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Close approaches and acoustic triangulation: techniques for mapping the distribution of booming Australasian bittern (*Botaurus poiciloptilus*) on small wetlands

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Abstract Reliable techniques need to be developed for monitoring the distribution and abundance of the endangered Australasian bittern (matuku, *Botaurus poiciloptilus*). We trialled 2 complementary methods for estimating the number of booming Australasian bitterns: acoustic triangulation from fixed listening stations, and using kayaks to quietly approach booming birds. Trials were conducted over 2 booming seasons (2011 and 2012) at Hatuma Lake, Hawkes Bay. The 2 methods gave similar estimates of the number of bitterns using Hatuma Lake (2011: 8-9 bitterns by triangulation and 9-10 bitterns by close approaches; 2012: 8-9 bitterns using triangulation and 7-8 bitterns by close approaches). We recommend using close approaches because there appeared to be less count-error or a combination of the 2 methods to estimate numbers of Australasian bitterns on small wetlands (< 250 ha). However, neither method appears suitable for larger wetlands if the calls of distant bitterns overlap those of close bitterns, if observers get saturated by too many calling birds, or if there is insufficient time between calls to estimate distance of calls reliably and reduce the ability to distinguish individuals consistently.

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INTRODUCTION

The Australasian bittern (matuku, *Botaurus poiciloptilus*) is classed as Endangered by the IUCN and Nationally Endangered in New Zealand because numbers have been drastically reduced throughout their range (Miskelly *et al.* 2008; BirdLife International 2013). Population estimates for New Zealand vary, but probably <1000 birds remain (Heather & Robertson 2000). There is no information on rates of decline in New Zealand. However, in Australia, regional declines in reporting rates of > 90% over the last 30 years are thought to represent genuine population declines (Buchanan 2009).

Little information is available on the ecology of Australasian bitterns in New Zealand, nor have techniques for the inventory and monitoring of Australasian bitterns been tested in New Zealand wetlands (Marchant & Higgins 1990; Heather & Robertson 2000; O'Donnell 2011). There is an urgent need to understand processes threatening Australasian bitterns so that conservation actions

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aimed at reversing declines can be implemented (O'Donnell 2011). This will require reliable methods for inventory (baseline surveys) to establish presence of populations, estimate population sizes, and identify critical sites and habitats to focus long-term monitoring and management. At present, it is uncertain whether populations are stable, increasing, or decreasing and when and where management intervention is necessary. Thus, methods for monitoring changes in populations over time, especially their response to wetland management are also required. In addition, bitterns are potential indicators of wetland health; their presence is likely to reflect the presence of healthy fish stocks and water regimes and predator free habitats (Gilbert *et al.* 2003, 2007; Polak 2007). Methods need to be sensitive enough to detect population changes in the order of 1-10% per year because these rates signal alert levels for changes in threat status (Miskelly *et al.* 2008).

Bitterns are highly cryptic and rarely seen, making inventory and monitoring challenging. Even when sightings are recorded, it is difficult to interpret what a sighting represents beyond a bittern being present. However, male bitterns give a deep resonant boom and these calls are associated with attracting mates and breeding in 2 close relatives to the Australasian bittern; Eurasian bittern (*B. stellaris*) and American bittern (*B. lentiginosus*) (Gibbs & Melvin 1997; Polak 2006; Puglisi *et. al.* 1997). The presence of booming bitterns and recording of calling rates provide potential tools for inventory and monitoring (Poulin & Lefebvre 2003; Polak 2006). Although not confirmed for Australasian bittern, it is most likely that only males boom (Marchant & Higgins 1990). Peak booming of Australasian bittern in New Zealand is between Sep and Nov (> 70% of records; O'Donnell 2011), although booming has been recorded in all months except May and Jul (O'Donnell 2011).

