BOPRC – DOC Collaboration: State of environment assessment on Australasian bittern/Matuku (*Botaurus poiciloptilus*).

Regional Bittern Monitoring Pilot Project: Contract number 2021 0030

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1. Acknowledgements:

I would like to thank Shay Dean, of the Bay of Plenty Regional Council, for assisting DOC in organising this collaboration to achieve important Australasian bittern monitoring work. It is also with great thanks to the BOPRC to help fund this work that aims to improve the assessment of bittern presence within a wider BOP catchment of wetland complexes. Lisa Bevan is also to be thanked for her effort in preparing, deploying, and retrieving monitoring devices in the field for this project.

2. Introduction:

In 2016 the status of Australasian bittern/Matuku (*Botaurus poiciloptilus*) was raised to Nationally Critical[1] and is now listed as a priority species for management within the New Zealand Threatened species strategy[2].

Matuku are apex predators in our wetland habitats which means they are important indicators of wetland health. Wetlands, including RAMSAR sites, hold many public interests for conservation and restoration efforts and matuku play a much-needed role as a flagship/iconic species for these sites of great importance. Although Australasian bitterns also occur in Australia, they have declined by >90% there in recent years[3], and New Zealand may now be the stronghold for the species. In addition, virtually nothing is known about their ecology in Australia.

Unfortunately, there are data deficient areas that require further research: the ecology, causes of decline, or how to manage and/or recover bittern populations[4,5]. Preliminary research thus far has focused on developing methods to find and monitor these highly elusive birds[6,7,8,9,10]. The continuing threats to matuku include wetland loss and degradation (sedimentation, flooding and nitrates), starvation, predation, and human forcing (e.g. power lines, vehicles and roads, urbanisation)[11].

The critical issue for bittern conservation is lack of knowledge of which techniques (management prescriptions) to use to recover populations effectively and secure the species from extinction.

Collaborations help us achieve additional goals beyond the direct focus of Arawai Kākāriki site restoration funding streams. Nevertheless, AK funds help provide direct advice for on-going monitoring strategies, new monitoring proposals and supervision, and indirect assistance in the form of equipment and field-based resources. With the addition of a BOPRC collaboration to begin a long-term bittern strategy we can expand some of our fundamental research into developing the key management prescriptions to help recover the populations effectively. This investigation aims to provide a foundation for future monitoring work across a wide wetland complex system in the Bay of Plenty and provide confidence in future deployments of acoustic monitoring devices.

1. Aims/outcomes for wetland bird monitoring in BOP:

Initiate a wide-reaching pilot study to inform a long-term monitoring plan on priority sites and create a foundation for future monitoring of bittern populations.

Establish long-term bittern monitoring stations within priority sites at locations deemed suitable.

Obtain and analyse one season's worth of pilot data from long-term bittern monitoring stations using ARD's and from pre-existing monitoring stations implemented by DOC previously.

Provide greater confidence in where future ARD priority sites should be situated for long-term monitoring of trends in male bittern population presence.

2. Site Planning and Details:

(i) Existing sites in Tauranga district are to be included in continued monitoring efforts if possible:

Little Waihi, Waihi, Maketu Estuary & WMR, Lower Kaituna WMR, Waimapu Estuary/Yatton Park, Matakana Island, extended Tauranga Habour sites (Margaret Jackson WMR, Jess Road WMR, Athenree WRR).

(ii) New sites to explore in the Rangitaiki Plains:

Sites mapped with possible ARD deployment locations (to be scouted by employee/DOC staff pre-deployment to check habitat viability and environmental sound levels that may interfere with recording. Starting from the East:

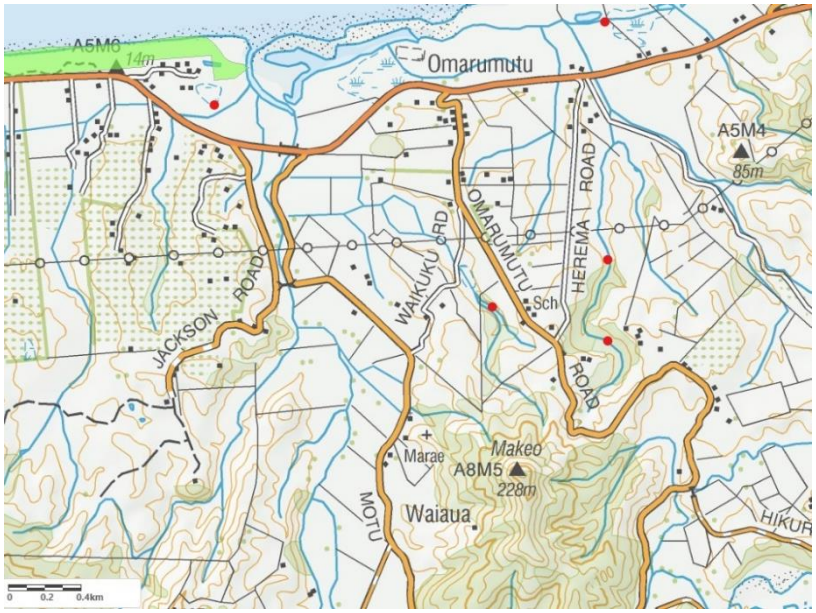

Figure 1. Herema Road: several patches of boggy wetland that we are aware bittern utilise in other parts of the country. Anecdotal evidence of bittern presence in this area that is worth investigating.

Figure 2. Ōpōtiki Harbour: a couple sites near the Waioeka River Estuary and within the Huntress Creek Conservation Area appear suitable for ARD monitoring. The sea may provide an issue for environmental sound interference.

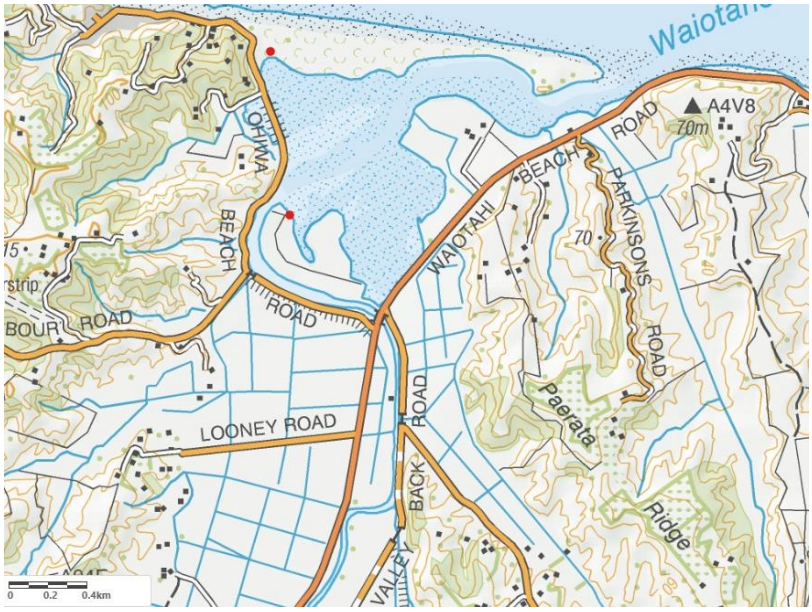

Figure 3. Waiotahe Estuary Scenic Reserve (bottom mark) and Waiotahe Spit Scenic Reserve.

