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Conservation management of the critically endangered matuku-hūrepo / Australasian bittern

A review of threats and preliminary management techniques

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Te Kāwanatanga o Aotearoa
New Zealand Government

Cover: radiotagged female matuku-hūrepo, photographed at Ōhiwa. Original image has been reversed. *Photo: Neil Hutton.*

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Abstract

The matuku-hūrepo or Australasian bittern (*Botaurus poiciloptilus*) is an endangered wetland bird and taonga to Māori. It is a top predator in wetlands and key flagship species for wetland health. Matuku-hūrepo were once common and widespread thought New Zealand, but with the loss of >90% of wetlands, and continued degradation of the remaining 10%, their numbers continue to decline. Adequate protection and management of their populations is urgently required to reverse population declines and secure the persistence of the species. There is still much to learn about the ecology and requirements of matuku-hūrepo. This document outlines what is already known about habitat requirements and threats, and describes potential management tools that could be applied immediately. This knowledge is based on recent New Zealand research and successful management practices applied to similar bittern species overseas. A complex array of threats includes habitat loss and degradation from a wide variety of anthropogenic pressures, loss of food supplies, poor water quality, unsuitable and often erratic water-level regimes, unsustainable predation by birds-of-prey and exotic mammals, weeds transforming and reducing habitat through encroachment, fire, collisions with vehicles and other infrastructure, and human-induced disturbance. These all contribute to starvation and low survival. Management should focus on increasing productivity and survival by maintaining and enhancing suitable habitats and reducing threats. To ensure knowledge gaps continue to be addressed, management practices should be applied as a series of management experiments so that the effectiveness of these practices is being determined at the same time as threats are being addressed.

Keywords: wetland birds, threatened species, water level management, predators, weed control, human disturbance, adaptive management, movement ecology, starvation, habitat loss

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1. Introduction

1.1 Conservation status of matuku-hūrepo

Matuku-hūrepo[1] / Australasian bittern (*Botaurus poiciloptilus*; hereafter matuku-hūrepo), is a cryptic, difficult-to-detect species that relies on wetlands to feed and breed (Fig. 1). They are a large wading bird, and a member of the heron family. Found only in New Zealand and Australia, this species is classed as Vulnerable by the International Union for Conservation of Nature (IUCN; BirdLife International 2023) and has recently been classed as Threatened – Nationally Critical, New Zealand's most severe threat classification (Robertson et al. 2021). Additionally, matuku-hūrepo is known to be the rarest of the bittern subfamily (Botaurinae; Williams 2016) and is categorised as being in 'serious trouble' by the Parliamentary Commissioner for the Environment (2017). Population estimates are less than 1000 per country and reduction in its range is known to be steep (> 90% in Australia; Buchanan 2009, > 50% in New Zealand; O'Donnell and Robertson 2016).

Several parties are becoming concerned about matuku-hūrepo nationally, especially since the recent change in threat classification. These include Department of Conservation, hapū, whānau, and iwi, regional and district councils, and community groups. As a result, new matuku-hūrepo-focused projects are starting, with the objectives of identifying sites of importance, clarifying reasons for declines, and restoring habitats using adaptive management practices. The species has an important role in wetland conservation since matuku-hūrepo share many characteristics of a good flagship or umbrella species (Simberloff 1997; author's unpublished data), something that is rarely available for many freshwater conservation programmes (Kalinkat et al. 2017); hence the benefits of matuku-hūrepo conservation are many.

Little is known about the precise nature of threats affecting matuku-hūrepo and the causes of decline, despite the seriousness of their conservation status (Kushlan 2007; O'Donnell 2011). However, several threats that are known to affect *Botaurus* bittern species overseas also exist in New Zealand, suggesting population declines here could be the result of a combination of threats. Such threats include habitat loss and degradation, loss of optimal food supplies, disturbance, poor water quality, unsuitable and often erratic water level regimes, weed encroachment, and predation (O'Donnell 2011).

1 See Appendix 3 for more details of Māori and European names for the Australasian bittern.

1.2 Mātauranga Māori

> Kei te matuku, e hū ana i te repo, i!
> A bittern booming in the marsh!
>
> (Keane-Tuala 2007)

Matuku-hūrepo were well known and significant to Māori traditionally. They are still known today, and recognised as taonga, by many hapū, whānau, and iwi. Matuku-hūrepo were a common food source for Māori, their feathers were used in headdresses, and they appear in language as part of rituals, legends, stories, and metaphor (O'Donnell and Robertson 2016).

1.3 Legislative status of matuku-hūrepo

Aside from the conservation status of the species, matuku-hūrepo are 'Absolutely Protected' under the Wildlife Act 1953. This means that under Section 63 of the Act, it is an offence to kill, hunt, possess, molest, or disturb the species or their eggs without proper authority. However, although this legislation provides complete protection for matuku-hūrepo (and parts of matuku-hūrepo), this Act provides no protection for habitats that are essential for matuku-hūrepo survival. Radio-tracking studies conducted to date show that matuku-hūrepo often use a range of areas that do not have reserve status. The recognition of these habitats as sites of significance for matuku-hūrepo is possible through Section 6c of the Resource Management Act (1991), but only if distributional data are available. Additionally, matuku-hūrepo are listed as 'highly mobile fauna' in the National Policy Statement for Indigenous Biodiversity 2023 (NPS-IB) and as a threatened 'freshwater-dependent' species in the National Policy Statement for Freshwater Management 2020 – Amended 2023 (NPS-FM) (See Appendix 2 for more details).