In Europe, booming calls are used to count numbers of male Eurasian bittern. To do this individual birds are distinguished from each other by mapping booming sites via acoustic triangulation and noting boom characteristics (White *et al.* 2006). This can be used to detect population trends if carried out in a standardised manner, taking time of day, environmental conditions and bittern density into consideration (Poulin & Lefebvre 2003). Applying these techniques in trials in Whangamarino wetland, a *c.* 7800 ha wetland in the Waikato region, proved unsuccessful, largely because bittern density was high (Ogle & Cheyne 1981), the calls of distant bitterns overlapped those of close bitterns, it was difficult to estimate distance of calls reliably, it was rarely possible to distinguish individuals consistently, and there were incidences of observer saturation (author's *unpubl. data*; A. Holzapfel, O. Overdyck, Department of Conservation, *pers. comm.*). However, it may be possible to apply techniques used in Europe to smaller wetlands where these problems may be less of an issue.

We trialled 2 complementary techniques for estimating the distribution and number of booming Australasian bittern at Hatuma Lake, Hawkes Bay, New Zealand between Jun and Oct 2011 and Sep and Oct 2012. Bitterns commenced booming in Jun 2011, two months earlier than usual (JC, *pers. obs.*). Hatuma Lake (40° 1'S 176° 52'E) was suitable for the trials because the lake was relatively small (226 ha), ~2.4 km long and 1.0 km at its widest (Fig. 1). Most of the lake is open water (150 ha) but 2.5 km of its shore is fringed with a narrow band (10–50 m wide) of raupo (*Typha orientalis*) dominant vegetation. At the southern and northern ends of the lake, raupo beds form discrete islands with a convoluted shoreline. Thus, in this narrow fringe, there was little chance of calls from bitterns further away being confused with other individuals. It was practical to circumnavigate the lake relatively quickly and observers could quickly and easily communicate with each other.

METHODS

Close approach method

We undertook 2 surveys of the lake by kayak aimed at counting the total number of Australasian bittern at Hatuma Lake in each of 2011 and 2012. All surveys were conducted in calm, fine weather conditions beginning about 1 h before sunset to coincide with peak booming (Teal 1989). On each occasion the lake was circumnavigated slowly. Observers noted the presence of booming birds as they passed them around the lake margin and quietly paddled towards them, repeatedly taking note of the bearing and subjectively estimating distance. We could quietly approach booming birds without disturbing them by sitting off the reedbeds in a kayak. None of the booming birds took flight during the surveys. It was possible to approach calling birds from more than one direction or even circle a calling bird to improve confidence in our estimates of location. When we were confident of the location of a booming bird, and that booms were not being uttered by more than 1 bird at the location, the observers noted the location on a map and recorded the co-ordinates using Garmin GPSmap 60CSx and moved to where the next bird was calling along the lake shore. The technique relied on spending as long as the observer thought was required to be confident about the locations of all booming birds on the lake. For example, the first survey in 2011, using 1 observer, took 5 h and the second, using 3 observers, 3.5 h.