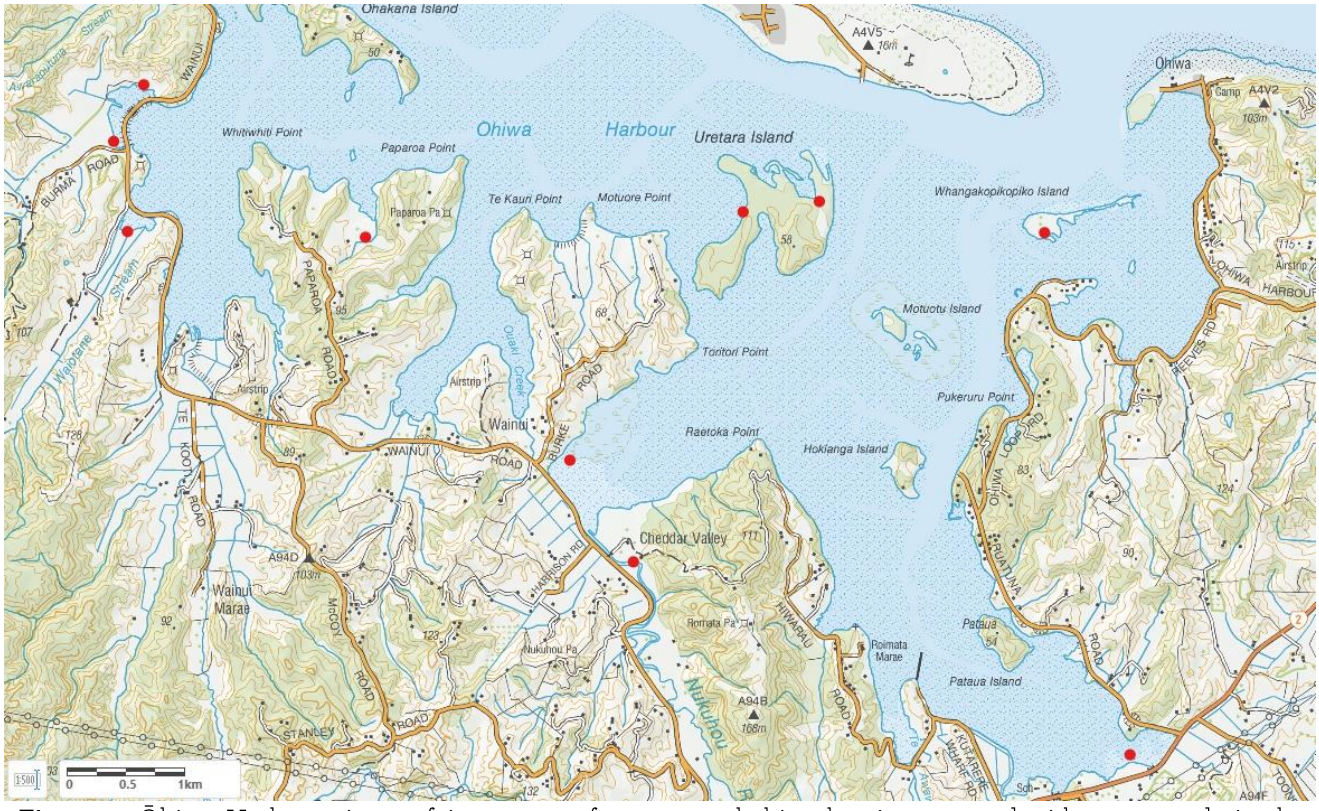

Figure 4. Ōhiwa Harbour sites: a fair amount of mangrove habitat but interspersed with some reeds in the freshwater inlets. Bittern known to visit mangrove swamps to forage, possible sites for booming marked for ARD deployments. ARD surveys have been performed here previous by DOC in 2016/2017 with successful booming recorded at 5 sites of the harbour12.

Figure 5. Rangitaiki River Estuary and Okorero - Thornton Lagoon Wildlife Management Reserve: sites are possibly too close to the sea to deploy ARD's due to the noise interference. Need visiting to make sure.

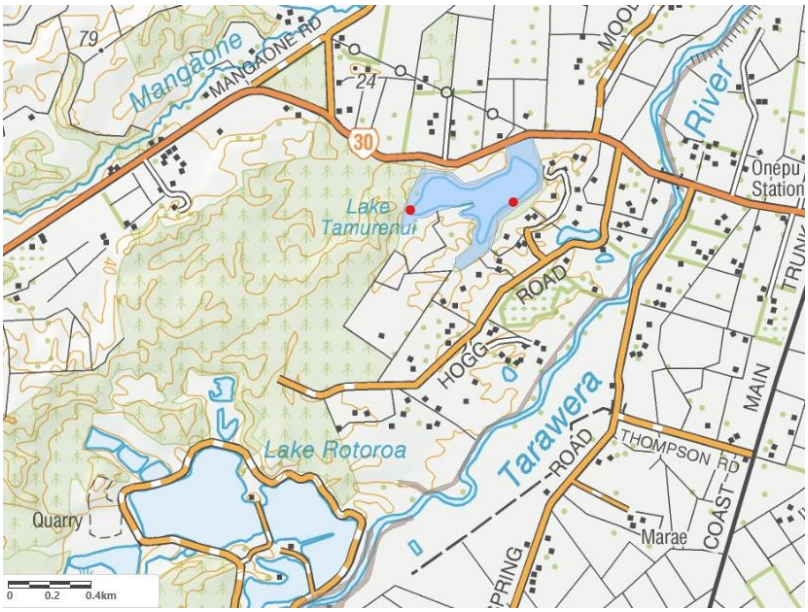

Figure 6. Lake Tamurenui Wildlife Management Reserve required access around the lake to assess possible ARD site.