1.4 Objectives

The objectives of this document are to summarise:

- the distribution, importance, and conservation status of matuku-hūrepo nationally
- current knowledge about the reasons for decline (threats) in matuku-hūrepo populations
- current knowledge of the ecology of matuku-hūrepo, and the characteristics that make matuku-hūrepo vulnerable to decline
- potential management actions that are already available for use in an adaptive management framework to assist the recovery of matuku-hūrepo populations
- methods currently available to monitor population responses to management actions, and where and when to apply these methods
- research needs and knowledge gaps that need filling to adequately restore populations.

Some of the data described in this report have yet to be published because studies are ongoing. However, the overall goal of the report is to provide a resource that encourages conservation managers to test the management techniques proposed within an adaptive management framework because attempting to recover matuku populations is urgent.

Figure 1. Matuku-hūrepo are usually extremely difficult to see because of their reed-like camouflage and are thus rarely reported. (A) Juvenile female matuku-hūrepo blends perfectly into a raupō-dominated habitat. *Photo: Emma Williams*. (B) An adult emerges from dry raupō. *Photo: Colin O'Donnell*.

2. Distribution of matuku-hūrepo

Historically, matuku-hūrepo were distributed throughout New Zealand, including the Chatham Islands and Stewart Island/Rakiura, with key North Island strongholds being associated with Waikato, Northland and Auckland, while the strongholds for the South Island were Canterbury and the West Coast (described in detail by O'Donnell and Robertson 2016). More recently, the population is known to have contracted significantly, at least since the 1970s, and now matuku-hūrepo occur across < 50% of their former range, although reports still occur widely throughout the country (O'Donnell and Robertson 2016).[2] Historical records show that Wellington was one of the earliest regions to experience a decline in matuku-hūrepo populations, with this decline shown to be particularly steep post-1970 (Stidolph 1939; Hill 1963; O'Donnell and Robertson 2016). Such a decline is no surprise given matuku-hūrepo have specialist habitat requirements and 90% of wetlands have been lost nationally (Ausseil et al. 2011), with most of the remaining 10% being under threat (Cromarty and Scott 1995). The scale of wetland loss has been dramatic in many regions. For example, virtually the whole extent of 177,000 ha of swampy flats lying between Waikanae and Rangitikei, where once matuku-hūrepo were 'abundant' (Buller 1888), have been cleared (Ausseil et al. 2008). Wetland loss has been particularly extensive within the Wellington, Hawke's Bay, Northland, Manawatū-Whanganui, East Cape, Coromandel, and Auckland regions (> 90% losses, Ausseil et al. 2008).

2 For interactive maps of changes in the distribution of matuku, see https://www.doc.govt.nz/our-work/monitoring-reporting/national-status-and-trend-reports-20152016/security-of-threatened-and-at-risk-taxa--australasian-bittern/

3. Ecological requirements – current knowledge

The Australasian bittern is one of the most understudied *Botaurus* species (Williams 2016), and as such has many behaviours and ecological requirements that are still not well understood. Despite this, the few studies that have been done to date suggest that internationally *Botaurus* species share similar behaviours, ecological needs, and threats (Teal 1989; Whiteside 1989; White et al. 2006; Williams 2016). This suggests that information can be inferred from closely related species, to allow management to commence in New Zealand, at the same time as knowledge gaps are being addressed through associated research programmes. However, for such an approach to work, it is important that managers recognise the limitations of current knowledge and take care to apply management interventions under a well-monitored adaptive management framework. The importance of such an approach is discussed further in Section 5.2. To assist managers in designing adaptive management approaches, the section below outlines what is known about matuku-hūrepo and what is inferred from closely related species.

3.1 Important habitat types for matuku-hūrepo

Historical records show that matuku-hūrepo occurred in a broad range of habitat types and wetland vegetation communities throughout New Zealand. These include a broad range of palustrine, estuarine, lake, and riverine habitats. Today the species is most frequently reported in coastal, lowland habitats (95% of records were < 400 m above sea level, in O'Donnell and Robertson 2016) but is also known to frequent saturated areas of farmland particularly outside the breeding season.

When breeding or feeding, matuku-hūrepo are typically recorded in mosaics of open freshwater and reed lands, often dominated by raupō (*Typha orientalis*), *Isolepis* spp., *Juncus* spp., and *Carex* spp. with occasional willows (*Salix* spp.) (Figs. 2–9). Also present in matuku-hūrepo habitats, but less prevalent, are species such as *Bolboschoenus fluviatilis, Schoenoplectus* spp., and *Apodasmia similis*. Recent surveys confirm the importance of raupō reed beds for breeding matuku-hūrepo, as most booming males were consistently found in these habitats during the breeding season (Fig. 2) (O'Donnell 2011; author's unpublished

Figure 2. Matuku-hūrepo breeding and feeding habitat at Boggy Pond Lagoon, adjoining Wairarapa moana. Raupō (*Typha orientalis*) in the foreground with a mosaic of open water. *Photo: Emma Williams*.

Figure 3. Matuku-hūrepo breeding and feeding habitat in the mineralised edges of the Whangamarino Wetland. *Photo: Colin O'Donnell*.

Figure 4. Matuku-hūrepo have also been known to boom and breed in areas of *Apodasmia similis*/*Isolepis* spp. Photo taken at Wairio Wetlands, adjoining Wairarapa Moana. *Photo: Colin O'Donnell*.

Figure 5. Bog habitats inhabited by matuku-hūrepo and dominated by mānuka (Leptospermum scoparium, *Baumea* spp. and wire rush (*Empodisma minus*), Whangamarino Wetland, Waikato. *Photo: Colin O'Donnell*.

data). However, nests have also been discovered in a range of other vegetation communities, including mineralised swamps with mixed communities of flax (*Phormium tenax*), sedges, rushes and reeds (Fig. 3), and *Apodasmia similis* / *Isolepis* spp. reed beds particularly in coastal regions (Fig. 4) (O'Donnell 2011; author's unpublished data). Matuku-hūrepo are also known to breed in mānuka (*Leptospermum scoparium*), *Baumea* spp., and open wire rush (*Empodisma* spp.) complexes, such as those seen at Whangamarino Wetland Management Reserve, Waikato (henceforth Whangamarino Wetland) (Fig. 5) (Ogle and Cheyne 1981).

