Monitoring Priority Threatened Species

A review of monitoring methods for the Australasian Bittern *(Botaurus poiciloptilus)*

September 2024

EMSA Ecological Monitoring System Australia

Australian Government
Department of Climate Change, Energy, the Environment and Water

tern Ecosystem Research Infrastructure

NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

Citation

TERN Australia (2024) Monitoring Priority Threatened Species: A review of monitoring methods for the Australasian Bittern (*Botaurus poiciloptilus*) Version 1 Report to the Department of Climate Change, Energy the Environment and Water. TERN, Adelaide.

Version

Version 2.

Last updated: 12 November 2024

Acknowledgements and contributions

This work was funded by the Australian Government Department of Climate Change, Energy, the Environment and Water.

Acknowledgement of Country

We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment and community. We pay our respects to the Traditional Custodians of the lands we live and work on, their culture, and their Elders past and present.

Copyright

Disclaimer

The views and opinions expressed in this publication do not necessarily represent the views of TERN, the Australian Government or the portfolio ministers for the Department of Climate Change, Energy, the Environment and Water.

The content of this publication does not constitute advice to any third party. Although due care and skill have been applied in the preparation and compilation of the information and data in this publication, no reliance may be placed on it by any other party. No representation expressed or implied is made as to the currency, accuracy, reliability, completeness, or fitness for the purpose of the information contained in this publication. The reader should rely on their own inquiries to independently confirm any information and comment on which they may intend to act.

TERN and the Commonwealth of Australia, its officers, employees, agents and the other parties involved in creating this report disclaim, to the maximum extent permitted by law, responsibility to any other party for any liability, including liability for negligence and for any loss, damage, injury, expense or cost incurred by any person as a result of accessing, using or relying upon any of the information or data in the publication.

This document is designed to be an information resource. It is not a statutory document or policy statement. If information diverges, the information in the statutory document(s) and policy statement(s) take precedence over this document. This document should be used in parallel with relevant survey guidance, conservation advice, and recovery plans.

Version control

Readers are advised that Threatened Species Literature Reviews regularly undergo revision. Readers should check the website emsa.tern.org.au/threatened-species-survey-guidelines to ensure they are viewing the current version.

The version history of this literature review is identified below.

Version	Date	Version update overview
1	2 September 2024	First published version
2	12 November 2024	Minor typographical correction in Section 2.2

About

This literature review collates information on one of the 110 priority threatened species identified in the *Threatened Species Action Plan 2022-2032* and has been reviewed by invited practitioners experienced in monitoring the species.

The *Survey Guidelines for Monitoring Threatened Species* project, a collaboration of the Department of Climate Change, Energy, the Environment and Water (DCCEEW) and the Terrestrial Ecosystem Research Network (TERN), aims to improve our knowledge of threatened species by enhancing accessibility and sharing of quality scientific threatened species data. Developing best practice field survey guidelines and recommendations will better equip practitioners to conduct standardised, repeatable surveys.

By identifying the monitoring methods typically implemented by practitioners, documenting and assessing the techniques known to work, and identifying opportunities to standardise the methods, we can move towards ensuring all monitoring is species-appropriate, comparable between practitioners and populations, and repeatable over time. Further, together with consistent terminology, guidelines, instructions, and data collection, we can refine efforts and resources to measure and share information. Data collected using robust, standardised methods will improve our knowledge of threatened species and underpin threatened species recovery at scale. This project is essential to establishing monitoring protocols and data repositories to enhance the accessibility and sharing of threatened species data.

TERN has prepared the literature reviews for the Department of Climate Change, Energy, the Environment and Water. For further information, please visit the EMSA Threatened Species Survey Guidelines website. Additional information, particularly monitoring methods and techniques not included that should be considered, can be brought to the author's attention by emailing tern@adelaide.edu.au for consideration for future updates.

Contents

Figures

Tables

1 Background

1.1 Species name

The Australasian Bittern (*Botaurus poiciloptilus*) (Wagler 1827) is a large bird in the heron family Ardeidae.

1.2 Conservation status

The Australasian Bittern is listed as Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). The species is one of 22 priority birds listed in the Australian Government Threatened Species Action Plan 2022-2023 (DCCEEW 2022). A national recovery plan was released in 2022 (Commonwealth of Australia 2022) and the EPBC Act conservation advice was updated in 2019 (Threatened Species Scientific Committee (TSSC) 2019). The International Union for Conservation of Nature's (ICUN) Red List of threatened species lists the species as Vulnerable citing the small and declining population, primarily due to the degradation of its wetland habitats (BirdLife International 2022). The conservation status of the Australasian Bittern is outlined in Table 1.

Table 1. International, national and state conservation status for the Australasian Bittern

Jurisdiction	Status	Legislation or listing
IUCN	Vulnerable	Global Status: IUCN Red List of Threatened Species: 2022.2 list
Commonwealth	Endangered	*Environment Protection and Biodiversity Conservation Act 1999*
Australian Capital Territory	Endangered	*Nature Conservation Act 2014*
New South Wales	Endangered	*Biodiversity Conservation Act 2016*
Queensland	Endangered	*Nature Conservation (Animals) Regulation 2020*
South Australia	Endangered	*National Parks and Wildlife Act 1972*
Victoria	Critically Endangered	*Flora and Fauna Guarantee Act 1988*
Western Australia	Endangered	*Biodiversity Conservation Act 2016*

1.3 Summary of data held in the Threatened Species Index

The Threatened Species Index (TSX) provides reliable and robust measures of change in the relative abundance of Australia's threatened and near-threatened species at national, state and regional levels. Understanding changes in species populations is crucial for monitoring Australia's conservation progress and allows users to measure and report on the benefits of conservation investments, and to justify and design targeted management responses. The index is currently restricted to birds, plants and mammals, with new groups to be added in the near future.

Table 2 summarises Australasian Bittern data held in the TSX. More information on the TSX, including how to contribute threatened species monitoring data to the index, can be found on the TSX website.

Table 2. Summary of Australasian Bittern data held in the Threatened Species Index (TSX).

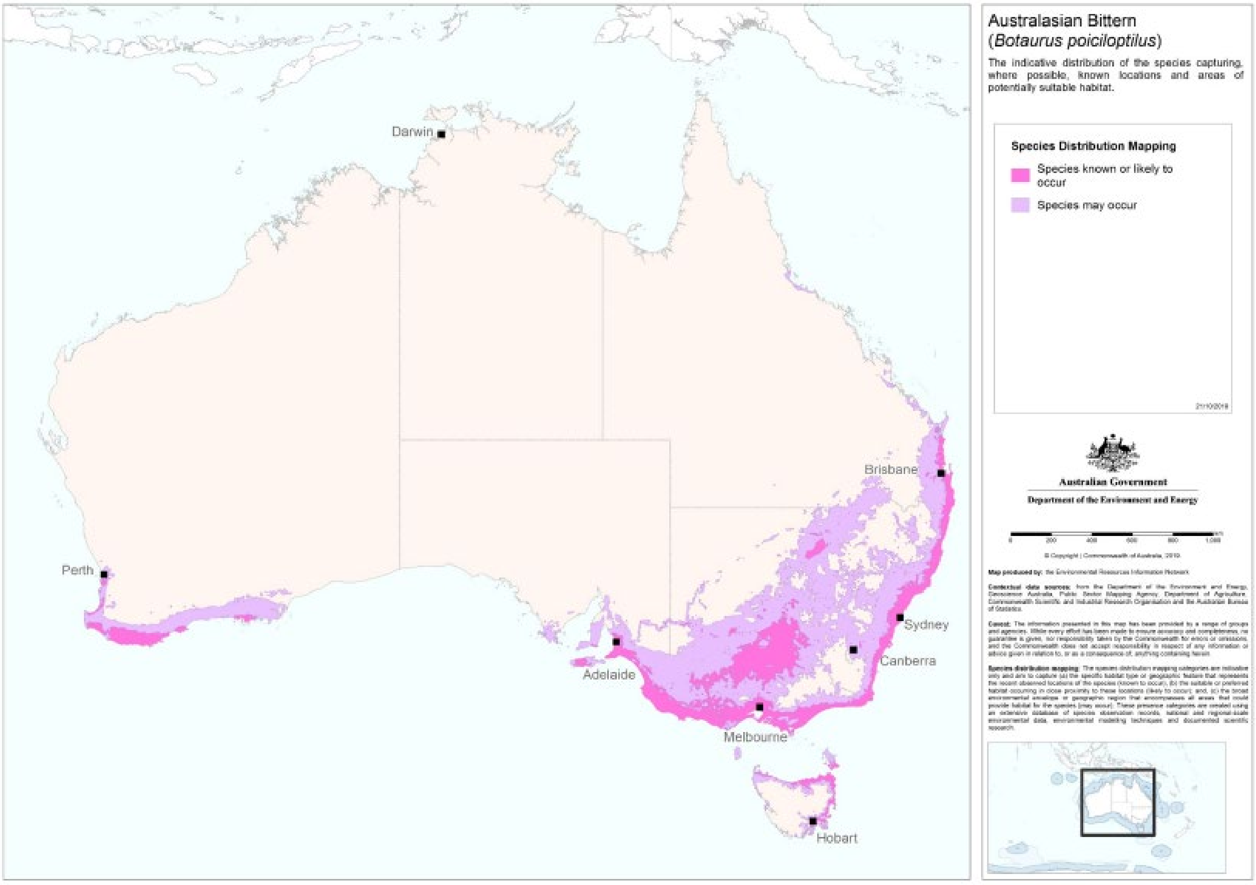
TSX Information	Data held
▪ Data held in the TSX	▪ Yes
▪ Number of data sources	▪ 2
▪ Number of unique sites	▪ 135
▪ Average time series length (years)	▪ 11.6

TSX Information	Data held
▪ Average number of sampling years	▪ 7.5

1.4 Distribution and abundance

In Australia, Australasian Bittern occur across a wide distribution, from south-eastern Queensland to south-eastern South Australia, as well as Tasmania and south-western Western Australia (Figure 1). Vagrants have also been recorded from northern Australia. Australasian Bittern also occur in New Zealand and there are unconfirmed historical records from New Caledonia (BirdLife International 2023; Commonwealth of Australia 2022; Garnett & Baker 2021; Herring 2022). Specific location information is provided in Commonwealth of Australia (2022) and Threatened Species Scientific Committee (TSSC) (2019).