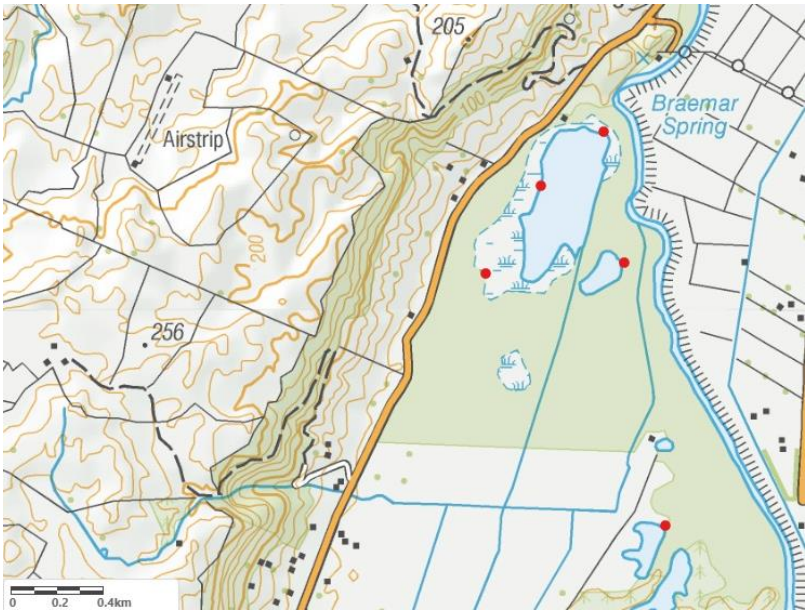

Figure 7. Braemar Spring: lake appears to be good habitat for bittern foraging and nesting with lots of water – reed/sedge surface contact. Required visiting to assess access for deploying ARDs.

Figure 8. Matata region wetlands: (starting from right hand side) Awaiti Wildlfie Management Reserve, Bregman Wildlife Management Reserve, Tarawera Cut Wildlife Management Reserve, and Matatā Wildlife Refuge Reserve. DOC did a survey at the Matata WRR in October 2019 and for three consecutive nights 1x, 2x, and 2x bitterns were heard, respectively13. Similarly, spotless crakes and fernbirds were also heard.

3. Monitoring sites finalised:

a) ARDs long-term deployments:

Table 1. Finalised wetland sites for long-deployment ARD locations including easting and northing of the wetland locations, not the ARD deployment stations.

Sites for ARD deployments: full season	Coordinates	ARD no.
Kaituna	E1897575 N5816321	5
Waihi Estuary	E1906801 N5814196	4
Yatton Park/Sanctuary Point	E1877892 N5819798	1
Ohiwa Harbour	E1962470 N5785337	5
Opotiki Harbour	E1974488 N5786101	2
Matata WRR	E1931064 N5799817	2
Awaiti WMR	E1935138 N5796501	2
Tarawera Cut & Bregman WMR	E1932947 N5797943	2
Full-length deployments:		**23**

b) ARDs short-term deployments:

Table 2. Finalised wetland sites for short-term deployments, 'snap-shot' surveys. Includes easting and northing for the wetland locations, not the ARD deployment stations. Interchangeable ARD deployments refers to the need to relocate limited number of devices among this list of sites for their short-term listening periods; 9 total stations between all sites, 3 ARD devices used cyclically.

Sites for ARD deployments: snap-shot surveys	Coordinates	ARD no.
Maketu Estuary	E1903046 N5815342	2
Margaret Jackson WMR	E1873440 N5824700	1
Jess Road WMR	E1868424 N5826515	1
Athenree WRR	E1861239 N5852542	2
Herema Rd	E1987062 N5785699	1
Waiotahe Estuary	E1967882 N5786823	1
Lake Tamurenui	E1927301 N5784555	1
Braemar Spring	E1928151 N5790490	1
Interchangeable ARD deployments:		**10 (3)**

c) ARD Eastings and Northings for all listening stations:

Table 3. Table showing ARD listening station coordinates for long deployment sites with eastings and northings.

Wetland	ARD Station coordinates					
	1	2	3	4	5	Days active
Kaituna	E1896909 N5816174	E1897514 N5816289	E1898079 N5816709	E1898733 N5816430	E1897916 N5815971	47-49
Waihi Estuary	E1907561 N5812900	E1906926 N5813354	E1906408 N5812910	E1906429 N5813338		35-36
Yatton Park, Sanctuary Point	E1877488 N5819589					33
Ōhiwa Harbour	E1956189 N5786079	E1960331 N5783299	E1962761 N5781680	E1963745 N5781680	E1964807 N5784465	35-45
Ōpōtiki Harbour	E1975901 N5785148	E1974040 N5786077				30-31
Matatā WRR	E1930669 N5800003	E1931325 N5799879				43
Awaiti WMR	E1935203 N5796099	E1935005 N5796750				44
Tarawera Cut & Bregman WMR	E1933274 N5797730	E1933083 N5798511				33-36

Table 4. Table showing ARD listening station coordinates for short-term deployment sites with eastings and northings.

Wetland	ARD Station coordinates		
	1	2	Days active
Maketu Estuary	E1903567 N5814825	E1900363 N5816027	6-13
Margaret Jackson WMR	E1873457 N5824569		2
Jess Road WMR	E1868262 N5826680		20
Athenree WRR	E1861660 N5852771	E1861345 N5852191	27-33
Herema RD	E1987062 N5785699		4
Waiotahe Estuary	E1967615 N5786297		9
Lake Tamurenui	E1927422 N5784617		14
Braemar Spring	E1928056 N5790813		36

4. Methods:

1. Equipment:

Approximately 30 automatic Acoustic Recording Devices

1 x 8GB-16GB SD card per recording unit

4 x AA batteries per recording unit

Wooden stakes or metal waratahs used for mounting ARD's to if no appropriate tree branches are available to deploy devices on

2. How the recorder works:

a) Setup:

The ARD will wake up automatically at the scheduled preset 'Start Time' every day and will continuously record for the preset 'Duration Time'. The recorder will be asleep and not draw much power when outside of the scheduled preset recording times.

When the ARD is prepped for deployment, it is fixed to a stake, waratah, or suitable tree at the designated 'listening station' coordinates. The duration of deployment varies according to desired listening periods prescribed for the monitoring effort. During this investigation deployments ranged from a couple days-couple weeks (snap-shot events) to more than a month (known bittern sites). Full procedure for setting up ARDs can be found in **Appendix 1** of *O'Donnell & Williams 2015: Protocols for the inventory and monitoring of populations of the endangered Australasian bittern in New Zealand*[7].