Foraging matuku-hūrepo are regularly seen in the above-mentioned habitats as well as in a variety of modified habitats. The use by matuku-hūrepo of mangroves (*Avicennia marina australasica*; Fig. 6), bogs, farm ponds, dams, drains, and wet or saturated pasture (Figs. 7 & 8) is mostly associated with their winter movements. This is supported by higher reporting rates / sightings of matuku-hūrepo in these habitats in winter (c. 15% of sightings) compared to summer, autumn, or spring in the Department of Conservation's National matuku-hūrepo/bittern database. Foraging also occurs in wet meadows dominated by seasonal adventives (Fig. 9). At Whangamarino Wetland, Waikato, this most commonly coincides with when optimum breeding habitat is inundated by floodwaters in September, October, and November (Williams and Cheyne 2016, 2017). This switch in habitat use to flood plains makes sense in terms of food sources because species such as invertebrates, frogs, or fish spread out into these more open habitats (Suren and Sorrell 2010; Morris 2012; Arthington et al. 2015; Clavero et al. 2015). In addition, in wetlands that are seasonally wet (ephemeral), the flush of water initiates a marked change in the composition of invertebrate communities (e.g., Brooks 2000), which in turn will attract many of the prey species eaten by matuku-hūrepo. These sites often coincide with areas where historic wetlands once occurred, or where drains have overhanging wetland vegetation, making ideal temporary foraging refuges that are important in enabling matuku-hūrepo to survive hard times.

Figure 6. Matuku-hūrepo feeding habitat along the shallow fringes of mangroves, Robert Findlay Wildlife Reserve, Pūkorokoro / Miranda, Firth of Thames. *Photo: Colin O'Donnell*.

Figure 7. In a radio/GPS tracking study, spring-fed creeks and saturated farmland, often dominated by long exotic grasses and *Juncus* spp., have been found to be important habitat for matuku-hūrepo. *Photo: Emma Williams*.

Figure 8. Juncus and wetland pasture rank grass adjacent to Waihi estuary, Bay of Plenty, is used daily by foraging matuku-hūrepo. *Photo: Emma Williams*.

Figure 9. Feeding habitats in flooded adventive vegetation and floating weed beds, Whangamarino Wetland, Waikato. *Photo: Colin O'Donnell*.

3.2 Breeding

3.2.1 Season

Research conducted to date shows that in New Zealand matuku-hūrepo breed during a short season in spring, laying eggs between September and December, and rearing chicks between October and February (with chick rearing appearing to peak in December; O'Donnell 2011). The earliest indication of breeding is the sound of male matuku-hūrepo booming, a low resonant call that is produced by all *Botaurus* species and is associated with mate attraction and territory defence (Teal 1989; Puglisi and Bretagnolle 2005; Polak 2006).

Historical records show that booming can occur in any month of the year, but usually peaks from mid-September to mid-November (O'Donnell 2011; Williams, Armstrong and O'Donnell 2018), hereafter referred to as the 'booming season' (Fig. 10). Within the booming season, calling is known to be predictable, with optimum times and conditions for booming males being identified as 1 hour before sunrise or within the first 30 minutes after sunset, when there is no rain and moon visibility is highest (Williams, Armstrong and O'Donnell 2018). What is known about breeding is summarised in Box 1.

Box 1: Summary of breeding characteristics of matuku-hūrepo (from Williams 2013; O'Donnell 2011)

Social structure	Female-only incubation and brood care
Breeding season	Aug Sep Oct Nov Dec Jan Feb Mar Apr May
Nest type	Floating platform, raised slightly above the water line
Nest description	Platform usually surrounded by water made from raupō, reeds, rushes and / or woody vegetation
Nest height (mean)	0.43 m
Maximum number of successful broods	1
Clutch size (mean)	4.3 eggs (range 2–6)
Mean egg dimensions (length)	51 × 37 mm
Egg colour	Olive-brown
Egg laying dates	Aug Sep Oct Nov Dec
Interval between eggs in a clutch	24–48 hours
Incubation behaviour	Female only
Incubation length (mean)	Approximately 25 days
Nestling type	Altricial
Nestling period (days)	Unknown
Age at fledging (mean)	Approximately 49 days (although chicks start exploring the area around their nest as early as 14 days old)
Age at independence	Unknown
Age at first breeding	Unknown
Maximum longevity	Unknown
Maximum dispersal	330 km (New Zealand); 550 km (Australia)

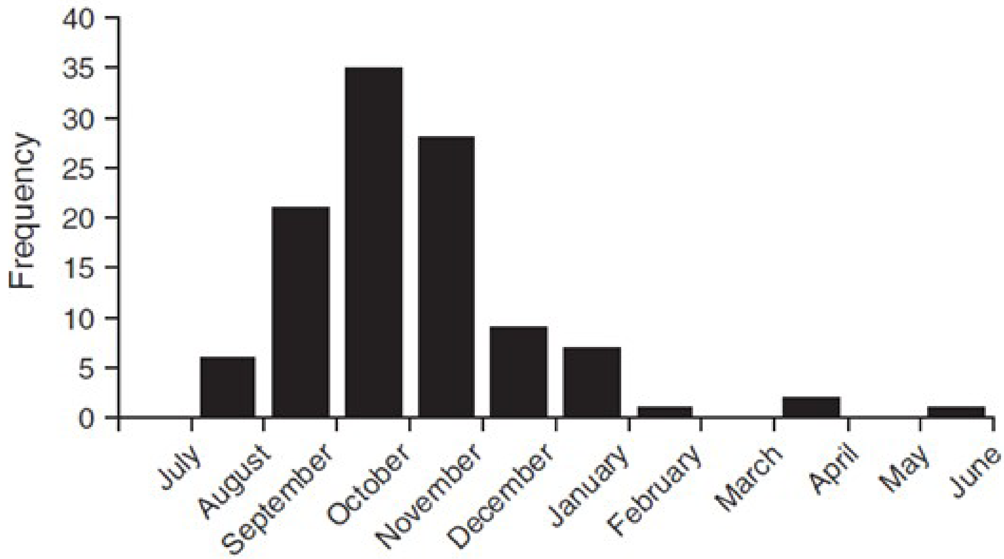

Figure 10. Seasonal distribution of booming records of male matuku-hūrepo denoting the breeding season (from O'Donnell 2011).