Figure 1. Distribution map of Australasian Bittern.



Source: (Commonwealth of Australia 2022).

In 2021, the Australian population was estimated at 1,300 individuals, and the New Zealand population was estimated at 700, meaning a global total of around 2,000 birds. This is an increase from the previous Australian population estimate of fewer than 1,000 birds (Pickering 2018).

The Australian population is split into two isolated subpopulations in eastern and south-western Australia. The eastern subpopulation comprises over 95 % of individuals (Garnett & Baker 2021), with about 950 birds occurring in the Murray-Darling Basin (Herring 2022). The Riverina region of southern New South Wales is the global stronghold for the species (estimated between 500 - 1000 birds) (Bull 2022; Herring 2022), followed by south-western Victoria and adjacent South Australia. Among Australia's most important sites are the Barmah-Millewa wetlands along the Murray River, the Lowbidgee and Fivebough Tuckerbil Wetlands in New South Wales, the Bool-Hacks Lagoon system in South Australia, and Hirds-Johnsons Swamp in northern Victoria (Herring 2022).

Tracking data suggests the species readily travels long distances, so there is likely to be mixing between eastern mainland and Tasmania (Garnett & Baker 2021). Birds are known to disperse from the Riverina to coastal wetlands in South Australia, Victoria and New South Wales, using wetland stopovers (Herring 2022; Herring et al. 2019). Birds in Western Australia are assumed not to mix with eastern populations (Garnett & Baker 2021), however closely related bittern species have been recorded moving over 2,000 kilometres, so connections between Australia's Australasian Bittern subpopulations and even those in New Zealand are plausible (Herring 2022).

The Australasian Bittern is thought to have been in decline at least since the 1980's, with the decline being more pronounced since 2000. The decline has been detected across the eastern and western subpopulations and is associated with losing key breeding habitats (Commonwealth of Australia 2022). The population trend is somewhat uncertain, given numbers can fluctuate depending on environmental conditions and because the species is so cryptic and difficult to monitor (Garnett & Baker 2021). With natural wetlands now conserved and wetlands being restored and managed (including rice farms) to support Australasian Bittern better, the aim is to achieve an upward trajectory in the number of birds at key wetlands compared to baseline counts (Commonwealth of Australia 2022).

1.5 Habitat requirements

Australasian Bittern habitat typically comprises freshwater wetlands, both permanent and seasonal, with fringing and emergent vegetation. Preferred wetland habitats are densely vegetated, with a mosaic of cover, from 0.5 - 3.5 metres in height, including sedges, rushes and/or reeds (e.g. *Phragmites, Cyperus, Eleocharis, Juncus, Typha, Baumea, Bolboschoenus*) or cutting grass (*Gahnia*) growing over a muddy or peaty substrate (Commonwealth of Australia 2022; Marchant & Higgins 1990). They typically favour the largest wetlands in the landscape, usually with little or no tree cover (Herring 2022).

Australasian Bittern habitat varies across the species range and use depends on the presence of water, vegetation cover and the availability of prey species. Habitat suitability can increase with the abundance of habitat and food resources following rainfall and inflows (Commonwealth of Australia 2022). Habitat availability is significantly reduced during periods of drought (Garnett & Baker 2021).

In south-western Australia, wetland habitats include those surrounded by sedges and patches of taller wetland shrubs (e.g. *Melaleuca, Agonis* spp.). In the Murray-Darling Basin, habitats include floodplain swamps that may include lignum (*Duma florulenta*) shrubs within sedge or reed beds. In the NSW Riverina, commercial rice-fields provide important habitat. On rare occasions, Australasian Bittern has been observed within estuaries and tidal wetlands (Commonwealth of Australia 2022) and in open pasture and shallow ephemeral wetlands with no fringing or emergent vegetation (Fitzsimons 2022). Artificial wetlands, farm dams and channels with shallow wetland area and water plant cover are regularly used during the non-breeding period and as stop over habitats (Herring 2022).

Breeding is limited to specific locations with suitable habitat conditions. Bitterns tend to remain at a particular wetland during breeding. However, if conditions change, such as a wetland drying out or a rice crop being harvested, they will move. The rice fields of the New South Wales Riverina support the largest breeding population (approximately 750 birds) (Herring 2022), with the rice fields that receive early permanent water being especially important (Herring et al. 2019). The area sown to rice and thus suitable for breeding varies by over an order of magnitude according to water availability (Herring et al. 2019). Standardised monitoring at rice fields during the first three years of an incentive program (growing rice with early permanent water) found between two and six times as many bitterns at the incentive sites compared to control sites, and 13 nests recorded at incentive sites compared to no nesting recorded at control sites. Vegetated wetland refuges adjacent to rice fields are important to complement rice fields during the growing season and provide habitat after the rice season ends. This is especially important for young birds that haven't fully fledged (Herring 2022).

1.6 Biology and Ecology

Australasian Bittern are shy, secretive, and well camouflaged wetland birds, that stand to about 80 cm high and have a wingspan over a metre. Life expectancy is estimated at 11 years (based on the better studied Eurasian Bittern), and the age of maturity is estimated to be one year. The generation length for the species is estimated to be 5.5 years, with low reliability (Garnett & Crowley 2000; Garnett et al. 2011; Herring 2022; Threatened Species Scientific Committee (TSSC) 2019).

Australian Bitterns are usually solitary or live in loose groups of two to five birds (Herring 2022). Male birds establish breeding territories and breeding pairs are solitary, occupying relatively large home ranges of 40-50 ha and occurring at low densities. They can be monogamous or polygamous, with booming males recorded with up to three nesting females in their territory (Herring 2022). Little is known of their courtship, breeding, and other social behaviour (BirdLife Australia undated). Their booming call is a good indicator of potential breeding, but evidence is emerging that many males either do not attract females, or no nesting occurs (Herring 2022).

Australasian Bittern are most active around dawn and dusk, as well as the early morning and late afternoon, although males can call throughout the night. During the middle of the day, they are often roosting and largely inactive (Herring 2022).

Australasian Bittern builds a platform nest of trampled reeds and rushes, about the size of a dinner plate, which sits 10-30 cm above water level, well hidden by surrounding tall dense stands of reeds or rushes. Nests are often located in the middle of the wetland in the deepest water, if dense plant cover is present. Females usually lay a clutch of four to five eggs, in spring to summer, with an incubation period of 25 days and fledging of young at about 7-8 weeks of age, although young can leave the nest and begin roaming from two weeks of age. Only the female incubates the eggs and raises the young (Herring 2022).

Australasian Bittern forage in still, shallow water up to 0.3 m deep, often at the edges of pools or waterways, or from platforms or mats of vegetation over deep water (Commonwealth of Australia 2022). They are visual, top order wetland predators, feeding on frogs, fish, freshwater crayfish and large invertebrates (Clarke et al. 2019), as well as mice and small reptiles (Herring 2022). They are known to feed on introduced Carp and the threatened Southern Bell Frog. Chicks feed on smaller prey like dragonfly larvae and tadpoles, but can also consume large fish (Herring 2022). They rely on clear water and areas where the vegetation isn't too tall or thick to locate prey (Herring 2022).

1.7 Threats

The main threat to Australasian Bittern has been wetland habitat loss and alteration, caused by the drainage of permanent and ephemeral wetlands for agricultural and urban development, the diversion of water for irrigation, reduced water inflows, and reduced water quality from salinisation, siltation and pollution. Most key natural breeding wetlands are now protected; others are being restored and managed to support bittern better (BirdLife International 2023; Commonwealth of Australia 2022).

Climate variability and change (i.e. increased frequency and intensity of drought and seasonal shifts in rainfall) is a significant threat, which will exacerbate the fluctuations in wetland habitat availability and result in changes to environmental water allocations (Commonwealth of Australia 2022; Herring et al. 2019; NSW Government Office of Environment and Heritage 2017). Less water is available for rice farming during periods of dryness, and there is greater pressure on rice farmers to adopt water-saving measures. Dry periods also make wetlands, including peat swamps, more susceptible to fire, and fire can result in habitats being unsuitable for Australasian Bittern for a number of years (BirdLife International 2023; DBCA 2018).