Devices in this investigation were setup to record during the optimal time for detecting bittern booms. 'Start Time 1' preset was set to 0400-0600AM and 'Start Time 2' preset was set to 1930-2130PM.

b) Sound files:

Recordings are stored on the device memory card as single channel .wav files in a folder labelled 'survey'. Each file is 15 minutes long and each is named with the current date and time (6 digits _6 digits, respectively). Files are stamped with the respective date and time in File Explorer. (e.g., 260210_212406.wav = 26/02/10 at 21:24:06PM).

c) Sound file Analysis:

Upon ARD deployment completion, devices were collected and the data from the SD card transferred to a computer and an external hard drive by the BOPRC (back-ups highly recommended as this data can corrupt easily). Sound files were then checked for corruption

and to determine if the ARD has correctly stored the files. It can become clear if the device has had some sort of fault or has been deployed incorrectly according to start/end times of listening periods and listening period durations by checking files.
Once all sound files had been transferred and checked they were distributed to three research assistants who visually analysed them using RavenLite or RavenPro 1.4 software (other related software can be used but Raven is recommended). Methods on how to use this software for the purpose of analysing bittern sound files can be found in **Appendix 5** of *O'Donnell & Williams 2015: Protocols for the inventory and monitoring of populations of the endangered Australasian bittern in New Zealand*[7].

All research assistants were issued the same sampling method for analysing sound files. Staff were instructed to analyse 1*AM and 1*PM 15-minute recording for each day of ARD deployment. Data is entered into an excel spreadsheet template that is fitted with a macro system for entering meta-data to ensure consistency in terms, weather, disturbances, and location data. This spreadsheet is formatted in preparation for statistical analysis in R[14]. Upon the staff completing their allotted sound-files the spreadsheet is returned for analysis.

The data was then sub-sampled by the following steps:

I. All observations that contained a missing or invalid number of birds were removed from the dataset.
II. Any observations that lay outside the optimal time-period were removed from the dataset. With the am time-period being defined as; a 1-hour period starting at 1.5 hours before sunrise and ending 30 minutes before sunrise and the pm time-period as; a 1-hour period starting 15 minutes before sunset and ending 45 minutes after sunset.
III. From the data that was recorded within the optimal time-period, for each day observations were recorded, one random observation per am & pm time-period was selected.
IV. Then finally from the remaining data for each am and pm time-period, 3 random observations per round of monitoring were selected. However, some ARD deployments were for less time than would provide 3*AM and 3*PM observations and so the maximum number of sub-sampled observations possible were acquired from these sites.

For the 2020 and 2021 survey period, ranged between December 2020 and January 2021, new sites not previously observed with ARDs were grouped into wetland complexes for display purposes; **Omokoroa:** Jess Rd; **Opotiki:** Ōōtiki 1 & 2; **Tarawera River:** Awaiti 2, Bregman WMR, Matatā 1 & 2, Tarawera Cut, and Braemar Spring; **Other Stations:** Waiotahe Estuary, Margaret Jackson, Herema Road, Lake Tamurenui.

5. Results:

1. **Sub-sampled bittern count data:**
   Station 'Awaiti 1' failed due to corrupt file recordings as did 'Waihi 1' thus their data was not included within the results. 'PM' data from Braemar Spring, Lake Tamurenui, and Jess Road was not able to be sampled as it was not present on the SD cards from the deployed ARD. 'AM' data from Athenree 1 and Ōhiwa 1 stations were similarly missing. This is likely due to the recording 'start period' not being set for the respective recording timeframe. This is down to human error and not technological, thus in Tables 5 and 6 there are only N=3 sub-sampled files for Braemar Spring, Athenree 1, and Ōhiwa 1. Waihi 3 station stopped working after two days of deployment, likely due to technological issues.

Table 5. Showing all ARD station locations from 2020-2021 recording data. Some site locations are missing data due to ARD failures and corrupted data. Maximum and minimum bittern booming sequences have been sub-sampled across all stations.

Year	ARD Station	Mean sequence	N	Max sequence	Min sequence	StdDev	SQRT_N	SE
2020	Athenree 1	0	3	0	0	0	1.732	0
2020	Athenree 2	0	6	0	0	0	2.45	0
2020	Awaiti 2	0.1667	6	1	0	0.4082	2.45	0.1667
2020	Braemar Spring	0	3	0	0	0	1.732	0
2020	Bregman WMR	0	6	0	0	0	2.45	0
2020	Herema Rd	0	3	0	0	0	1.732	0
2020	Hiwarau	0	4	0	0	0	2	0
2020	Jess Rd	0.3333	3	1	0	0.5774	1.732	0.3333
2020	Kaituna 1	0.1667	6	1	0	0.4082	2.45	0.1667
2020	Kaituna 2	0.3333	6	1	0	0.5164	2.45	0.2108
2020	Kaituna 3	0.3333	6	1	0	0.5164	2.45	0.2108

2020	Kaituna 4	0	6	0	0	0	2.45	0
2020	Kaituna 5	0	6	0	0	0	2.45	0
2020	Lake Tamurenui	0	6	0	0	0	2.45	0
2020	Maketu 1	0	6	0	0	0	2.45	0
2020	Maketu 2	0	6	0	0	0	2.45	0
2020	Margaret Jackson	0	2	0	0	0	1.414	0
2020	Matatā 1	0	6	0	0	0	2.45	0
2020	Matatā 2	0.6667	6	1	0	0.5164	2.45	0.2108
2020	Ōhiwa 1	0	3	0	0	0	1.732	0
2020	Ōhiwa 2	0	6	0	0	0	2.45	0
2020	Ōhiwa 3	0	6	0	0	0	2.45	0
2020	Ōhiwa 4	0	6	0	0	0	2.45	0
2020	Ōhiwa 5	0	6	0	0	0	2.45	0
2020	Ōpōtiki 1	0	6	0	0	0	2.45	0
2020	Ōpōtiki 2	0	6	0	0	0	2.45	0
2020	Tarawera Cut	0	6	0	0	0	2.45	0
2020	Waihi 2	0.3333	6	1	0	0.5164	2.45	0.2108
2020	Waihi 3	0	2	0	0	0	1.414	0
2020	Waihi 4	0.3333	6	1	0	0.5164	2.45	0.2108
2020	Waiotahe Estuary	0	6	0	0	0	2.45	0
2020	Yatton Park	0	6	0	0	0	2.45	0
2021	Athenree 1	0	3	0	0	0	1.732	0
2021	Athenree 2	0	6	0	0	0	2.45	0
2021	Awaiti 2	0	6	0	0	0	2.45	0
2021	Braemar Spring	0.3333	3	1	0	0.5774	1.732	0.3333
2021	Bregman WMR	0	6	0	0	0	2.45	0
2021	Jess Rd	0	2	0	0	0	1.414	0
2021	Kaituna 1	0	6	0	0	0	2.45	0
2021	Kaituna 2	0	6	0	0	0	2.45	0
2021	Kaituna 3	0	6	0	0	0	2.45	0
2021	Kaituna 4	0	6	0	0	0	2.45	0
2021	Kaituna 5	0	6	0	0	0	2.45	0
2021	Matatā 1	0	6	0	0	0	2.45	0
2021	Matatā 2	0	6	0	0	0	2.45	0
2021	Ōhiwa 1	0	3	0	0	0	1.732	0
2021	Ōhiwa 2	0	6	0	0	0	2.45	0
2021	Ōhiwa 3	0	6	0	0	0	2.45	0