3.2.2 Nesting and behaviour

Studies to date show that home-range sizes of booming male matuku-hūrepo vary from 1.7 to 25.7 ha during the breeding season,[3] with core booming areas being less than 1.2 ha (Teal 1989, Williams 2016). In other *Botaurus* species, that have been more intensively studied, females are known to visit males early in the booming season and choose their mates based on boom quality / fitness, and several habitat characteristics associated with breeding success (Poulin and Lefebvre 2003). In New Zealand, male matuku-hūrepo boom in dense beds of reeds/rushes, most frequently dominated by raupō or *Bolboschoenus* spp. Data from Whangamarino wetland, Waikato, show matuku-hūrepo boom in mean water depths of about 5 cm (n = 5) in tall reeds (mean stem heights of about 80 cm [n = 5]; Williams and Cheyne 2017). Males are polygamous, and booming males have been known to have 0–5 nesting females within 200 m of their core booming areas (Teal 1989; author's unpublished data). Limited nest records from New Zealand suggest female matuku-hūrepo generally build semi-floating nests in reedbeds with shallow water 20–60 cm deep (86% of nests were semi-floating, n = 21 nests; O'Donnell 2011).

Matuku-hūrepo nests are notoriously difficult to find, are located under dense cover, and few have been found or studied. Those that have been found to date were a platform of reeds, usually 20–30 cm above the water and hidden among dense vegetation. Eggs are usually laid between August and December (peaking in November) (O'Donnell 2011), and are incubated for about 25 days before hatching. Clutch sizes vary from 2 to 6 eggs per nest, with a mean of 4.3 (O'Donnell 2011).

3 Measured as the mean 95% utilisation distribution, which is defined as the area that has a 95% probability of containing the bird (UD; Van Winkle 1975). Territory sizes presented here are based on six radio-tagged males at Lake Whatumā, Hawke's Bay (12.46 ha, ± 10.16; Williams 2016), and two radio-tagged male matuku from Whangamarino Wetland Management Reserve, Waikato (8 ha ± 2.83; Teal 1989).

Nestlings are usually reported between September and February and fledge from November to May (Fig. 11). Once hatched, chicks can be very vocal making a 'see-see' noise. Chicks remain in the vicinity of the nest for about seven weeks but start to explore the general area at about two weeks old. They frequently return to the nest but may also be brooded at other, more temporary nests, within proximity to the main nest. During this period, chicks are thought to be particularly vulnerable, as they are very vocal, curious, and naïve. Mortality at this age appears to be common, with trauma due to collisions (i.e. with vehicles or powerlines) being the most frequent cause of death reported within a birds first year of life, followed by starvation (n = 16; trauma due to collisions = 43.75 %; starvation = 31.25 %; both trauma and starvation = 18.75 %; other = 6.25 %; author's unpublished data). Chicks 2–7 weeks old have also been periodically reported wandering through urban areas, with over seven found by members of the public in the city centres of Tauranga and Christchurch. These birds turn up in a variety of places, such as dog parks, on roads, roundabouts, with one even walking into someone's garage (J. Stevenson pers. comm., Bird Rescue Christchurch).

Based on anecdotal evidence and overseas species, it is assumed that nests are built entirely by the female within 50 m of the booming male, and that she alone is responsible for incubation and chick rearing. Males are thought to play no role in nesting or rearing young (Puglisi and Bretagnolle 2005). Observations in New Zealand support this, as radio-tagged males focus much of their time and energy on booming or feeding during the breeding season. Despite this, a photo taken by Soper (1958; DOC Image Library) appears to show a matuku-hūrepo with a distinct blue lore (a characteristic thought to be indicative of breeding males) present at a nest, suggesting the bird attending the nest is male. Observations to hand of birds of known sex support the postulation that a male has a blue lore during the breeding season but too few females have been handled to date to confirm that the same characteristic is completely absent in females.

Figure 11. Newly hatched matuku-hūrepo chicks, Awarua Bay, Southland. *Photo: Sarah Crump*.

3.3 Productivity and survival

Little is known about basic population parameters, largely because matuku-hūrepo nests are very difficult to find and monitor, banding studies have not been operative for long enough, and recaptures are few. Thus, measures such as annual productivity, age of first breeding, life span and annual survival are unknown. O'Donnell and Robertson (2016) estimated generation time to be in the order of 5–10 years, based on very limited survival data from *Botaurus* bittern overseas. Birdlife International (2020) estimates generation time of *Botaurus stellaris* as 5.5 years based on a small amount of banding data. However, some birds in the overseas datasets are still alive. Longevity records (some birds still alive) for Eurasian bittern (*B. stellaris*) and American bittern (*B. lentiginosus*) are >11 years (Clapp et al. 1982; Hagemeier and Blair 1997; Fransson et al. 2010; Garnett et al. 2011; BTO 2016).