Other threats include:

- peat mining, reducing the extent and quality of habitat
- predation of juvenile and adult birds and eggs by introduced animals such as the Fox (*Vulpes vulpes*), feral Cat (*Felis catus*) and Rat (*Rattus* sp.)
- overgrazing by livestock
- degradation of wetlands by invasive herbivores such as feral Pig (*Sus scrofa*), Horse (*Equus caballus*), Goat *(Capra hircus*) and Deer (*Cercus* spp., *Axis* spp., and *Dama* sp.)
- inappropriate fire regimes
- altered rice farming practices (e.g. delayed permanent water in rice crops resulting in fewer successful breeding events)
- habitat loss due to vegetation clearance and weeds
- use of herbicides, pesticides and chemicals near wetland areas
- nest abandonment following human disturbance

(BirdLife International 2023; Commonwealth of Australia 2022; NSW Government Office of Environment and Heritage 2017; Pickering 2018).

2 Existing monitoring

2.1 Overview of monitoring methods

The Australasian Bittern is more often heard than seen (DOE 2023). The best indicator of their presence at potentially suitable wetland habitat is the distinctive 'boom' call of the male during the breeding season (September to December) (DOE 2023; Herring 2022). The call is likened to a foghorn, which is typically repeated three to four times, and sometimes up to ten times in succession, known as a "boom train". Calls are most often heard around sunset or sunrise (BirdLife Australia 2022; Love Our Lakes 2019). Not detecting bittern calls does not mean they are absent. Rather, it may be that birds were silent during the survey because conditions were unsuitable or they were somewhere else in the wetland at the time (O'Donnell & Williams 2015).

Key population monitoring measures include:

- presence/absence (inventory of wetland use) (O'Donnell & Williams 2015)
- distribution
- relative abundance (estimate of the number of booming males)
- number of known sites (i.e. site occupancy)
- area of occupancy
- extent of occurrence
- habitat use and suitability (based on monitoring key indicators, including wetland health and vegetation cover)
- availability of potential habitat
- movement patterns (via tracking individuals)
- breeding success

(Commonwealth of Australia 2019; DBCA 2018; O'Donnell & Williams 2015; Pickering 2018).

Monitoring the abundance of the cryptic Australasian Bittern relies on the use of index methods. Detectability is often confounded by unidentified covariates, and calling rates vary spatially and temporally, making it necessary to account for this when using call counts to index abundance (O'Donnell & Williams 2015).

2.2 Monitoring resources

Key resources with information for monitoring Australasian Bittern include:

- National Recovery Plan for the Australasian Bittern *Botaurus poicilptilus* (Commonwealth of Australia 2022)
  - A National Recovery Plan for the Australasian Bittern released in in 2022 (Commonwealth of Australia 2022), which is overseen by a National Recovery Team. The key objective of the national recovery plan is to demonstrate, by 2030, an upward trajectory in the abundance of mature individuals comprising populations at key wetlands compared to 2020 baseline counts.
  - The National Recovery Plan identifies the need to design and implement a long-term monitoring program to identify population trends, with performance criteria that includes:
    - developing a standardised survey technique suitable for across the species' range

    - annual monitoring at key locations and a minimum of every three years at other locations, using a standardised surveying protocol and survey effort
    - monitoring of population trends annually for key locations, and where possible, other locations as data becomes available
    - increased understanding of the recovery trajectory of monitored populations, and responses to management interventions
    - integration of databases to capture national population, habitat and distributional information and a central repository for reporting observations
    - survey data that is to be analysed to increase understanding of population dynamics (e.g. population size, age, cohort, dispersal rates)
  - The recovery plan also identifies the need to improve knowledge of the species' ecology and biology, including:
    - research on breeding success, survival and causes of mortality
    - research on local and long-distance movements through the landscape
    - diet and prey availability in wetlands supporting Australian Bittern
    - population genetic structure across its range (Commonwealth of Australia 2019, 2022).
- BirdLife Australia's Bittern Survey Guide (BirdLife Australia undated)
  - Guidelines for an annual survey program for two species of bittern (the Australasian and Australian Little Bittern), beginning in the 2008-9 breeding season
  - Outlines guidelines for intensive listening surveys and intensive transect surveys.
  - Outlines data collection for the number of breeding and non-breeding birds as well as information about the wetlands in which they are recorded. The aim of the survey is to inform population estimates and record the number of sites where 'booming males are heard as well as the number of individuals calling.
  - The document includes examples of data collection forms
  - Recommends surveying suitable wetlands fortnightly, beginning mid-October until the end of March.
  - Indicates that the best time to hear the male 'booming' call is in the two hours around dawn, with peak calling occurring 30 mins before sunrise. The second best time to hear 'booming' calls is in the two hours around sunset. Bitterns will often call during the night
  - Indicates that weather conditions may affect booming call activity and that warm calm conditions are optimum.
  - Indicates that wetland water level is important during breeding season. Suggests that Bitterns prefer fresh water 30 cm deep with tall reeds or similar vegetation for shelter and shorter vegetation for foraging during their breeding period.

- Australasian Bittern Call Inventory: Surveys (Clarke-Wood 2022)
  - Guidelines for volunteers gathering citizen-science observations using *Birdata* app
  - Provides instructions for conducting surveys at known bittern wetlands.
  - The guidelines identify the dates on which surveys should be undertaken, the procedure to be followed and all of the observations that should be recorded
  - The document also provides a guide using screenshots for using the app to submit the observations to Birdlife (see Appendix 6)

- The Action Plan for Australian Birds 2020 (Garnett & Baker 2021)

- Provides a national overview of the conservation status of all birds occurring in Australia, identifies threats and recommends research and management actions that will minimise those threats.
- Monitoring described as Medium (Garnett & Baker 2021); male breeding call surveys undertaken annually on many wetlands. Suggests that conservation and management actions would benefit from a nationally consistent monitoring program across the species range. Satellite tracking is underway or planned in several regions which will help identify non-breeding and refuge sites.
- Listed research required includes:
    - establishing a national monitoring program, incorporating known sites and strategically targeting potential habitat on private property
    - determine ecological requirements at drought refuge sites
    - assess population impacts of fire and predators (particularly cats and foxes)
    - Map known and potential habitat management guidelines for increasing Australasian Bittern density and breeding success
    - Compare genetic diversity of western, eastern and Tasmanian populations

- Australasian Bittern (*Botaurus poiciloptilus*): Western Australian Recovery Plan. (DBCA 2018)
- A BirdLife WA Australasian Bittern Project committee was established in 2017 (Pickering 2017) and a WA Recovery Plan for Australasian Bittern was released in 2018 (DBCA 2018), identifying the following survey and monitoring objectives:
    - develop and implement an Australasian bittern population monitoring program
    - establish a monitoring program for Australian bittern habitat to detect changes in habitat area and quality. Monitoring should include vegetation condition, weed invasion, water levels, water chemistry, hydrology, sedimentation, and predator densities
    - periodically undertake additional surveys in potential habitat
    - undertake analysis and interpretation of both population and habitat monitoring data and communicate findings to stakeholders
    - develop a shared system to collate population and habitat monitoring results and improve data management and sharing
    - calculate the extent of occurrence and area of occupancy of Australasian bitterns based on consolidated survey results

- NatureMaps (DBCA 2018)
    - A national bittern database and webpage has been established by BirdLife Australia. The occurrence records are input into the Bird Atlas and are then available through the NatureMaps (DBCA 2018).
- Developing monitoring methods for cryptic species: a case study of the Australasian Bittern, *Botaurus poiciloptilus* (Williams 2016)
    - PhD thesis focusing on developing monitoring methods for the cryptic Australasian bittern, which led to the development of four protocols for the inventory and monitoring of Australasian bittern in New Zealand, and a guide to choosing the most appropriate method for a particular objective
    - The protocols build on previous methods that have been developed in other countries, tested and adapted for New Zealand conditions, and extended through the use of automatic recording approaches, to allow efficient sampling in remote and inaccessible locations.

- Protocols for the inventory and monitoring of the endangered Australasian bittern (*Botaurus poiciloptilus*) (O'Donnell & Williams 2015)
  - Protocol for undertaking inventory and monitoring programs for the Australasian Bittern in New Zealand.
  - Information may be used to determine the distribution and relative abundance of the species nationally, identify significant habitats, sites and populations to enable their protection and implement conservation management, measure the response and effectiveness of management practices and measure the health of wetlands,
  - The document describes four protocols for inventory and monitoring of the species. And a guide to choosing the most appropriate method for a particular objective.
  - The protocols represent current 'best practice', but further refinements will likely be made in the future.
  - Includes a decision guide for choosing the optimal protocol to follow (see Appendix 1) and field sheets for data collection (see Appendix 5.).

Monitoring protocols for bittern species from other countries may have relevance include:

- North American Marsh Bird Monitoring Protocols (Conway 2011)
- Least Bittern survey protocol (Jobin et al. 2011)
- Canadian Protocol for Capturing, Banding, Radio-tagging and Tissue Sampling Least Bitterns (Mackenzie & McCracken 2011)
- Optimal sampling protocols for Great Bittern (Poulin & Lefebvre 2003a).

There are also various papers available on call-based monitoring techniques for related bittern species, many of which were reviewed by Williams (2016), e.g.:

- density estimates pre-and post-habitat restoration (Vanausdall & Dinsmore 2020)
- visualisation and machine learning methods to monitor Least Bittern (Znidersic et al. 2020)
- detection probability and occupancy modeling of Least Bitterns using call response broadcast surveys and passive surveys (Cherukuri et al. 2018)
- territory mapping (Van Turnhout et al. 2010)
- booming in relation to reproductive cycle and harem size (Polak 2006)
- radio-tracking Great Bittern to quantify habitat preferences (Gilbert et al. 2005)
- Eurasian Bittern factors affecting distribution (Adamo et al. 2004)
- booming in relation to condition (Poulin & Lefebvre 2003b)
- acoustic triangulation (Lefebvre & Poulin 2003)
- call playback (Lor & Malecki 2002)
- call response (Gibbs & Melvin 1997)
- seasonal booming activity (Puglisi et al. 1997).