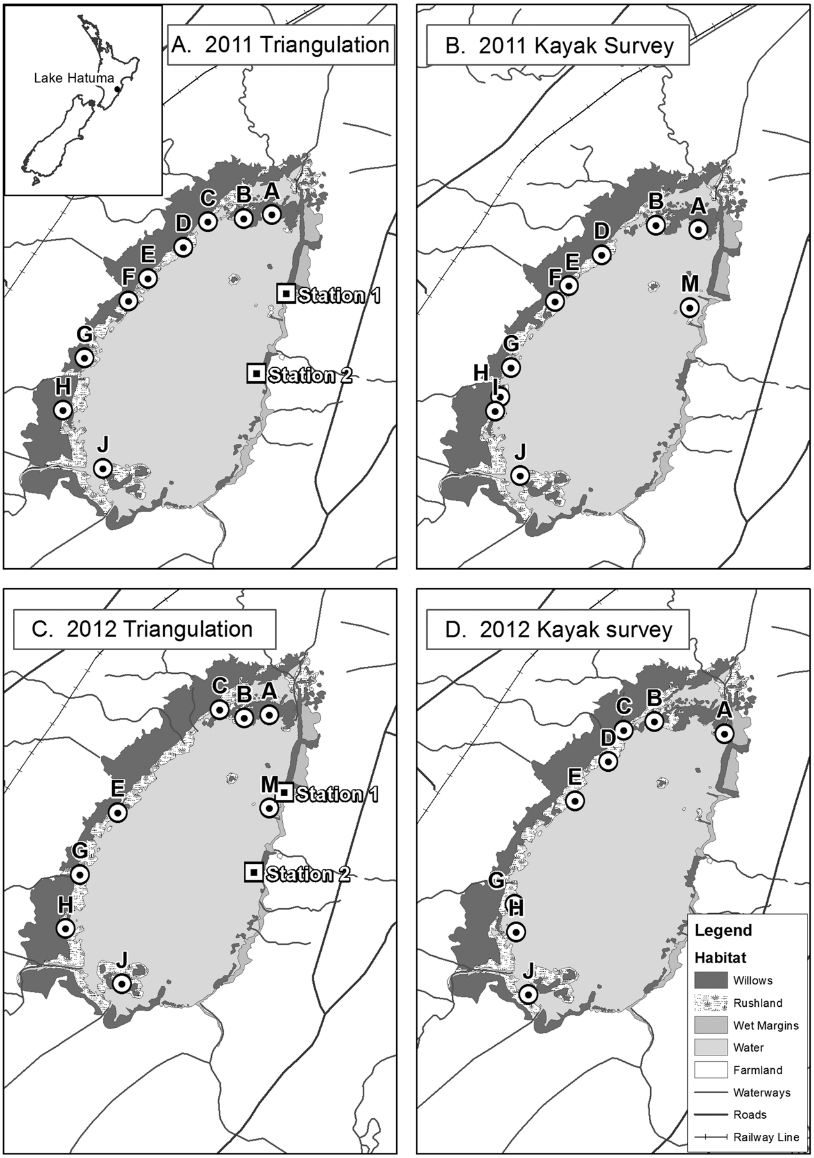


Fig. 1. Examples of the distribution of Australasian bittern sightings on Hatuma Lake in spring on: (A) 22 Jun 2011 using triangulation from count stations 1 and 2, (B) 13 Oct 2011 using kayak survey, (C) 15 Oct 2012 using a kayak survey, and (D) 16 Oct 2012 using triangulation from count stations 1 and 2. Letters refer to individual booming bittern identified on field sheets.

Acoustic triangulation method

Acoustic triangulation involves repeatedly taking compass bearings in the direction of booming bitterns from 2 different listening stations over a period of time. We used 2 accessible locations, *c.* 500 m apart on the eastern shore of Hatuma Lake (Fig. 1) in 2011 and 2012. The entire lake was visible from these stations, and about 70% of the lake was visible from individual stations. Bearings were taken simultaneously whenever birds were heard booming for one 1 hour at dusk (starting 30 min before sunset) and in 2012, one hour at dawn (starting 90 minutes before sunrise); these are periods when booming usually peaks (Teal 1989; *unpubl. data*). We recorded the time, compass bearing in degrees, estimated distance (m), and number of booms within a boom train for each record. A boom train was defined as the number of individual booms uttered by a bird during an individual call sequence (Gilbert *et al.* 1994). We also labelled the estimated location each different bird on a schematic map.

After the recording session, the observers conferred to check data, locate the bearings on a map of the lake using ArcView 3.2 GIS, and compare results. We estimated the total number of birds and their locations by comparing the time, synchronicity, estimated distance, and estimated location of each boom train.

Table 1. Estimates of the numbers of Australasian bitterns booming on Hatuma Lake during the 2011 and 2012 booming season.

Year	Technique	Number of birds (average)	Average effort (hr)	Number of surveys
2011	Triangulation	8-9 (8.5)	1	2
	Close approach (kayak)	9-10 (9.5)	4.25	2
2012	Triangulation	7-9 (8)	1	4
	Close approach (kayak)	7-8 (7.5)	3.5	2

Table 2. Number of fixes on 8 Australasian bitterns booming on Hatuma Lake during a 1 hour acoustic triangulation session on 16 Oct 2012.