3.4 Food and feeding behaviours

In New Zealand, no formal foraging or dietary studies have been done on matuku-hūrepo, which is in part due to the cryptic and secretive nature of the species. Matuku-hūrepo often forage within or along the edges of thick vegetation, making feeding behaviours and prey items a challenge to observe. Despite this, much can be inferred from the anecdotal observations that do exist and dietary studies that have been done overseas. In general, matuku-hūrepo diets appear to be diverse, and opportunistic. A wide range of native or non-native prey items have been reported, including fish, amphibians, small birds, rodents, lizards, large invertebrates, arachnids, and crustacea (Reischek 1885; Oliver 1955; Moon 1967; Edgar 1972).

The most common component of the matuku-hūrepo diet is reported to be medium-sized freshwater fish, particularly eels (*Anguilla* spp.) (Buller 1888; Potter 1950; Whiteside 1989; author's unpublished data), with lengths up to 20–60 cm reported (Buller 1888; Potter 1950; Whiteside 1989; author's unpublished data). Observations of introduced fish species being preyed upon by matuku-hūrepo in New Zealand include goldfish (*Carassius auratus*), mosquito fish (*Gambusia affinis)* and trout (sp. unknown) (Edgar 1972; author's unpublished data). Sizes of non-aquatic prey species also support the notion that small- to medium-sized prey are taken, with rats (*Rattus* spp.) being the largest mammalian prey item recorded, and other commonly reported prey items include small species such as mice (*Mus musculus*), introduced frogs and frog tadpoles (Reischek 1885; Drew 1896; Soper 1958).

Most observations of foraging matuku-hūrepo suggest the species relies on the ability to stalk, sight and stab prey in clear water (Williams and Brady 2014; Commonwealth of Australia 2019). For example, matuku-hūrepo are most often seen walking slowly along the edge of tall vegetation (reeds and rushes) with their necks outstretched looking for prey. They are rarely seen foraging out in the open and appear to favour areas where they can forage completely out of view or have the option to hide quickly if required.

3.5 Seasonal movements and habitat requirements

Results from radio-tracking studies using traditional VHF transmitters and conducted in New Zealand to date show that, in general, males have high site fidelity within and across breeding seasons, but are more transient and have larger home ranges during the non-breeding season (Teal 1989, Williams 2016; author's unpublished data). Preliminary radio tracking studies of 24 matuku-hūrepo in the Hawke's Bay, Canterbury, Waikato, and Bay of Plenty regions showed that males tended to occupy breeding territories between July and December, then moved to numerous non-breeding sites during the rest of the year.

In the Hawke's Bay Region, radio-tagged male matuku-hūrepo visited a complex mosaic of more than nine wetlands outside the breeding season. Most of these birds stayed within a c. 20 km radius of their breeding site (Lake Whatumā), although some birds appeared to move outside the study area. They fed in habitats that included spring creeks, swamps, and farm dams, often with raupō present (7 out of 10 males radio-tagged; author's unpublished data). Any matuku-hūrepo that appeared to move beyond this radius (and therefore could not be followed across all seasons) returned for the booming season during the following spring. Nationally, only one radio-tagged matuku-hūrepo, a female, occupying estuarine habitat in Bay of Plenty Region, has been sedentary over the 18 months it has been tracked to date (author's unpublished data).

The longest distances moved to date include (A) a rehabilitated juvenile female matuku-hūrepo from Canterbury that moved c. 145 km between the Waimakariri and Ōpihi Rivers over the three months after release, and (B) an adult male that moved, seemingly regularly, between Lake Ellesmere / Te Waihora in Canterbury and the Wairau Lagoons Wetland Management Reserve in Marlborough, a round trip of c.660 km (author's unpublished data; Fig. 12).

Studies at Whangamarino Wetland in Waikato, characterising seasonal habitat requirements, suggest that matuku-hūrepo movements are driven by changes in water levels, with mean water depths of c. 15 cm (SD ± 6) preferred for foraging (Williams and Cheyne 2017; Williams 2018). This study also indicated that matuku-hūrepo utilise a range of vegetation types for foraging, but rely only on a few plant species to breed – largely raupō and *Bolboschoenus* spp. Thus, daily and seasonal movement patterns may also be defined by whether breeding and feeding habitat are separate and fragmented, or continuous.

3.6 The importance of wetland networks

More recent research by the author, tracking matuku-hūrepo using new-generation GPS tracking technology, is revealing more-intimate real-time data on movements. These trackers show that previous radio-tracking work underestimated the scale of movements, with males regularly moving distances > 100 km through the year. In some populations, these movements do not appear to be restricted to the non-breeding season, with male matuku-hūrepo in Canterbury and Waikato Regions regularly undertaking movements of this scale during the breeding season (Figs. 12 and 13). This is counter to the theory that males hold small territories during this period and is a cause for concern given that such movements are energetically expensive and could suggest breeding sites are falling short of male breeding requirements (i.e., there could be a lack of females at these sites or suitable breeding habitat is not consistently available).