2.3 Survey methods

Monitoring of Australasian Bittern mainly relies upon call-based surveys. This includes targeted listening surveys and autonomous acoustic recorders to record male birds during the breeding season. Other monitoring methods, often combined with call-based surveys, include walking and wading surveys, camera trapping, thermal drones and radio-tracking (DBCA 2018; Pickering 2018). More information about these survey methods include:

2.3.1 Call-based survey

Call-based survey is the most common and feasible technique to detect (presence/absence) and monitor (count) Australasian Bittern (O'Donnell & Williams 2015), with call-based surveys undertaken annually at many wetlands (Garnett & Baker 2021). Call-based survey involves listening for the distinct low booming calls of the males during the breeding season (spring-summer), particularly in the two hours around dawn and dusk (BirdLife Australia 2022, undated). On a quiet night at a quiet location, calls may be heard up to 6 km away (Pickering 2018).

Calling rates appear to be predictable and can thus inform measures of absolute abundance, occupancy and long-term trends (Williams et al. 2019). Williams et al. (2019) showed a reduction in calling rate with rain, consistent with studies of Eurasian and American Bitterns, and an increase in calling rates when the moon was fully visible compared with when the moon was completely covered by cloud. Analyses has showed that the best time to detect calls is one hour before sunrise, in September (austral spring), on a moonlit night with no cloud or rain (Williams et al. 2019).

The results of BirdLife Australia (2021) suggest that calling rates may peak after a heavy rainfall event. Regular and sustained calling by Australasian Bittern is indicative of wetland conditions being suitable for breeding, and an increase in calling rates between monitoring events suggests improved conditions for breeding (BirdLife Australia 2021).

The traditional approach to call-based survey involves people standing on the edge of wetlands before sunrise or after sunset to listen for birds (Clarke et al. 2019). This approach is still used for detection (Clarke et al. 2019), and is an important component of citizen science-based survey (BirdLife Australia 2022). Call-playback is sometimes used as part of listening surveys, however, its effectiveness is unclear (BirdLife Australia 2022). Audio recorders are not generally used during in-person surveys, having been replaced in favour of passive surveillance using Autonomous Recording Devices (ARDs) (Pickering 2018).

In-person call-based surveys are time-consuming. However, they provide the benefit of being able to determine the direction of calls. Acoustic triangulation is used to provide a population estimate of male birds within a wetland, based on the time, distance and bearing of the calls (Hearn 2020). Repeat surveys can be used to detect population trends if carried out in a standardised manner, considering time of day, environmental conditions and bittern density. Triangulation data can be collected simultaneously by multiple observers from fixed listening points, but may be unsuccessful at large wetlands (O'Donnell et al. 2013).

BirdLife Australia oversees an annual volunteer-based listening survey for Australasian Bittern that began in 2008 (BirdLife Australia undated). with the 2022 survey being the most extensive survey completed thus far. The survey occurs at numerous well-vegetated wetlands across south-eastern Australia and in the south-western corner of Western Australia. The survey aims to gain an accurate picture of Australasian Bittern distribution and numbers, with ongoing surveys enabling monitoring of population trends and improved knowledge of their ecology (BirdLife Australia 2022). Participants are provided with detailed instructions and guidance, and field data in entered directly into BirdLife Australia's BirdData App (BirdLife Australia 2022).

Passive sampling using Autonomous Recording Devices (ARDs) is a cost-effective and practical approach, which overcomes logistical constraints restricting sampling possibilities (Williams 2016). ARDs have been utilised for targeted bittern monitoring since 2012 (Clarke et al. 2019). Song Meters are the device of choice (Pickering 2017, 2018) and have been used on a large scale since 2016 (Pickering 2017). ARDs are positioned near core wetland habitat, enabling the capture of sounds without human disturbance impacting the results (Brown 2016). The ARDs are programmed to record at peak bittern calling times (i.e. an hour before sunrise). They are weatherproof and require low personnel time in the field, with batteries replaced twice a year (Pickering 2018). ARDs enable large volumes of data to be recorded, however this also means lots of processing time in the office. Unlike in-person surveys, the direction of the calls cannot be determined (Pickering 2018). Identifying individual birds from their vocalisations may be possible but has limitations (Graff 2014; Pickering 2018).

In addition to the targeted ARD survey for bitterns, acoustic data collected for the Southern Bell Frog project from 65 wetland sites across the NSW Murray and Murrumbidgee catchments and the Great Cumbung Swamps and neighbouring wetlands sites, is also being analysed for Australasian Bitterns (Spencer 2022b).

Automated acoustic recognition software (e.g. Song Scope) can be programmed to recognise potential bittern calls to speed up the processing time, however there is still error associated with this method, and it is time-consuming to listen to the files to confirm or discount calls (BirdLife Australia 2021; Pickering 2018). Audacity software has been used to boost recordings in the hertz range of bittern calls. Manual use of visual and audio processing (e.g. scanning visually through the sonogram) Is the favoured method for processing at this point in time (Pickering 2017, 2018). Typically only a subset of recordings are processed, for example, every five nights and when conditions are not too windy (BirdLife Australia 2021). Detailed instructions on how to analyse call files is provided in Williams (2016).

O'Donnell and Williams (2015) have developed call-based survey protocols for Australasian bitterns in New Zealand, which can inform the development of standard monitoring protocols for Australia (see Appendix 1). They include protocols for inventory (presence/absence) and relative abundance based on counts of the number of male bitterns booming. The protocols draw upon the wealth of literature on monitoring bitterns and other swamp bird species worldwide, field data from New Zealand identifying when booming bitterns were most detectable and least variable in relation to environmental factors, and calibrating call counts against density estimates. Protocols were designed to suit a range of different situations. The protocols include use of ARDs, which allow passive, efficient sampling in remote and inaccessible locations. Call-based surveys (in-person or ARDs) are often undertaken in combination with walking/wading surveys, camera trapping and, more recently, thermal drone surveys.

The Bitterns in Rice Project was established in 2012, bringing together the Ricegrowers' Association of Australia, Birdlife Australia, Riverina Local Land Services, Murray Local Land Services, rice farmers, local community groups, and a range of other organisations. A pilot study in 2012 formed the basis for a refined standardised population monitoring methodology for bitterns in the rice fields, which has been used for random population surveys since (Bull 2022; DAWE 2022).

Table 3. Methods overview of key studies using call-based surveys.

Survey type	Study design	Survey effort	Location	Reference
Call-call based survey	▪ Citizen science program run by Birdlife Australia ▪ Training on survey process and Bittern call familiarity provided by	▪ Survey duration of 1.5 hr at sunrise or sunset throughout breeding season (Sept-Dec)	Surveys conducted at established Australasian Bittern Wetland	(Bell & Webb 2023; BirdLife Australia 2022, undated)

Survey type	Study design	Survey effort	Location	Reference
Presence, relative abundance	Birdlife Australia prior to conducting surveys ▪ Data collected includes location, time and duration of survey, presence/absence of Australasian Bittern boom calls. ▪ Estimate of the number of individuals boom calling is optional ▪ Surveyors ideally positioned within 10 m of the wetland ~500 m from other surveyors		monitoring sites in SA, Vic, NSW, WA and Tas	
Call-based survey Acoustic recordings Presence-relative abundance	▪ Song Meter SM4 acoustic recorders ▪ Audio files were analysed manually for bittern calls using Audacity software and SongScope ▪ Only a subset of recordings were processed, usually every five nights and when conditions were not too windy	▪ Lake Pleasant View surveys occurred from Oct 5 2020 to Jan 1 2021 ▪ Big Boom Swamp surveys occurred Sept 24 to Dec 31 2020 ▪ Acoustic recorders set to record for the 2.5 hr before sunrise and 1 hr after sunset	Lake Pleasant View and Big Boom Swamp, WA	(Clarke-Wood 2022)
Call based survey Acoustic recordings	▪ Autonomous Recoding Units (ARU) were deployed in wetlands ▪ ARU units were battery or solar powered ▪ Analysis of the data conducted by volunteers from BirdLife WA.	▪ Acoustic recordings occurred in over 30 wetlands ▪ Recorded during peak calling periods for up to six weeks ▪	WA	(Clarke et al. 2019)
Call-based surveys Acoustic recordings	▪ Wetlands monitored using song meters ▪ Recording collected and reviewed for Australasian and Australian Little Bittern using Audacity and Song Scope software, ▪ Reviewing initially undertaken by by trained staff and then by volunteers	▪ Surveys late Sept-Dec 2016 ▪ Twelve wetlands monitored ▪ Song meters programmed to record for a 2 hr period in the pre-dawn period on survey days	Swan coastal plain wetlands and Muirunicup wetlands, WA	(Pickering 2017)
Call-based survey Counts	▪ Stations located ≥ 400 m from one another in accessible areas around the wetland ▪ The first station surveyed was chosen randomly and then stations in close proximity were surveyed subsequently ▪ Observers counted all bittern 'Boom' call sequences. ▪ Call direction and call characteristics (call volume and number of booms in a sequence) were used to discriminate between individual calling males. ▪ A call sequence was noted as being from a new bird if any of the following were found to be true: 1) the bearing of the new call was greater than 10˚ different from the baring of a previous call; 2) the bearing of the call was within 10˚ but the call volume was different;3) the bearing of the new call was within 10˚ of another call but consistently has a different number of booms within its boom sequence. ▪ Other variables collected at each station include: cloud cover (in oktas), ordinal background noise and moon visibility (see Appendix 2 and Appendix 3).	▪ Surveys occurred from Oct-Nov in 2009 and Sept- to Nov in 2010 ▪ Surveys conducted in one of two daily periods 3 am-8 am or 5:50 pm-8:30 pm ▪ Surveys conducted at 65 fixed points (stations) in 2009. 34 of these stations were revisited in 2010. ▪ Stations visited between 2-49 times depending on water levels and accessibility ▪ Observations were recorded for 15 mins and then surveyors moved to the next station	Whangamarino wetland in the Waikato region, New Zealand	(Williams 2016; Williams et al. 2019)

