migrated outside of their territories during the winter; this migration is common with other species of owls (Gehlbach 1994). Therefore, it is possible that morepork migrate away from some sites, perhaps in relation to changing food supplies.

The drop off in calling rates at both sites in March corresponds with the time that chicks have fully fledged. Reduced call rates could relate to body condition of adult morepork, which would be expected to be at their lowest immediately post-breeding, and increasing body weight could take priority over territorial defence and, hence, calling. The seasonal pattern of calling at TKP was more similar to that observed by Brighten (2015) on Ponui Island than that observed at Hodges Bush. Brighten (2015) reported low amounts of calling

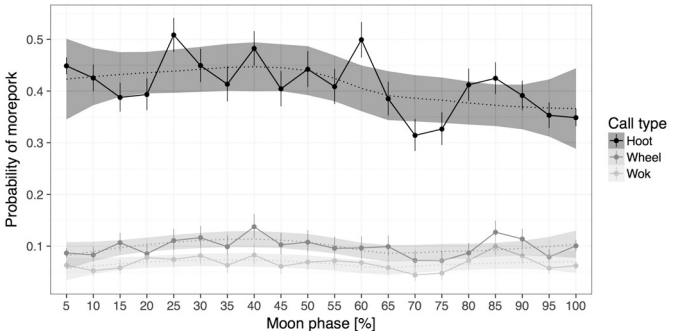

Fig. 6. The effect of moon phase on morepork call rates (by type) at Hodges Bush, January 2012 to January 2013. Dotted lines show localised regression (LOESS) curves to smooth the results, with 95% confidence intervals of these indicated by shading.

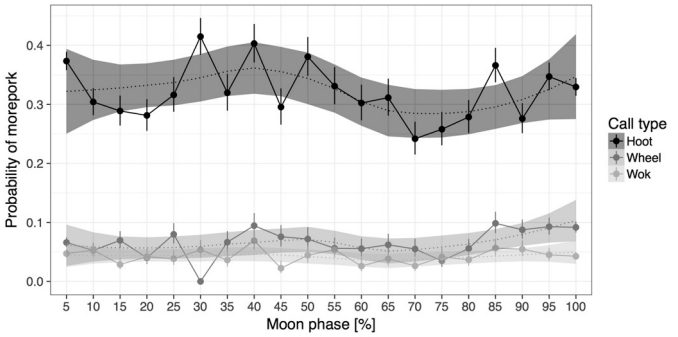

Fig.7. The effect of moon phase on morepork call rates (by type) at Trounson Kauri Park, January 2012 to January 2013 (100 is full moon). Dotted lines show localised regression (LOESS) curves to smooth the results, with 95% confidence intervals of these indicated by shading.

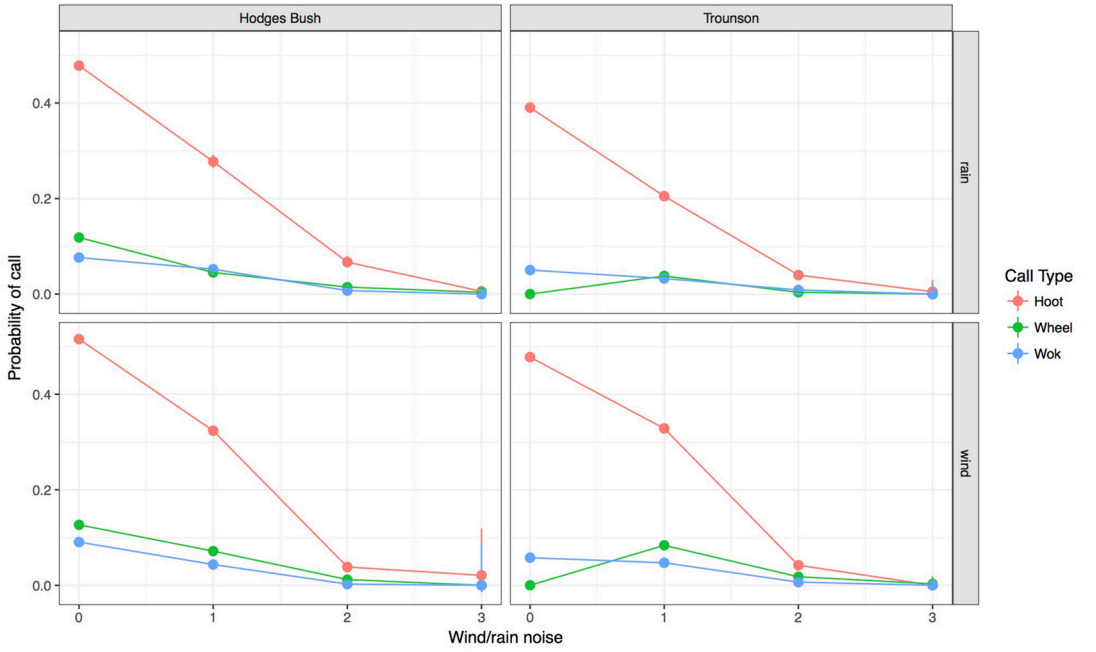

Fig. 8. The impact of rain and wind on detected calls at Hodges Bush and Trounson Kauri Park determined from shading intensities on the spectrograms from rain and wind. Wind and rain noise were scored subjectively, with 0 the lowest noise and 3 the highest.

in winter compared with summer and appeared to coincide the morepork breeding cycle that ran from September to February. Brighten (2015) also reported that numbers of calls peaked from November to January and was lowest in February when adults still had dependant chicks.

'Morepork' calls were more frequent 3 hours after sunset at both sites, with calls reducing through the night at TKP, but remaining constant at Hodges Bush (with a small peak in probability 2 hours before dawn) before dropping off markedly. The other types of calls were constant throughout the night with a pre-dawn peak at Hodges Bush. Our findings were consistent with Brighten (2015) in that number of calls heard in the first 2 hours after sunset were significantly lower than the rest of the night.

Calls were recorded in strong winds and moderate to heavy rain; however, overall there was a reduction in calling with increasing wind speed and precipitation. The advantage of acoustic recorders is that spectrographs allow the higher harmonics of calls (particularly the 'wheel' calls) to be detected above the lower-frequency wind noise. Likewise, in light to moderate rain, morepork vocalisations can still be 'heard' (especially the 'morepork' hoots). Because morepork hoots are low frequency, very simple to detect and are by far more frequent than any other morepork vocalisation (Table 1), monitoring morepork from hoots alone maybe a time and cost-effective means of monitoring morepork populations than from monitoring all calls.

We believe that recording vocal activity provides a potential means of monitoring morepork populations (determining trends in changes of indices of abundance); however, the results from these 2 sites should not be interpreted as reflecting the likely results in other parts of New Zealand. For example, Pryde & Greene (2015) found that morepork in southern beech forest have home ranges much larger than in other more productive forests. Sites will reflect local variations in forest types and food resources. Defining a generalised time to survey and monitor morepork everywhere in New Zealand would therefore require more information from many more sites and from different population densities of morepork. An important requirement before recorded morepork call rates can be used to monitor population trends will be to calibrate call rates against actual density at a range of sites to see if there is a predictable relationship between calls and numbers of birds.

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