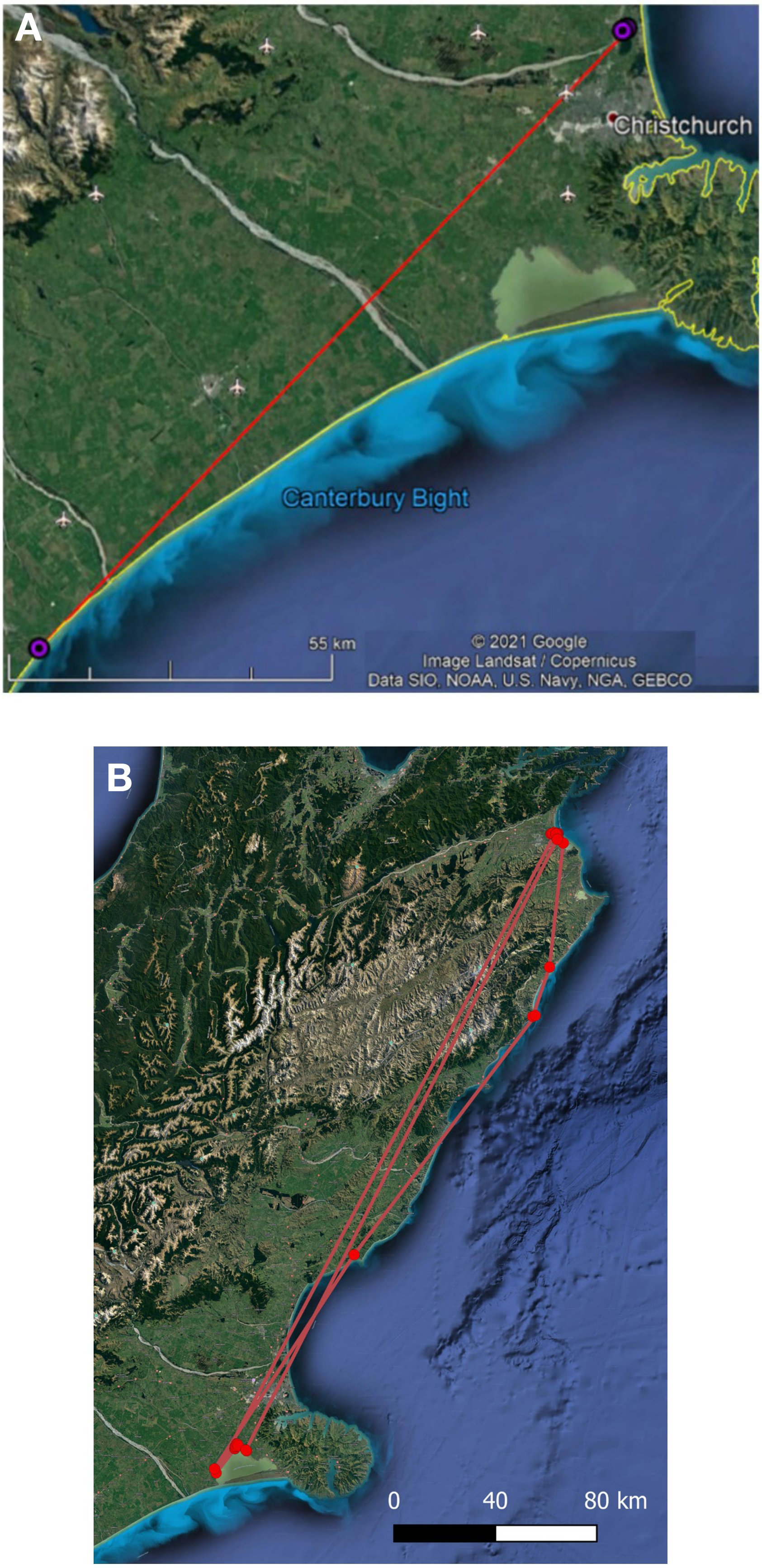

Figure 12. Long distance movements of matuku-hūrepo. Examples include: (A) a rehabilitated juvenile female from Canterbury was known to have moved c. 145 km over a period of 3 months post-release, and (B), an adult male was known to move c. 660 km, seemingly regularly, between Te Waihora / Lake Ellesmere in Canterbury and the Wairau Lagoons in Marlborough.

GPS tracking data also show that the network of sites relied on by matuku-hūrepo populations is more extensive than originally thought, with birds moving on a regional landscape scale, regularly crossing different rohe, takiwā, or territorial authorities' jurisdictions. This creates additional monitoring and management challenges for those trying to protect matuku-hūrepo since the habitats, threats, and tenures of land used by matuku-hūrepo are varied. The flight paths used by birds will also be an area of vulnerability. Many of these are still unidentified and poorly understood, and none are managed or protected. Sites and flyways frequented by individual animals will fall under the jurisdiction of multiple groups within DOC, Treaty partners, regional councils, district councils, landowners, community groups, and NGOs. Complete protection of matuku-hūrepo will only be achievable via a coordinated effort involving the stakeholders for all sites and flyways.