Survey type	Study design	Survey effort	Location	Reference
	▪ Counts were not conducted in heavy rain or strong winds			
Call-based survey Acoustic recordings	▪ Recorders deployed >400 m apart around perimeter of the lake. ▪ Mono recording units used were developed by the Department of Conservation, Stereo recording units consisted of an Olympus LS-10 recording device with two external microphones and an external 4 x D-cell power source and were programmed to record at 128 kbps at max recorder level with mic sensitivity at high and no limit. ▪ Recordings were saved as .wav files. ▪ Recording unit was fixed on a post at a height of 1.5 m (approximately ear height) and set to record for the duration of the count surveys.	▪ Mono recorders were deployed for six days per month ▪ At six point locations ▪ Recorded two daily observation periods: a morning period and starting 1.5 h before sunrise, finishing at sunrise and an evening period: starting 30 mins before sunset until 1 hr after sunset. ▪	Whangamerino wetland, Waikato region, Lake Whatumā, Hawkes bay NZ	(Williams 2016)
Call-based surveys Territory mapping (naïve observers)	▪ Surveyors were naïve (had no or little prior knowledge of site or bittern numbers present on the lake) ▪ Basic training in monitoring method was provided prior to the surveys ▪ Acoustic triangulation ▪ Observers noted all calls heard from two accessible locations 500 m apart along the lake shore ▪ Observers record if calls are from an individual bird or one that has previously called based on the bearing of the call or call characteristics. ▪ Close approach ▪ Observers slowly circumnavigated the lake on a kayak noting the presence of any booming calls as they passed around the margin of the lake. ▪ When confident of the location and that the call was only made by one bird, the location was recorded on a map using a Garmin GPS map 60CSx. ▪ Observers spent as long as necessary to be confident in the locations of the calling individual. ▪ Post surveys using either method observers reconvened and decided upon an overall number of booming bitterns detected on the lake.	▪ Surveys occurred from September to November 2014 ▪ Acoustic triangulation ▪ Survey period 1 hr ▪ Counts conducted one hour before sunrise of within the 30 mins of sunset. ▪ Close approach ▪ Counts were conducted between 2 pm and sunset	Lake Whatumā, Hawkes bay NZ	(Williams 2016)
Call-based survey Acoustic recordings	▪ Surveys were undertaken in combination with physical surveys and other remote monitoring techniques ▪ Song Meter SM3 acoustic recorder was deployed in grasslands adjacent to tall marsh, aquatic herbland, brackish wetland and Gahnia sedgeland. ▪ Song meters deployed at a height where they were free from contact of moving and rustling vegetation on the microphones, this did not however protect against wind interference	▪ Surveys were undertaken from Jul-Dec in 2016 ▪ The song meter was programmed to record for 1 hr on, 1 hr off from Aug 1 to Sept 18. From this date song meters recorded for 3 hr at dawn and 3 hr at dusk until end of Dec ▪	Boneo Park, Southern Gippsland Plains, Vic	(Brown 2016)

Survey type	Study design	Survey effort	Location	Reference
	▪ Batteries lasted approximately 12 days before needing replacement ▪ 637 hours of recordings were sent to BirdLife Australia for analysis			
Call-based survey Acoustic recordings	▪ Aim was to determine if vocal individuality could be detected and to identify optimal recording time for capturing calls ▪ Once detected, recordings were made using Fostex FR-2LE digital sound recorders linked to RØDE NTG-2 shotgun microphones ▪ Automated recordings taken using SongMeter 2 automated recording units (ARUs) ▪ Recordings saved in Waveform Audio File Format (.wav files) to prevent loss or distortion of sound signal through data compression. And in mono with a sampling rate of 44.1 kHz. ▪ Recordings taken from 50-150 m distance (as close as possible given water depth and minimising likelihood of disturbing the bird) ▪ Recordings were also saved in Waveform Audio File Format but were made in stereo using a sampling rate of 16 kHz.	▪ Surveys occurred at 20 wetlands where or close to where the species had previously been detected ▪ Initial surveys to locate calling bitterns had a 20 min duration ▪ Automated recordings taken at 4 locations. The ARUs recorded for 11 hrs over night commencing at sunset	South-western Australia	(Graff 2014)
Call-based surveys Acoustic triangulation	▪ Surveys are undertaken in conjunction with observations from a kayak ▪ Observers noted all calls heard from accessible locations 500 m apart along the lake shore ▪ The entire lake was visible from the two stations with about 70 % visible from the stations individually. ▪ Observers recorded time, compass bearing in degrees, estimated distance (m), number of 'booms' within a boom train for each record.	▪ Surveys undertaken in 2011 and 2012 ▪ Surveys occurred at dusk (starting 30 mins before sunset), or dawn (90 mins before sunrise) for a duration of 1 hr ▪ Surveys occurred at two locations	Hatuma Lake, NZ	(O'Donnell et al. 2013)

2.3.2 Direct counts

Ground survey – diurnal counts

Visual counts can be conducted to confirm the number of booming males birds (O'Donnell et al. 2013). Non-breeding birds appear not to call, and it is suspected that many Australasian Bitterns do not breed when conditions are unsuitable (BirdLife Australia 2022). Thus, to determine the presence and estimate the abundance of female birds and non-breeding male birds relies on visual daytime counts. Total counts are unlikely given the dense habitat and secretive nature of the birds, and that the birds can 'freeze' and remain undetected even when an observer is in proximity (Herring 2022).

The chance of visual detection is maximised by walking through or around a wetland in an attempt to flush the birds out of hiding (BirdLife Australia 2022). Wading surveys of wetlands are typically conducted by skilled observers, to look for birds, feathers and signs of nesting activity (Clarke et al. 2019). Close approaches using observers in kayaks is also a useful method to estimate the number of Australasian Bitterns on small wetlands (O'Donnell et al. 2013). Trained detection dogs were historically used to detect bitterns, but are highly invasive, and unnecessary given the availability of thermal drone technology (Waikato Herald 2022).

Table 4. Methods overview of key studies using direct count surveys.

Survey type	Study design	Survey effort	Location	Reference
Ground Survey	▪ Bitterns were detected at 18 wetland surveys during surveys from 2012-2022 ▪ Specific details not provided	▪ Annual survey spring surveys between 2012 and 2022 ▪ 65 wetland sites monitored	Riverina wetlands, NSW	(Spencer 2022a)
Waterbird count	▪ Waterbird counts undertaken as part of a wetland monitoring and assessment program – surveys not specific to Bitterns ▪ Wetlands surveyed using binoculars, tripod mounted spotting scopes ▪ Most conducted from a single vantage point, however some sites required surveyors to check on foot also. ▪ At some sites surveyors walked through stands of Cumbungi (Typha sp.) and reeds (Phragmites sp.) in search for bitterns. ▪ This survey technique is unlikely to detect all individuals of a cryptid and therefore counts of each species were classified as complete or partial according to the observer's perceptions of whether a survey coverage was sufficient to detect all individuals ▪ The following variables were recorded: species count, evidence of breeding, the habitat type in which each species was observed, the percentage of species or species groups actively feeding within each habitat type. ▪ All observed birds were classified into feeding guilds as a way of simplifying the dataset (bitterns were assigned the guild of skulkers (being birds that live in marshy places). ▪ Breeding was only regarded as confirmed if nests containing eggs or chicks were observed, or if family groups including chicks not yet capable of flight were recorded ▪ Surveyors also noted potential breeding behaviour such as territorial or mating behaviour, and the carrying of nesting material or food. ▪ The App ProofSafe was used in the 2019-2020 survey season for data capture	▪ Surveys conducted between 2017 and 2020 ▪ 267 waterbird counts carried out across 20 wetlands ▪ Surveys conducted in daylight hours by two-person teams. ▪	Central northern Vic	(Papas et al. 2021)
Kayak close approach survey	▪ Survey undertaken in combination with acoustic triangulation survey ▪ Surveys undertaken by kayak, circumnavigating the lake slowly ▪ Surveys were conducted in calm, fine weather ▪ Observers noted the presence of booming birds, repeatedly taking note of the bearings of calling individuals and subjectively estimating distance ▪ It was possible to approach calling birds from more than one direction or even encircle a calling bird to improve the confidence of location. ▪ Location was recorded using a Garmin GPSmap 60CSx	▪ Surveys conducted in 2011 and 2012 ▪ Two surveys undertaken ▪ Surveys duration ~1 hr before sunset ▪ The technique relies on spending as long as the observer needs to be confident of the locations of all bitterns on the lake	▪ Hatuma Lake, NZ	(O'Donnell et al. 2013)

Opportune observations

Occasionally, Australasian Bittern are observed when flushed from vegetation, feeding on the edge of wetlands, or in flight (e.g., moving between a roost and a feeding area). In short vegetation, such as rice or rushes, where you can scan across the wetland with binoculars, their head can sometimes be seen sticking up just above the vegetation like a periscope (Herring 2022). In the rice fields, bitterns are easier to see early in summer when the rice plants are still short (Bitterns in Rice Project 2023). On rare occasions, bitterns are observed in open areas (Fitzsimons 2022).