	Station 1			Station 2		
Bird number	Number of fixes	Average booms in train*	Approximate distance (m)	Number of fixes	Average boom train*	Approximate distance (m)
A	13	3.69	400	7	3.14	960
B	9	2.88	500	2	2.5	900
C	17	2.94	550	3	2	960
E	8	3.38	900	10	2.6	800
G	2	2.5	1200	3	2	950
H	0	-	1500	6	2.33	1100
J	2	2.7	1500	0	-	1000
M	19	3.84	120	7	3.57	400
A/M§	0	-	-	3	4	-
A/C	0	-	-	2	4	-
B/C	0	-	-	1	4	-
E/G	4	3.25	-	0	-	-
Missed	2	-	-	6	2	-

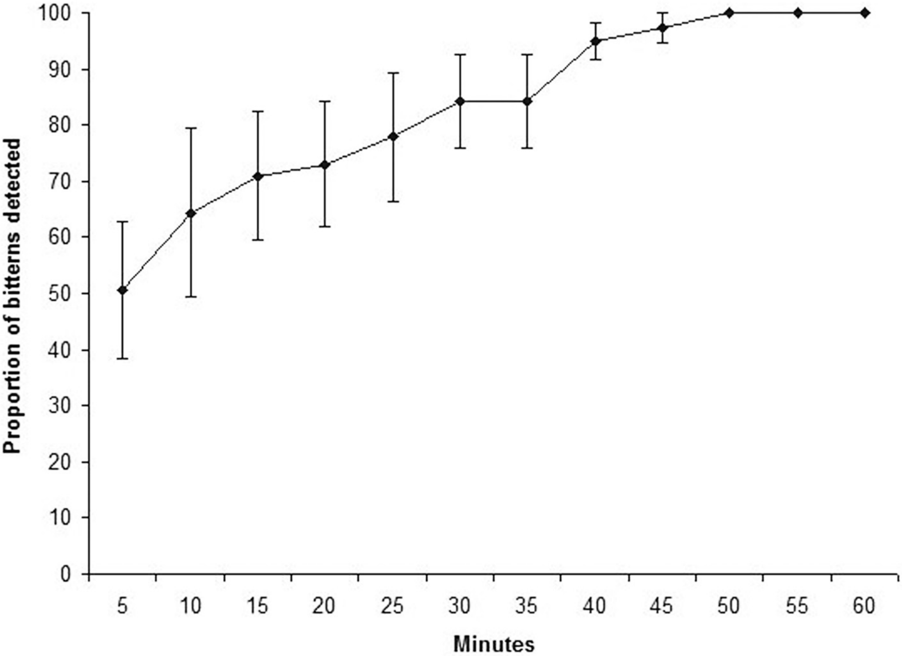
* A boom train is defined as the number of individual booms uttered by a bird during an individual call sequence.
§ All of these calls were recorded from station 2 where bearings for birds A and M were so similar that Observer 2 could not determine which calls came from each bird. However, when calls heard from Station 1 (where there was a greater ability to distinguish between these 2 birds) were also taken into consideration, all calls appear to be from bird M only.

RESULTS

We recorded 8 to 10 Australasian bitterns booming on Hatuma Lake during 4 surveys in 2011; using close approaches we estimated 9–10 bitterns and using triangulation we estimated 8–9 bitterns (Table 1). Booms from individual call locations were recorded repeatedly during all count sessions (for example, 2–19 fixes per location per h, Table 2), offering numerous opportunities to estimate the locations of calling birds. Birds could be heard up to 1.5 km from the observers (Table 2). Similar results were recorded in 2012, when 7–8 bitterns were estimated from close approaches and 8–9 bitterns from triangulation (Table 1). We consider that the 1-h triangulation exercises were long enough to detect all bitterns booming on Hatuma Lake during each sampling session, because no new birds were detected after 45 minutes (Fig. 2).

Not all bittern booms were heard from both stations during the acoustic triangulation exercises (*e.g.*, Table 2). For example, during the exercise of 16 Oct 2011, we considered that booms from the northern end of the lake were clearer, and bearings more precise, for birds A, B, C and M from Station 1 than those recorded for the same birds from Station 2. Similarly, better differentiation of bearings for birds E, G, and H was achieved from Station 2 (Fig. 1). The locations of birds were similar for all 4 surveys, except that in the Jun survey 2 additional birds were present at the northern end of the lake (bird D and bird F) and 1 bird was absent from a small raupo bed near Station 1 (Bird M – Fig. 1). This

Fig. 2. Cumulative proportion of individual Australasian bitterns detected (mean per 5 minute period ± SE) during triangulation periods lasting 1 hour at Hatuma Lake, Oct 2012.



second additional bird (F) was also present for the 13 Oct 2011 kayak survey.