2021	Ōhiwa 4	0	6	0	0	0	2.45	0
2021	Ōhiwa 5	0	6	0	0	0	2.45	0
2021	Ōpōtiki 1	0	6	0	0	0	2.45	0
2021	Ōpōtiki 2	0	6	0	0	0	2.45	0
2021	Tarawera Cut	0	6	0	0	0	2.45	0
2021	Waihi 2	0	6	0	0	0	2.45	0
2021	Waihi 4	0	6	0	0	0	2.45	0
2021	Yatton Park	0	6	0	0	0	2.45	0

Table 6. Showing grouped wetland-site data for all station ARDs. Average bittern counts from sub-sampled soundfile data shown.

Year	Region	Wetland Group	Average bittern count (sequence/15min)
2020	Bay of Plenty	Athenree	0
2020	Bay of Plenty	Greerton	0
2020	Bay of Plenty	Kaituna	0.1389
2020	Bay of Plenty	Lake Tamurenui	0
2020	Bay of Plenty	Maketu	0
2020	Bay of Plenty	Ohiwa Harbour	0
2020	Bay of Plenty	Omarumutu	0
2020	Bay of Plenty	Omokoroa	0.3333
2020	Bay of Plenty	Ōpōtiki	0
2020	Bay of Plenty	Tarawera River	0.1515
2020	Bay of Plenty	Waihi Estuary	0.2857
2020	Bay of Plenty	Waiotahe Estuary	0
2020	Bay of Plenty	Wairoa Pa	0
2021	Bay of Plenty	Athenree	0
2021	Bay of Plenty	Greerton	0
2021	Bay of Plenty	Kaituna	0
2021	Bay of Plenty	Ohiwa Harbour	0
2021	Bay of Plenty	Omokoroa	0
2021	Bay of Plenty	Ōpōtiki	0
2021	Bay of Plenty	Tarawera River	0.0303
2021	Bay of Plenty	Waihi Estuary	0

Of the 56 ARD stations that were deployed between December 2020 and January 2021 only 9 returned bittern count data when subsampled (Table 5). When stations were grouped into wetland sites this corresponded to 5 of 23 sites returning bittern count data (Table 6). Bittern count data was identified in Kaituna, Omokoroa, Tarawera River, Waihi Estuary. Omokoroa and Waihi Estuary returned the highest averages of 0.3333 and 0.2857 ± SE calls per 15-minute period respectively within the subsampled data (Table 6).

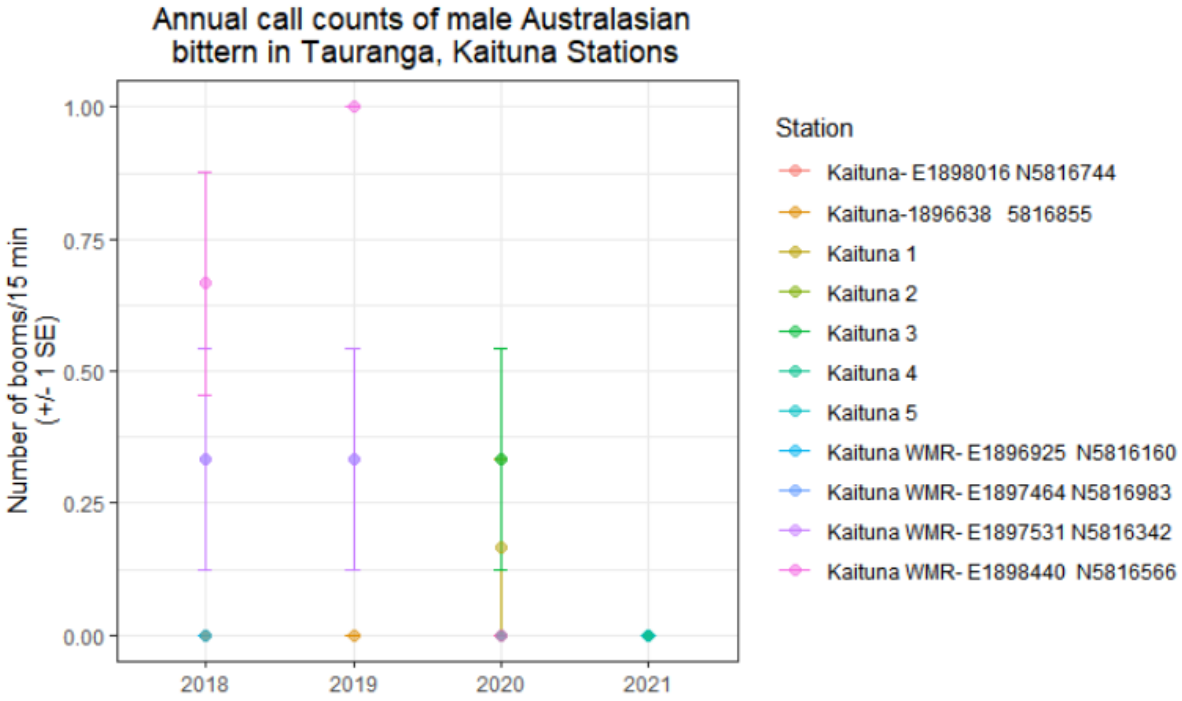

Figure 9. Showing annual male bittern call counts at all Kaituna Wetland stations from 2018 historical data to 2021. Sub-sampled bittern count data is shown with SE of the mean number of booms per 15 minute sound recording. Some stations have been renamed between monitoring years and also changed positions, these stations are renamed: Kaituna E1898016 N5816744 = Kaituna 3; Kaituna WMR - E1896925 N5816160 = Kaituna 1; Kaituna WMR – E1897531 N5816342 = Kaituna 2; Kaituna WMR – 1898440 N5816566 = Kaituna 4.