When conditions are suitable, opportunistic survey is undertaken at some of the important wetlands in WA that are formally monitored for Australasian Bittern (DBCA 2018). Opportune observations can be undertaken whilst onsite to service passive surveillance equipment. For example, on entering a wetland site, (Brown 2016) scanned the area using a camera with 600mm lens, providing the ability to clearly identify bird species of least 30 cm at up to approximately 800 meters distance with the naked eye.

Opportune observations are recorded through various platforms, such as iNaturalist, through Birdlife Australia's BirdData App, and using the Bitterns in Rice Project 'Report a Sighting' web form. Inexperienced observers may mistake immature Nankeen Night Herons (*Nycticorax caledonicus*) and Australian Little Bittern (*Ixobrychus dubius*) for Australasian Bittern (Commonwealth of Australia 2019; Herring 2022), data obtained from these platforms should therefore, be considered with some scrutiny.

Aerial survey - UAV

Uncrewed aerial vehicles (UAVs), also known as drones, provide a birds' eye view above the vegetation, enabling time-saving survey of difficult to access areas, avoiding disturbance associated with in-person surveys, and recording behaviours that have not previously been observed (Brown 2016).

A drone fitted with an RGB camera was used by Brown (2016) to record Bittern behaviour. Drones equipped with thermal imaging cameras were trialled for monitoring Australasian Bittern in 2018, in rice crops in NSW, and were successfully able to detect the heat signature of Australasian Bittern camouflaged in wetland vegetation (Bitterns in Rice Project 2023; Pickering 2018)(Figure 2). Thermal drones have since been used in taller and denser natural habitats (Hearn 2020).

Figure 2. Thermal image of a waterbird (left); raw image of a possible bittern (right)

Source: Hearn (2020)

Thermal drones provide the opportunity to obtain a more accurate estimate of bitterns within a wetland, including females, non-breeding and breeding males, whereas listening surveys are based on booming male numbers only (Waikato Herald 2022). Results have shown that thermal drones improve the ability to locate nests, monitor breeding success (in combination with remote cameras), and improve understanding of wetland habitat use (Bitterns in Rice Project 2023; Herring 2022; Pickering 2018). They are also useful for detecting introduced predators (Pickering 2018). Identifying Bitterns through taller natural vegetation is more challenging than in the shorter rice crops. Trial results in natural wetland habitats were comparable to acoustic survey results done at the same time of year (Hearn 2020). With ongoing refinement of flying technique and camera and filtering technology, the quality and reliability of the outputs is expected to increase, and the technology is likely to become an important component of future population monitoring (Hearn 2020).

Table 5. Methods overview of key studies using Aerial survey - UAV surverys.

Survey type	Study design	Survey effort	Location	Reference
UVA - thermal	▪ Bitterns monitored in rice fields undertaking bittern friendly rice management and control sites. ▪ Monitoring conducted using thermal drones to locate nests and watch for females delivering food to chicks ▪ Monitoring breeding success through to fledglings	▪ n/a	Fivebough, Tuckerbil, Campbells Wetland and Turkey Flat, NSW	(Herring 2022)
UVA - thermal	▪ Trial of thermal drone equipment to detect bitterns ▪ Nests located by thermal drone imagery were then surveyed using camera traps ▪ Drones were successful at identifying nests in relatively short vegetation of rushes but yet to be trialled in thicker vegetation ▪ Drone mounted thermal camera searches for nesting female bitterns. ▪ A variety of activity was captured including mating. The drone's presence did not seem to disturb the bittern. ▪ Flights began at 5:30 am to capture best temperature contrast	▪ Surveys occurred at five sites ▪ 49 flights conducted Flight duration was around 20 mins covering 10-15 ha	Little Waihi Estuary, Kaituna Wetland, Waimapu Estuary, Pahoia Estuary and Whangapoua Harbour, NZ	(DoC 2022; Waikato Herald 2022)
UVA- thermal and RGB	▪ Trial using thermal imaging in combination detect Australasian Bitterns in Ramsar wetland habitat ▪ Thermal camera imagery and RGB imagery was used to detect and locate adult bitterns and direct ground crew to locate and tag the birds. ▪ Imagery was not able to detect nesting bitterns in more dense vegetation such as Phragmites and Giant Rush species ▪ Data collected by the drones was found to be comparable to the acoustic surveys undertaken at the same time of year	▪ n/a	Milewa Wetlands, Southern Riverina NSW	(Bull 2019; Hearn 2020)
UAV - RGB	▪ UAV surveys undertaken for incidental observation to compliment on-ground physical surveys and ARD (Song Meter) surveys at Tootgarook Swamp, Victoria ▪ A lightweight (under 2 kg) Parrot Bebop 211 UAV with mounted camera was deployed for surveys ▪ A single Australasian Bittern was detected, directly after a bird had been flushed through manual observation. ▪ No bittern nests were detected.	▪ n/a	Tootgarock swamp, Borneo Park	(Brown 2016)

Remote tracking

Satellite tracking and radio tracking of Australasian Bittern has been undertaken in New South Wales' rice fields, and in New Zealand (Pickering 2018), and is underway or planned in several regions (Garnett & Baker 2021). Tracking provides information about the birds' long and short movement patterns, and the wetlands and areas within wetlands being used (Pickering 2018), including identifying non-breeding sites, drought refuge sites (Garnett & Baker 2021) and stop over sites (Herring 2022). Satellite tracking has shown that tagged birds disperse from New South Wales' Riverina to coastal wetlands in South Australia, Victoria and New South Wales (Herring et al. 2019).

The National Recovery Plan identifies the need to trial and refine techniques to track movements of Australasian Bittern (Commonwealth of Australia 2022) Live trapping is required to fit individual birds with tracking devices. Trapping also provides the opportunity to collect morphometric data, and DNA samples.

Table 6. Methods overview of key studies using remote tracking surveys

Survey type	Study design	Survey effort	Location	Reference
Satellite tracking	▪ A crowd-funded tracking program followed recently fledged young and adult males ▪ Birds were captured using custom-designed traps, call playback of territorial boom calls and mirrors to lure them using their own reflection ▪ Fitted with 22-16 g solar powered GPS satellite transmitters ▪ Tracking gave insight into short and long range movements, dispersal and habitat use during breeding season and non-breeding season periods	▪ Nine birds had been fitted with satellite trackers. ▪ The first bird was fitted with satellite tracker in April 2015. This bird was tracked for 323 days before losing contact. ▪ Transmitters sends locations of varying accuracy for eight hours and then switches off for 48 hr to conserve battery power	Riverina region, NSW	(Herring 2018; Herring 2022)
Radio tracking	▪ Trapped by luring birds into cage traps using a combination of calls and mirrors ▪ Banded with metal M-band and attached radio transmitters ▪ Measurements included weight, tarsus length bill length, wing length and tail length and photographs of bill and feather patterns ▪ Locations from transmitters were compared with on-ground call survey results to determine a) if tracked birds were calling and b) if they were detected during call surveys	▪ September 2017	Lake Whatumâ, NZ	(Luecht 2018; Williams 2018)
Radio tracking	▪ Once captured each bittern was fitted with a numbered metal butt ended band (size M) and a 2-stage Sirtrack transmitter weighing <19 g ▪ Transmitters attached to each bird using a back mounted harness design made of braided nylon cord with a weak link ▪ Each transmitter produced a signal on a unique frequency for tracking using a TR-4 or TR-2 receiver	▪ August -November 2014 ▪ Six male Bitterns caught and fitted with radio trackers	Lake Whatumâ, NZ	(Williams 2015; Williams 2016)
Radio tracking	▪ Bird was fitted with a numbered metal butt-end band (size M) and a 2-stage Sirtrack® transmitter weighing 30 g ▪ The transmitter was attached to the bird using a back-mounted harness design ▪ Once the transmitter was fitted the bird was released into an aviary to and observed for signs of discomfort before being released into the wild ▪ Released weighing 1292 g ▪ Post release the bird was tracked using a TR-4 receiver.	▪ Single wild bird was found sick, nursed back to health and then released with radio transmitter ▪ Released in April 2014 ▪ The bird was tracked for 54 days before found dead	YikoTiko arm of Lake Whangape, NZ	(Williams & Brady 2014)

Survey type	Study design	Survey effort	Location	Reference
	▪ Surveyors determined that the transmitter did not contribute to the bird's death, but more likely the initial illness returned			

2.3.3 Camera trapping

Camera traps have become a standard component of monitoring programs, providing important insight into Australasian Bittern's presence, habitat use, breeding, behaviour, diet, and plumage. Capture of juveniles on camera confirms that breeding has occurred (Pickering 2018). Camera traps also help to identify the presence of introduced predators and other fauna (Clarke et al. 2019; Pickering 2018).