DISCUSSION

We are satisfied that the counts of booming Australasian bitterns for Hatuma Lake are accurate and, despite a small amount of variation, the estimates among surveys relatively consistent. Estimates in the number of birds varying by 1 or 2 individuals in repeat surveys can be explained by daily variability in booming rates. Not all bitterns necessarily boomed during any one of our visits and the intensity of booming can vary from day to day and during different climatic conditions (Teal 1989; *unpubl. data*). Thus, these counts should be considered estimates of relative abundance rather than a true census, largely because we do not know how many female and non-booming birds are present in a wetland, and on any one visit there may be an unknown number of birds that did not boom. Nevertheless, the methods provide a census of number of booming males on the day. The use of the number of booming males as a measure of relative abundance for this highly cryptic bird has been shown to be an informative and useful tool for conservation managers of the Eurasian bittern (*e.g.*, Adamo *et al.* 2004; Poulin *et al.* 2009; van Turnhout *et al.* 2010) and has potential for use with American bittern (Gibbs & Melvin 1997). Gilbert *et al.* (1994) showed that sonograms of booms are specific to a single male, and recommended that an accurate count of bitterns may be made by recording booms and electronically analysing their patterns. However, it is not known if this technique would work for the Australasian bittern. In addition, it is labour intensive and the ability to differentiate individuals may become less reliable at higher densities (Gilbert *et al.* (1994).

We recommend using either close approaches or a combination of close approaches and acoustic triangulation to estimate numbers of Australasian bitterns on small wetlands. We felt that close approaches were better than triangulation because the errors associated with taking compass bearing were minimised. If kayaking is not possible, acoustic triangulation by itself appears suitable, although on Hatuma Lake we probably underestimated the total number of birds booming by 1 or 2 birds. We did not conduct formal triangulation, where intersections of bearings are formally mapped and error polygons calculated around estimated locations (White & Garrott 1986). Previous attempts in Whangamarino wetland using this technique indicated that error polygons were too large to be useful (A. Holzapfel, O. Overdyck Department of Conservation, *pers. comm.*). Interpreting results from triangulation alone is not straightforward because the ability to differentiate between individual birds varies and seems to depend upon the observer's location. At Hatuma Lake, our 2 teams needed to confer at the end of the monitoring session and cross reference the times and directions of each boom train. There was variation in each observer's compass bearings on the same bittern location, which is always a source of error using triangulations techniques (White & Garrott 1990). We also recommend that surveys be undertaken at least 3 times during a booming season, so that confidence in population estimates can be measured.

Our estimates of numbers are based on the assumptions that booming birds are: (a) relatively sedentary during the booming season, (b) booming birds do not move location within a survey period, and (c) all bitterns present boom during the survey period. Literature on the Eurasian bittern suggests that males are highly territorial throughout the breeding season (Alessandria *et al.* 2003; Polak 2006; Gilbert *et al*. 2002). Our experience (and of Teal 1989) suggest that this is also the case for the Australasian bittern. While it is possible some birds move location within a booming season, we have repeatedly been able to predict the location of booming birds at wetlands in the Hawkes Bay and Waikato wetlands. For example, one of us (JC) monitored 1 booming bird for >1 month in the same small patch of raupo, which was likely the same bird based on its distinctive "croaking" boom. This bird boomed from a platform on the edge of an isolated patch of raupo (5 x 15 m) on the edge of Hatuma Lake. The nearest booming bird was >500 m away. Although we cannot confirm this was always the same bird, it seems likely given anecdotal observations of the predictable locations of other Australasian bittern over a long period.

We are uncertain of the maximum wetland size suitable for these techniques to be used because this is likely to depend on the shape of the site, width of riparian vegetation, and density of bitterns. Similar surveys are being carried out on lakes up to 150 ha in size in Hawkes Bay (*e.g.*, Lake Runanga *c.* 130 ha, Lake Oingo *c.* 70 ha; *unpubl. data*). In these sites, riparian reedbeds are narrow (usually <20 m) and there is little chance of overlapping booms being confused. The ability to obtain close approaches in large wetlands is difficult where access is not possible at night, vegetation is difficult to penetrate, water deep and it would be dangerous to attempt surveys. Other techniques will need to be developed for larger wetlands (*e.g.*, using remote sensing techniques).

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