Between 2018 and 2019 there was strong bittern indication within the Kaituna WMR, ranging between 0.3 and 1.0 ± SE boom sequences per 15-minute period (Figure 9). The recent BOPRC collaboration survey indicated similar bittern presence within Kaituna WMR during the December 2020 season but only peaking at 0.3 ± SE boom sequences per 15-minute period (Figure 9). January 2021 indicated no subsampled bittern counts at Kaituna WMR (Figure 9).

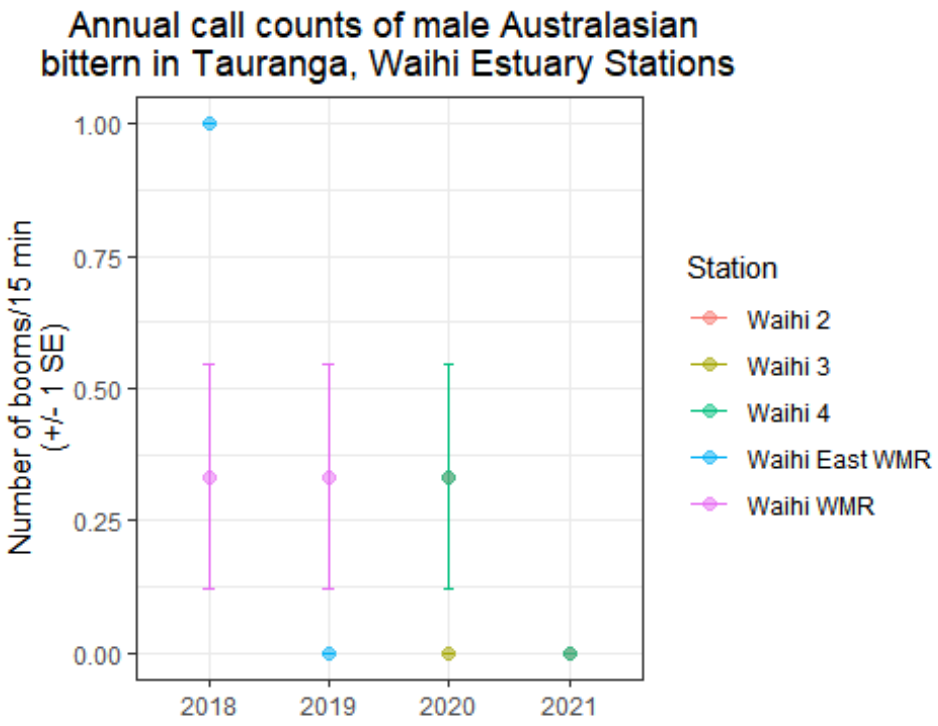

Figure 10. Showing annual bittern call counts at all Waihi WMR stations from 2018 historical data to 2021. Sub-sampled bittern count data is shown with SE of the mean number of booms per 15 minute sound recording. Some stations have changed name for easier recognition. Waihi East and Waihi WMR are no longer used and have been replaced by Waihi 2, 3 and 4. The ARD at Waihi 1 failed to record this season.

In Figure 10, there was a similar result within Waihi WMR to Kaituna WMR in Figure 9 between the years 2018 and 2019, showing a range of 0.3 to 1.0 ± SE boom sequence per 15-minute count average. Further, the continuation of the similar trend is observed into the December 2020 survey performed by the BOPRC collaboration (Figure 10). No bittern count was subsampled for the January 2021 period at Waihi WMR (Figure 10).

New sites not previously surveyed with ARDs are shown in Figure 11. No bittern count data was observed across all subsampled stations for January 2021 except for Braemar Spring (Figure 11). Jess Rd (Omokoroa wetland group) observed a bittern count average of 0.3 ± SE during December 2020. At the Tarawera River wetland group bittern count average ranged from 0.2, 0.3, and 0.7 ± SE at Awaiti 2, Braemar Spring, and Matatā 2 respectively (Figure 11). Braemar Spring was the only site surveyed that bittern count data was observed within during January 2021 after subsampling data (Figure 11).

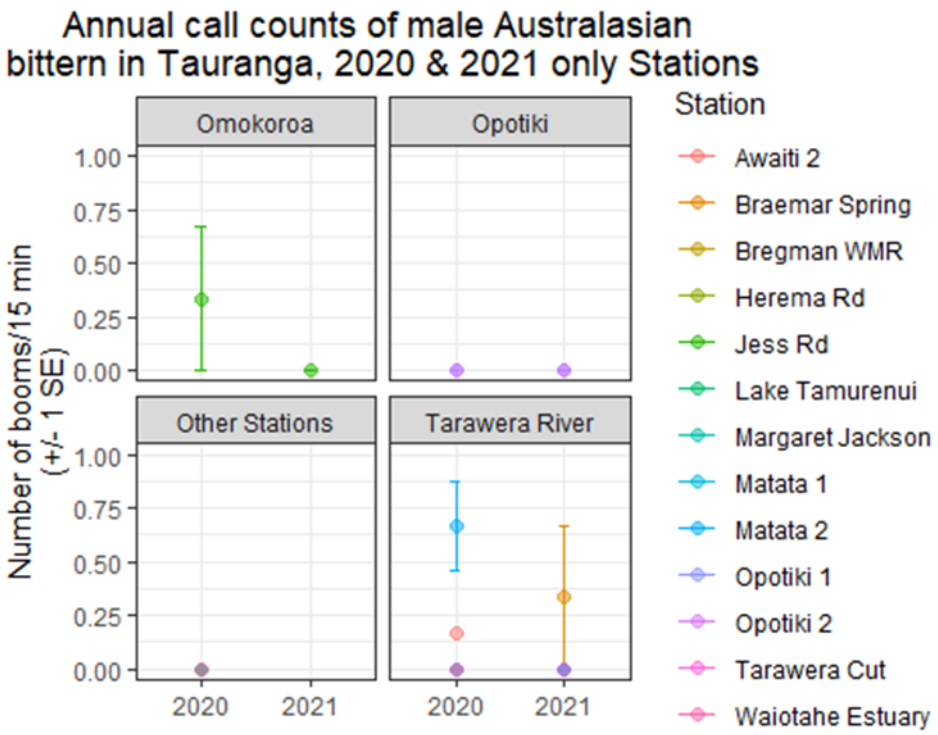

Figure 11. Showing annual bittern call counts across all newly monitored wetland sites in the BOP. No historical ARD data was present for these sites. Sub-sampled bittern count data is shown with SE of the mean number of booms per 15 minute sound recording. Individual sites were grouped into four; **Omokoroa:** Jess Rd; **Ōpōtiki:** Ōpōtiki 1 & 2; **Tarawera River:** Awaiti 2, Bregman WMR, Matata 1 & 2, Tarawera Cut, and Braemar Spring.; **Other Stations:** Waiotahe Estuary, Margaret Jackson, Herema Road, Lake Tamurenui.