Table 7. Methods overview of key studies using camera trap surveys

Survey type	Study design	Survey effort	Location	Reference
Camera trap	▪ Remote cameras deployed in known and potential habitat in targeting Australasian Bittern. ▪ More specific details not provided	▪ n/a	South-west WA wetlands including Gingilup Swamps, Vasse-Wonnerup system, Lake Pleasant View/Mt Manypeaks wetlands, Benger Swamp,	(DBCA 2018)
Camera trap	▪ Camera traps deployed by Parks and Wildlife to detect wetland birds and other fauna. ▪ Specific details not provided.	▪ n/a	South-west WA	(Pickering 2018)
Camera trap	▪ Camera traps compliment traditional on ground surveys, and remote sensing technology ▪ Camera traps were deployed at locations through to be suitable habitat based around the historical dataset, used in combination with SongMeter and UAV. ▪ An array UOVision covert Zero-Glow (940 nm wavelength) wildlife cameras were used. Two of the cameras were attached to a fence while the other five were firmly attached to garden stakes (in inundated waters), away from rustling and moving vegetation and placed in optimal locations to avoid glare from the sun.	▪ Seven camera traps were deployed in an array ▪ Cameras and song meters were deployed for a number of months	Tootgarook Swamp, Victoria	(Brown 2016)

2.3.4 Other methods

Other monitoring methods that may have future applications include:

- Habitat assessment to provide better understanding of the optimal conditions for breeding with flow on effects for management and monitoring (Clarke et al. 2019).
- UAVs may have useful applications for wetland habitat assessment (Chabot & Bird 2015)
- DNA (e.g. of feathers from birds/nestlings) to identify individuals and inform understanding of population structure (Clarke et al. 2019)
- eDNA (e.g., water sampling) could potentially be used to detect the presence of and, if technologies advance, identify individuals.

3 Key agencies and organisations involved in the species research and recovery

Key agencies, organisations or individuals identified as having been previous, or currently actively involved in monitoring the Australasian Bittern include:

- Robyn Pickering, Birdlife WA
- John Graff, Birdlife WA
- Emma Williams, NZ Department of Conservation
- Colin O'Donnell, NZ Department of Conservation
- Alan Clark
- Sarah Comer, WA Department of Biodiversity, Conservation and Attractions
- Matt Herring, Murray Wildlife, and Charles Darwin University
- Andrew Silcocks, Birdlife Australia
- Jim Lane, Department of Biodiversity, Conservation and Attractions
- Ali Borrell, Murray-Darling Wetlands Working Group
- Jen Spencer, NSW Department of Planning, Industry and Environment
- Damien Cook, Wetland Revival Trust
- Bob Green, Birdlife South East SA / Avian Monitoring Services
- Liz Znidersic, Charles Sturt University
- Neil Bull, Rice Growers Association, Bitterns in Rice Project, Bittern recovery project (Environmental organisation), Funded by the Victorian State Government
- Lachlan Farrington, Nature Glenelg Trust, State Wide Integrated Flora and Fauna Teams
- Jacinta Hendriks, Glenelg Hopkins CMA, State Wide Integrated Flora and Fauna Teams

4 Key survey guideline recommendations gathered from the literature

This literature review of the monitoring methods relating to the Australasian Bittern has identified some key points that must be addressed when developing species-specific guidelines. These points include:

- The need for a standardised national monitoring approach to assess population trends of Australasian Bittern is well recognised (BirdLife International 2023; Commonwealth of Australia 2022; DBCA 2018; Garnett & Baker 2021; Threatened Species Scientific Committee (TSSC) 2019). A national monitoring program should incorporate known sites across the range, and strategically target potential habitats on private property (BirdLife International 2023; Garnett & Baker 2021).
- Monitoring typically includes a combination of survey methods, with the core method being call-based surveys, to confirm the presence of the species and provide counts of breeding males. This can be done via autonomous recording devices (i.e. Song Meters), which can be left in the field, or in-person listening surveys. Camera traps and thermal drones are fast becoming standard components of monitoring. Other approaches include in-person direct counts and satellite and radio tracking.
- Surveys generally take place between September to December (breeding season), before sunrise or after sunset. Analysis of survey data has shown that the best time to detect Australasian Bitterns is 1 hour before sunrise, in September, on a moonlit night with no clouds or rain.
- Several targeted Australasian Bittern monitoring projects are being undertaken using a combination of technologies, with a range of recent survey reports and data available. BirdLife Australia runs a dedicated Bittern Recovery project with their survey program beginning in the 2008-2009 breeding season and oversees volunteer-based surveys, with data entered directly into the BirdData App.
- The need for a standardised approach to monitoring is well recognised (Commonwealth of Australia 2019; DBCA 2018; TSSC 2011). The New Zealand Department of Conservation (O'Donnell & Williams 2015) has developed protocols for monitoring Australasian Bittern in New Zealand, including detailed field and data analysis instructions, which can form the basis of a standardised monitoring protocol for Australia.
- Improved knowledge of the species' biology and ecology, particularly of movement patterns, breeding and habitat use, will assist in developing and implementing a standardised monitoring strategy.
- The EMSA modules that can be leveraged for this species include the Vertebrate Fauna Module (bird surveys, and acoustic and ultrasonic surveys protocols), and the Opportune Module.

5 Reference

Adamo, M, Puglisi, L & Baldaccini, N 2004, 'Factors affecting bittern *Botaurus stellaris* distribution in a Mediterranean wetland', *Bird Conservation International*, vol. 14, no. 3.

Bell, P & Webb, M 2023, Final report to cradle coast authority: defining and mapping habitat requirements to support the survival of King Island threatened birds, King Island threatened birds project 2021-2022, Biodiversity Maintenance Australia.

BirdLife Australia 2021, Australasian bittern survey summary June 2021.

BirdLife Australia 2022, *Bittern survey*, viewed 30/01/2023, <https://birdlife.org.au/events/bittern-survey/>.

BirdLife Australia undated, BirdLife Australia's bittern survey guide: guidelines for surveying Australasian and Australian little bitterns.

BirdLife International 2022, *Pedionomus torquatus*, The IUCN Red List of Threatened Species 2022.

BirdLife International 2023, *Species factsheet: Botaurus poiciloptilus.* , BirdLife International, viewed 25/01 2023, <http://datazone.birdlife.org/species/factsheet/australasian-bittern-botaurus-poiciloptilus/distribution>.

Bitterns in Rice Project 2023, *Bitterns in rice project*, Webpage, viewed 21/02/2023, <https://www.bitternsinrice.com.au/>.

Brown, C 2016, Draft report: song meter survey, wildlife camera, and UAV survey in Tootgarook swamp, Rosebud West (capel sound) and Boneo: to determine the possible breeding and presence of Australasian bittern Botaurus poiciloptilus, Tootgarook swamp Australiasian bittern monitoring 2016, Birdlife Australia, Boneo Park, Natural Systems Mornington Peninsula Shire, Trust for Nature, Save Tootgarook Swamp Inc, and Wildlife Acoustics., Victoria.

Bull, N 2019, *Australasian bitterns x ricegrowers' association of Australia*, Wildlife Drones, viewed 2/3/2023, <https://wildlifedrones.net/rga-australasian-bitterns>.

Bull, N 2022, *Bitterns in rice project update*, AgriFutures Rice Extension.

Chabot, D & Bird, DM 2015, 'Wildlife research and management methods in the 21st century: where do unmanned aircraft fit in?', *Journal of Unmanned Vehicle Systems*, vol. 3, no. 4, pp. 137-155.

Cherukuri, A, Strong, A & Donovan, TM 2018, 'Monitoring least bitterns (*Ixobrychis exilis*) in Vermont: detection probability and occupancy modeling', *Northeastern Naturalist*, vol. 25, no. 1, pp. 56-71, 16.

Clarke-Wood, B 2022, Australasian bittern call inventory surveys: a guide, BirdLife Australia.

Clarke, A, Comer, S, Burbidge, A, Barrett, P & Stokes, V 2019, The Australasian bittern in Western Australia - understanding 'Boordenitj": a cryptic wetland predator, WA.

Commonwealth of Australia 2019, Draft national recovery plan for the Australasian bittern Botaurus poiciloptilus, Australian Government,.

Commonwealth of Australia 2022, National recovery plan for the Australasian bittern (Botaurus poiciloptilus), Canberra, ACT.

Conway, CJ 2011, 'Standardized North American marsh bird monitoring protocol', *Waterbirds*, vol. 34, no. 3, pp. 319-346.

DAWE 2022, *Monitoring, evaluation, reporting and improvement tool (MERIT)*, <http://www.nrm.gov.au/my-project/monitoring-and-reporting-plan/merit>.

DBCA 2018, *Australasian bittern (Botaurus poiciloptilus): Western Australian recovery plan*, Wildlife management program no. 64, Department of Biodiversity, Conservation and Attractions, Perth, WA.

DCCEEW 2022, *Threatened species action plan 2022–2032*, Commonwealth Government of Australia, Canberra, ACT.

DoC 2022, 'Thermal camera tracks down elusive bird', *Department of Conservation media release*, viewed 18/10/2023, <https://www.doc.govt.nz/news/media-releases/2022-media-releases/thermal-camera-tracks-down-elusive-bird/>.

DOE 2023, *Botaurus poiciloptilus in species profile and threats database*, Department of the Environment, Canberra, ACT, viewed 7/02/ 2003, <www.environment.gov.au/sprat>.

Fitzsimons, J 2022, 'Diurnal foraging in short pasture by the endangered Australasian bittern (*Botaurus poiciloptilus*) on Kangaroo Island, Australia', *Journal of Heron Biology and Conservation*, vol. 7, no. 3, 10/10.