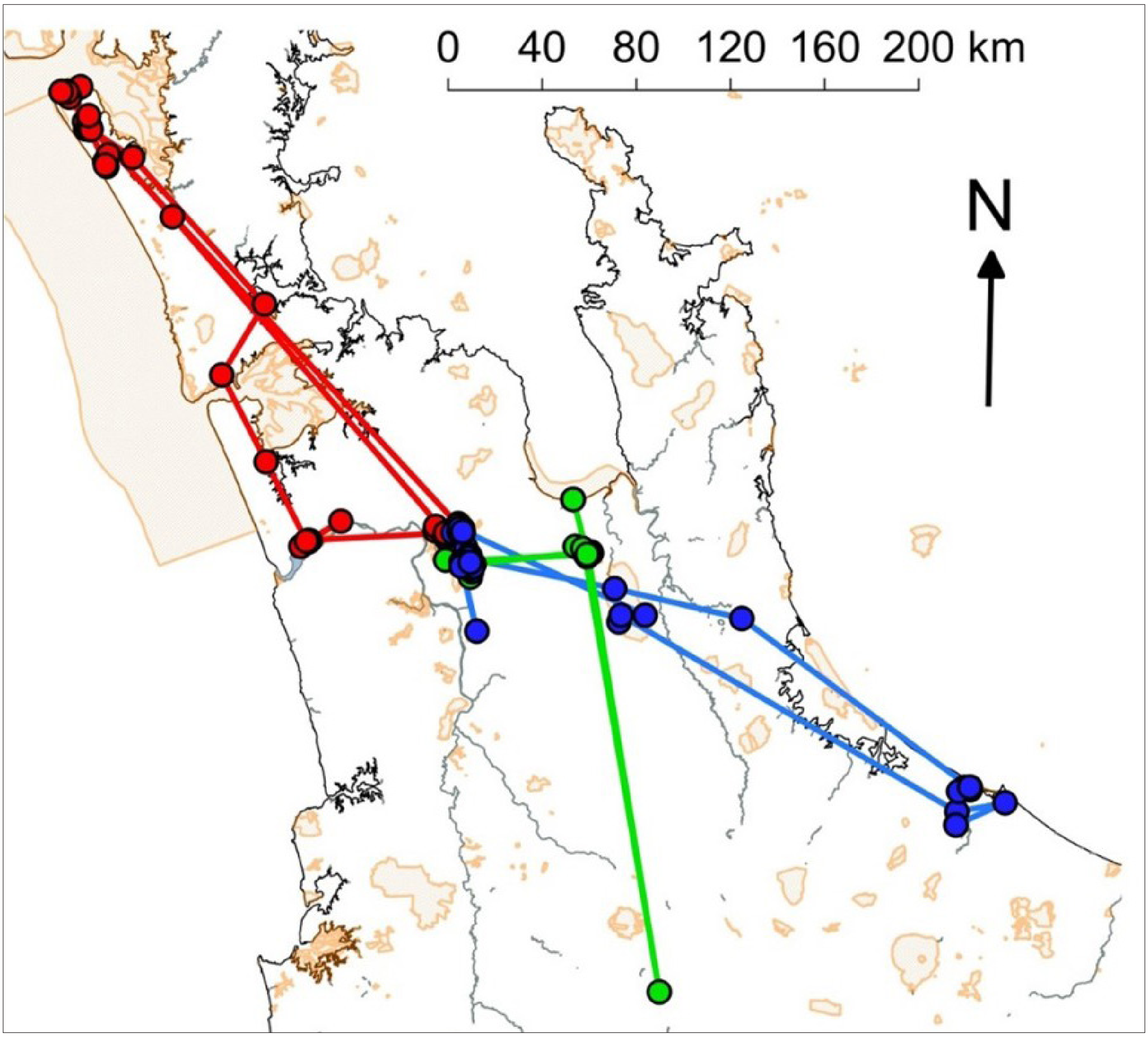

Figure 13. Movement networks for three male matuku-hūrepo, tagged while booming at Whangamarino Wetland, Waikato, September to December, 2018 (Author's unpublished data).

4. Reasons for decline (threats)

4.1 Habitat loss and degradation

Habitat degradation and loss is one of the most fundamental threats to the viability of matuku-hūrepo populations, given that > 90% of wetlands, their primary habitat, have been drained since Europeans arrived in New Zealand (Ausseil et al. 2011). Wetlands now cover as little as 2% of the area in some regions (Ausseil et al. 2008). The impact of habitat loss on matuku-hūrepo is high because of their specialist requirements, relying on wetlands to feed and breed (O'Donnell 2011). The ongoing effect of this habitat loss on matuku-hūrepo is likely to be significant and the need for habitat restoration and creation is self-evident if matuku-hūrepo populations are to recover. Wetland loss is continuing; for example, the rate of wetland loss in Southland since 1990 has been 0.5% of wetland area per year (Robertson et al. 2019).

Additionally, the 10% of wetlands that remain are continuing to degrade (Cromarty and Scott 1995, Ausseil et al. 2011; Office of the Prime Minister's Chief Science Advisor 2017). Causes of this degradation, and therefore additional threats likely to affect matuku-hūrepo populations, include threats that reduce food supplies and food accessibility, such as unnatural water level extremes, declining water quality, increased turbidity, effects of aquatic pests, sedimentation, and weed encroachment.

4.2 Threats to food supplies, foraging restrictions, and starvation

Starvation in New Zealand's matuku-hūrepo population is a cause for concern. The matuku-hūrepo radio-tracking programme, starting in 2012, has shown that starvation is the most common cause of death of matuku-hūrepo (7 out of 17 birds monitored for > 12 months to date have died; of these mortalities 71.4% starved (n = 5), 14.3% had an unknown cause of death (n = 1), 14.3% were hit by a car (n = 1); author's unpublished data). This is no surprise given the degree of waterway modifications that have been known to disrupt fish supplies by altering community structure, increasing turbidity, and reducing food supplies of aquatic vertebrates (e.g., Ryan 1991; Hayes et al. 1992; Rowe 2007). Despite the apparent importance of starvation to matuku-hūrepo, we still cannot say how starvation ranks in relation to other threats for matuku-hūrepo populations. The Department of Conservation matuku-hūrepo radio-tracking programme is still in its infancy, and the majority of matuku-hūrepo that have starved are rehabilitated birds (57% of rehabilitated matuku-hūrepo starved, n = 4 of 7; 10% of wild-caught matuku-hūrepo starved, n = 1 of 10). However, given that most radio-tagged matuku-hūrepo have been monitored for < 2 years so far (71% birds; 17 of 24), insufficient time has passed to determine the long-term effects of starvation on the viability of the population. In the meantime, it is clear that we need to investigate any potential factors that could affect food availability and prey accessibility.

Habitat loss and fragmentation, and subsequent depletion of food supplies have also been identified as a principle cause of decline of the Eurasian bittern (Tyler et al. 1998, Gilbert et al. 2003; Gilbert et al. 2005a; Gilbert et al. 2007). The diversity of prey items known to be taken by matuku-hūrepo would suggest they have a degree of robustness against starvation when food availability fluctuates. However, their lack of flexibility in relation to their foraging strategies and specific needs in terms of prey size could limit the species' ability to feed in degraded wetlands.