6. Discussion:

This collaboration between DOC and BOPRC was initiated with the aim to survey a large span of wetland complexes from Tauranga Harbour in the west to Ōpōtiki in the east. The objective was to identify and solidify wetland complexes for future male-bittern population monitoring efforts. This pilot study would become a foundation for prioritising sites for ARD deployments that encompass a wide-reaching space in the Bay of Plenty to establish a long-term bittern monitoring strategy.

Matakana Island, Rangitaiki Estuary/Thornton Lagoon WMR did not get surveyed as originally planned. Wetlands that were included in the short-term deployment surveys (Table 4) recorded for between 2 and 36 days. While the original aim was to sample these

sites for between 5-14 days each, the logistical requirements for deploying, re-gathering, and then re-deploying at a new site across the BOP region proved difficult. This was also compounded by the fact that the persons responsible likely had other responsibilities, reducing the amount of time available. Christmas holidays were also in-between many of these deployments, further reducing chance of moving them more often. The extended deployments of Athenree WMR, Jess Road WMR, and Braemar Spring were likely due to these factors mentioned. The sites that did not get surveyed as originally planned were also likely due to the same factors.

Further considerations must be made for the sites that were surveyed but with error. Station 'Awaiti 1' failed due to corrupt file recordings as did 'Waihi 1'. 'PM' data from Braemar Spring, Lake Tamurenui, and Jess Road was recorded. 'AM' data from Athenree 1 and Ōhiwa 1 stations were similarly missing. These errors are a mix of technological and human error, respectively. As Braemar Spring, Athenree 1, and Jess Rd had all observed bittern presence during the survey period, the additional 'AM' and 'PM' data from these sites may likely have increased the resolution of bittern count data and strengthened our confidences.

Sites that had been previously surveyed with ARDs by the Department of Conservation (Waihi Estuary and Kaituna shown in this report) continued to illustrate male bittern presence, however, this recent survey event began in December whilst previous survey years have begun earlier within the breeding season in October and November. It is safe to assume that the peak male-booming period had passed by the time the 2020-2021 survey period was initiated. Nevertheless, boom sequences had been observed in all previously known bittern 'hot-spots' and within new non-surveyed wetland sites. This successful identification of bittern presence in these novel sites gives confidence that bittern visit and utilise these new sites within the wider BOP wetland complex. This is particularly the case with Jess Rd WMR, Braemar Spring, Matatā WMR, and Awaiti that all observed bittern count data following the subsampling methods.

The subsampling method used in this investigation is a standard method for analysing male bittern count data over the long-term and for comparing year-to-year variations. However, this investigation seeks to discover bittern presence in sites previously either unknown for bittern presence or limited to anecdotal evidence and garner reason to continue monitoring them for bittern should presence be observed. In the **Appendix** raw data has been attached; this data shows all data points from the ARD sounds files that were analysed by the research

assistants (Table 7, Figure 12). Figure 12 clearly indicates that some sites did indeed observe bittern presence where the subsampling methodology did not. Such as Athenree, Yatton Park, Bregman WMR, Ōpōtiki and Tarawera Cut. The reason why the subsampling does not always pick up bittern count data is simply due to the low number of sequences compared to the amount of recording data present. These sites had low activity, as seen in Figure 12 and Table 7. Given that some of these sites were surveyed for short periods of time and outside the optimal male bittern booming season it is reasonable to conclude that male bitterns frequent these sites during the breeding season.

While we have recently discovered male bitterns moving vast distances, it is likely that a handful of bitterns will circulate smaller wetland sites in search of females, thus, the same bittern could be observed across numerous ARD sites. Nevertheless, this investigation has found that there are more wetland sites being utilised by male bittern in the search of breeding females than previously accounted for. We have considerable confidence that moving forward we have discovered some important wetland sites for future monitoring.

7. Recommendations:

1. **Review of sites:**

Despite some shortfalls in this investigation as discussed earlier, this was a successful pilot study. The discovery of several key male bittern booming sites that were previously unaccounted for with data has provided confidence in future monitoring of the same sites again as longer-term deployments: Braemar Spring, Matatā WRR, Awaiti WMR, Bregman WMR, Tarawera Cut, Jess Road WMR, Waiotahe Estuary, and Ōpōtiki Harbour wetland sites should be included within future monitoring efforts alongside Kaituna, Waihi WMR, Yatton Park/Sanctuary Point, Athenree WRR, and Matakana Island. Other surveyed sites both previous and new: Maketu, Ōhiwa Harbour, Lake Tamurenui, Margaret Jackson, and Herema Road require considerations.

Ōhiwa Harbour is an expansive site requiring 5 ARD deployments but is situated between Ōpōtiki and Whakatane and contains a lot of possible bittern habitat. Due to its considerable size, it is worth surveying again despite its lack of bittern data during

December 2020 and January 2021. An earlier survey period may present bittern count data when the peak booming period is more likely.

Maketu, like Ōhiwa is a potential bittern habitat but only requires 2 ARD devices. It is worthwhile to continue surveying this site as bittern have previously been recorded here (not illustrated in this report). It is important to recognise that bittern can visit sites one year but not the next and Maketu sits along the wetland complex where bittern travel.

Lake Tamurenui was a snap-shot deployment south of Braemar Spring but situated near the Tarawera River. It is possible that bittern may visit this site as it contains some raupō beds, but the extent of breeding habitat is limited. I recommend excluding this site from future survey efforts.

Margaret Jackson WMR, situated within Tauranga Harbour, remains a possible bittern habitat as it shares similarities with Jess Road Reserve and Yatton Park. Situated along the Wairoa River there is some confidence that bittern may utilise this site as we have records of a GPS tagged bird visiting these small bays throughout the harbour. However, there is no certainty about whether this is a possible bittern breeding ground. Margaret Jackson WMR could be surveyed as a 'snap-shot' site again but not as a long deployment.