Garnett, S & Crowley, GM (eds) 2000, *The Action Plan For Australian Birds 2000*, Environment Australia, Canberra, ACT.

Garnett, S, Szabo, J & Dutson, G 2011, *The action plan for Australian birds 2010*, CSIRO Publishing, Clayton, Victoria.

Garnett, ST & Baker, GB (eds) 2021, *The Action Plan for Australian Birds 2020*, CSIRO Publishing, Melbourne, Victoria.

Gibbs, JP & Melvin, SM 1997, 'Power to detect trends in waterbird abundance with call-response surveys', *Journal of Wildlife Management*, vol. 61, pp. 1262-1267.

Gilbert, G, Tyler, G & Smith, K 2005, 'Behaviour, home - range size and habitat use by male great bittern *Botaurus stellaris* in Britain', *Ibis*, vol. 147, pp. 533-543.

Graff, J 2014, 'Vocalisations and vocal individuality in the endangered Australasian bittern (*Botaurus poiciloptilus*) in south-western Australia, with applications for conservation ', Unpublished Honours thesis thesis, University of Western Australia, Perth, WA.

Hearn, J 2020, *Drones used to track bitterns. Central Murray Ramsar project. NRM News August 2020* NSW Government Local Land Services, <https://www.lls.nsw.gov.au/regions/murray/articles,-plans-and-publications/nrm-news-august-2020/drones-used-to-track-bitterns>.

Herring, M 2018, *Tracking bunyip birds*, Bitterns in Rice Project, New South Wales, viewed 18/10/ 2023, <www.bitternsinrice.com.au/tracking-bunyip-birds/>.

Herring, MW 2022, Saving the endangered Australasian bittern: a guide to wetland management and Bittern-friendly rice farming, Riverina Local Land Services, Griffith, NSW.

Herring, MW, Robinson, W, Zander, KK & Garnett, ST 2019, 'Rice fields support the global stronghold for an endangered waterbird', *Agriculture, Ecosystems & Environment*, vol. 284.

Jobin, B, Bazin, R, Maynard, L, McConnell, A & Stewart, J 2011, 'Least bittern (*Ixobrychus exilis*) survey protocol', *Waterbirds*, vol. 34, no. 2, pp. 225-233.

Lefebvre, G & Poulin, B 2003, 'Accuracy of bittern location by acoustic triangulation', *Journal of Field Ornithology*, vol. 74.

Lor, S & Malecki, RA 2002, 'Call-Response Surveys to Monitor Marsh Bird Population Trends', *Wildlife Society Bulletin (1973-2006)*, , vol. 30, no. 4, pp. 1195–1201.

Love Our Lakes 2019, *Love our lakes Gippsland lakes: one bittern, very shy!*, viewed 8/2/ 2023, <https://www.loveourlakes.net.au/one-bittern-very-shy/>.

Luecht, S 2018, *Finally revealed by DU transmitters*, Ducks Unlimited New Zealand, New Zealand, viewed 18/10/ 2023, <www.ducks.org.nz/flight-magazine/item/197-the-secret-life-of-male-bitterns>.

Mackenzie, SA & McCracken, JD 2011, *National protocol for capturing, banding, radio-tagging, and tissue sampling least bitterns in Canada*, Environment Canada - Canadian Wildlife Service, The National Least Bittern Recovery Team.

Marchant, S & Higgins, PJ (eds) 1990, *Volume 1: ratites to ducks*, Handbook of Australian, New Zealand & Antarctic birds, Oxford University Press, Melbourne, Vic.

NSW Government Office of Environment and Heritage 2017, *Australasian bittern - profile*, viewed 25/01/2023, <www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10105>.

O'Donnell, C, Williams, E & Cheyne, J 2013, 'Close approaches and acoustic triangulation: techniques for mapping the distribution of booming Australasian bittern (*Botaurus poiciloptilus*) on small wetlands', *Notornis*, vol. 60, pp. 279-284.

O'Donnell, CFJ & Williams, EM 2015, Protocols for the inventory and monitoring of populations of the endangered Australasian bittern (Botaurus poiciloptilus) in New Zealand., Department of Conservation Technical Series 38, Department of Conservation, Do Conservation, Wellington.

Papas, P, Hale, R, Amtstaetter, F, Clunie, P, Rogers, D, Brown, G, Brooks, J, Cornell, G, Stamation, K, Downe, J, Vivian, A, Sparrow, A, Frood, D, West, M, Purdey, D, Sim, L, Bayes, E, Caffrey, L, Clarke-Wood, B & Plenderleith, L 2021, *Wetland monitoring and assessment program for environmental water: stage 3 final report*, Technical Report Series No. 322, no. 176105368X, Arthur Rylah Institute for Environmental Research,, Department of Environment Land Water and Planning, Heidleberg, Victoria.

Pickering, R 2017, 'Rejuvenating the Australasian bittern project', *Western Australian Bird Notes*, vol. No. 163 viewed 04/09/2023.

Pickering, R 2018, *Technology used to survey the endangered Australasian bittern*, BirdLife Australia, , Youtube Video, 15/08/18, <www.youtube.com/watch?v=Z30Vb-zkurl>.

Polak, M 2006, 'Booming activity of male bitterns *Botaurus stellaris* in relation to reproductive cycle and harem size', *Ornis Fennica*, vol. 83, no. 1, p. 27.

Poulin, B & Lefebvre, G 2003a, 'Optimal sampling of booming bitterns *Botaurus stellaris*', *Ornis Fennica*, vol. 80, no. 1, pp. 11-20.

Poulin, B & Lefebvre, G 2003b, 'Variation in booming among great bitterns *Botaurus stellaris* in the Camargue, France', *Ardea-wageningen*, vol. 91, no. 2, pp. 177-182.

Puglisi, L, Cima, O & Baldaccini, NE 1997, 'A study of the seasonal booming activity of the bittern *Botaurus stellaris*; what is the biological significance of the booms?', *Ibis*, vol. 139, no. 4, pp. 638-645.

Spencer, J 2022a, 'Monitoring responses of Australasian bitterns to water for the environment in the New South Wales Murray-darling basin.', in *Bringing back the bunyip bird Australasian bittern conservation summit,* NSW Government, Leeton, NSW.

Spencer, J 2022b, 'Monitoring responses of Australasian Bitterns to water for the environment in the New South Wales Murray-Darling Basin. Abstract from is part of the ', in *Bringing Back the Bunyip Bird Australasian Bittern Conservation Summit 1-4 Feb 2022,* NSW Government, Leeton, NSW, <https://www.lls.nsw.gov.au/regions/riverina/projects-and-programs/bringing-back-the-bunyip-bird-australasian-bittern-conservation-summit/abstracts/monitoring-responses-of-australasian-bitterns-to-water-for-the-environment-in-the-new-south-wales-murray-darling-basin>.

Threatened Species Scientific Committee (TSSC) 2019, *Conservation Advice Botaurus poiciloptilus Australian Bittern*, <http://www.environment.gov.au/biodiversity/threatened/species/pubs/1001-conservation-advice-18012019.pdf>.

TSSC 2011, *Commonwealth listing advice on Botaurus poiciloptilus (Australasian bittern)*, Threatened Species Scientific Committee, , Department of Sustainability Environment Water Population and Communities, Canberra, ACT.

Van Turnhout, C, Hagemeijer, E & Foppen, R 2010, 'Long-term population developments in typical marshland birds in the Netherlands', *Ardea*, vol. 98, no. 3, pp. 283-299.

Vanausdall, RA & Dinsmore, SJ 2020, 'Detection and density of breeding marsh birds in Iowa wetlands', *PloS ONE*, vol. 15, no. 1.

Waikato Herald 2022, 'Thermal-imaging drone provides new insights to breeding bittern', *Waikato Herald*, viewed 27/02/2023, <https://www.nzherald.co.nz/waikato-news/news/thermal-imaging-drone-provides-new-insights-to-breeding-bittern/BW3H6DDASF4FPU5YSKOSRD25OI/>.

Williams, E 2015, 'Australasian bitterns in serious trouble', *Environmental News*, no. 34, <www.gbiet.org/en34-australasian-bitterns>.

Williams, E 2018, *It's not all boom and gloom*, Ducks Unlimited New Zealand, New Zealand, viewed 18/10/2023, <www.ducks.org.nz/flight-magazine/item/153-it-s-not-all-boom-and-gloom>.

Williams, EM 2016, 'Developing monitoring methods for cryptic species: a case study of the Australasian bittern, *Botaurus poiciloptilus*', Ecology, Doctor of Philosophy thesis, Massey University, Manawatū, New Zealand.

Williams, EM, Armstrong, DP & O'Donnell, CFJ 2019, 'Modelling variation in calling rates to develop a reliable monitoring method for the Australasian bittern *Botaurus poiciloptilus*', *Ibis*, vol. 161, no. 2, pp. 260-271.

Williams, EM & Brady, MW 2014, 'Monitoring of an Australasian bittern (*Botaurus poiciloptilus*) following release into the wild', *Notornis*, vol. 61, pp. 208-212.

Znidersic, E, Towsey, M, Roy, WK, Darling, SE, Truskinger, A, Roe, P & Watson, DM 2020, 'Using visualization and machine learning methods to monitor low detectability species—the least bittern as a case study', *Ecological Informatics*, vol. 55, p. 101014.

EMSA

Ecological Monitoring System Australia

emsa.tern.org.au