Herema Road ARD observed no bitter count data, and only was only deployed for a short duration of 4 days. The location of the ARD was non-optimal in retrospect and should be moved for another 'snap-shot' survey further to the north. There are three pools of water along the waterfront surrounded by raupō and other wetland plants. For the eastern Ōpōtiki wetlands, this may be one of the only possible bittern breeding sites east of the Waiaua River and west of Toatoa village.

2. Future survey times, sites, and requirements:

a. Long deployment sites:
   - Matatā WRR (2 ARD)
   - Awaiti WMR (2 ARD)
   - Bregman WMR (1 ARD)
   - Tarawera Cut (1 ARD)
   - Jess Road WMR (1 ARD)
   - Waiotahe Estuary (1 ARD)
   - Ōpōtiki Harbour (2 ARD)

- Kaituna (5 ARD)
- Ōhiwa (5 ARD)
- Matakana Island (~4 ARD)
- Athenree WRR (2 ARD)
- Waihi WMR (4 ARD)
- Maketu (2 ARD)
- Yatton Park (1 ARD)

Total = 33 ARDs

b. Possible snap-shot deployment sites (2 ARDs deployed for 2 weeks at each site):
   - Thornton Lagoon/Rangitaiki Estuary (2 ARD)
   - Toatoa beach (2 ARD)
   - Whakatane Estuary (2 ARD)

Total = 6 ARDs (2) cycled

Total for season = 35 ARDs

It is recommended that the survey period for **2021 spring/summer runs from mid-October to the end of November** in expectation that peak-bittern booming will occur during this timeframe.

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9. Appendix:

Table 7. Shows raw data from all surveyed sites December 2020 and January 2021. Raw data prior to subsampling methods illustrates sites with bittern presence that subsampling processes may not indicate.

2020-2021 (Dec-Jan)				
Row Labels	**n files**	**Sum of Number sequences**	***Max of Number of birds**	Sequences/15mins
Yatton Park 1	66	4	2	0.06
Waiotahe Estuary	16	0	0	0.00
Waihi 4	70	23	1	0.33
Waihi 3	2	0	0	0.00
Waihi 2	70	29	1	0.41
Tarawera Cut 1	66	1	1	0.02
Ōpōtiki 2	60	0	0	0.00
Ōpōtiki 1	60	1	1	0.02
Ōhiwa 5	76	0	0	0.00
Ōhiwa 4	72	0	0	0.00
Ōhiwa 3	68	0	0	0.00
Ōhiwa 2	75	0	0	0.00
Ōhiwa 1	45	0	0	0.00
MJ1	2	0	0	0.00
Matatā 2	84	143	1	1.70
Matatā 1	84	0	0	0.00
Maketu 2	26	0	0	0.00
Maketu 1	11	0	0	0.00
Lake Tamurenui 1	14	0	0	0.00
Kaituna 5	96	0	0	0.00
Kaituna 4	124	4	1	0.03
Kaituna 3	111	32	2	0.29
Kaituna 2	93	73	1	0.78
Kaituna 1	124	53	1	0.43
Jess Rd 1	20	3	1	0.15
Hiwarau	5	0	0	0.00
Herema Road 1	4	0	0	0.00
Bregman WMR 1	68	3	1	0.04
Braemar Spring 1	36	31	1	0.86
Awaiti 2	85	106	3	1.25
Athenree 1	27	8	1	0.30
Athenree 2	65	0	0	0.00

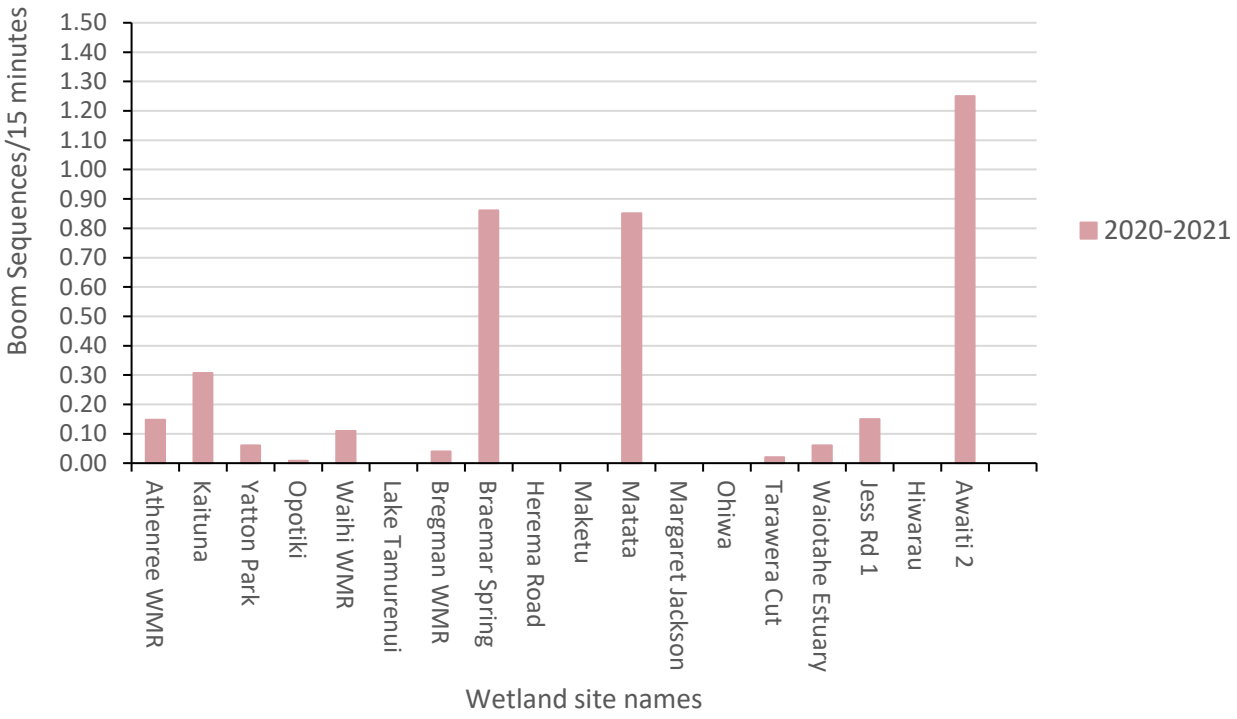

Figure 12. Ilustrates the raw bittern count data of Table 7.