The availability of fish of small-to-medium size is likely to be driven by the availability of their food sources and habitat quality, factors affecting fish recruitment (i.e., availability of spawning habitat and low fish harvesting pressures), and the presence of exotic fish species that prey on indigenous fish (e.g., perch, *Perca fluviatilis*).

The bulky size of matuku-hūrepo suggests large quantities of prey are required to sustain populations. Indeed, reports of gut content or regurgitate recorded in an individual's stomach have included as many as: five rats (Reischek 1885); "a silver-eye (*Zosterops lateralis*), frog, five locusts, a large spider, two common sand-lizards and the remains of a small fish" (Drew 1896); five eels (up to 20 cm in length each); numerous invertebrates including two nursery web spiders (*Dolomedes minor*), five locusts and a common black field cricket (*Teleogryllus commodus*) (Whiteside 1989); and four introduced frogs (nest regurgitate, Soper 1958). This suggests that the small prey items that matuku-hūrepo are commonly seen feeding on, such as insects, mosquito fish, and frog tadpoles, are unlikely to be able to sustain a matuku-hūrepo population long-term unless they are particularly easy to catch in large quantities. Despite this, such small prey items may still have a role as seasonal food sources that can bridge gaps in availability of preferred food items.

The stalk-stab foraging strategy is used by all species in the heron family, but unlike matuku-hūrepo, other heron species commonly feed in open wetland habitats and have a suite of foraging strategies that allow them to adapt as wetland environments change. In contrast, *Botaurus* species only have two foraging strategies: stand and wait, or walk slowly, which they almost always do in vegetation cover, making them one of the least adaptable species in the heron family (Kushlan 1976). Such a limited foraging repertoire is likely to penalise matuku-hūrepo survival rates in circumstances where water clarity is poor (meaning aquatic prey items are not visible), water levels are too high/deep (meaning aquatic prey cannot be caught without diving), water levels are too low (meaning aquatic prey items are not present), or there is little or no vegetation in the area where the food sources are available (meaning matuku-hūrepo have to expose themselves in order to forage).

4.3 Water level extremes

Wetlands are naturally dynamic environments that are driven by seasonal water level changes. However, wetlands that dry or are flooded unnaturally are unlikely to provide optimum matuku-hūrepo habitat unless the requirements of the birds are factored into management regimes. The impact of particularly high or low water levels has already been discussed, above, in terms of the influence on aquatic prey availability and matuku-hūrepo feeding strategies. To some extent, matuku-hūrepo populations will have adapted to these water level changes, and the natural influence these changes have on prey availability. This is supported by some evidence that matuku-hūrepo follow an asynchronous chick hatching system like that observed in birds of prey, as these behaviours are often associated with species that have erratic prey sources (Clark and Wilson 1981). In addition, the ability of matuku-hūrepo to utilise numerous wetlands throughout year, also suggests they can adapt when wetland conditions change seasonally, provided that a sufficient number and diversity of wetland sites remain within their habitat network.

Unfortunately, in recent times, water levels in many places have not changed naturally with the seasons and have been instead controlled and driven by human interventions. An example of this can be found at Whangamarino Wetland, a site of international importance for matuku-hūrepo, and with Ramsar status. This site is used by the regional council as a second holding pond to keep flood water off farmland (O'Donnell 2014). Hence, water levels are raised artificially and suddenly by 1–2 m, flooding the majority of matuku-hūrepo feeding and breeding areas. Research characterising water level preferences and seasonal habitat requirements of matuku-hūrepo at Whangamarino Wetland has shown matuku-hūrepo prefer mean water depths of 15.9 cm (SD ± 6.2) for foraging (Williams and Cheyne 2017; Williams 2018). At Whangamarino Wetland, 20% of habitat is available to matuku-hūrepo when river water levels are 3.4 mRL (mean river level); however, this drops to as little as 5% when river water levels increase above 3.7 mRL or drop below 3.3 mRL (Blyth and Nation 2020, unpublished).

The limited records of matuku-hūrepo breeding in New Zealand show that they build semi-floating nests within reedbeds. Water depths at nests have ranged from 0 to 75 cm, averaging 38 cm deep (SD ± 19.8) (Teal 1989; author's unpublished data; O'Donnell 2011). The use of floating nests and booming platforms allows these structures to rise and fall naturally to some degree with water level fluctuations. If water levels increase slowly, birds have some ability to build up these structures before they are flooded. However, if water level changes are large and/or quick, birds are unlikely to be able to modify their nests appropriately. This suggests nesting matuku–hūrepo are most vulnerable to sudden and extreme water level changes.

4.4 Water quality, sedimentation, and turbidity

The effect of poor water quality, high sedimentation, and turbidity on matuku-hūrepo populations is likely to be more indirect and is currently understudied. Sedimentation is thought to have a negative impact on matuku-hūrepo because it alters natural water depths and changes the vegetation composition of matuku-hūrepo habitats so that conditions favour invasive weed species at the expense of reedbeds (O'Donnell 2014). It is also possible that sedimentation affects food supplies by clogging spaces between pebbles and vegetation, reducing invertebrate populations and the foraging opportunities of many aquatic prey species (Henley et al. 2000). Turbidity and poor water quality are more associated with reduced light penetration, high nutrient loading, reduced phytoplankton populations and, at its extreme, lake toxicity (Henley et al. 2000). These factors, in turn, affect matuku-hūrepo since they negatively affect the health of aquatic prey populations.

4.5 Predation

Matuku-hūrepo have been identified as one of the species most at-risk from invasive predators based on their clutch size, clutch frequency, and ground nesting behaviours (O'Donnell et al. 2015). To date, there have been few observations of matuku-hūrepo being preyed upon by introduced mammals. However, such events are difficult to observe with such a secretive species, and the probability of finding matuku-hūrepo bodies / nests after predation events is likely to be low. Existing observations include two records of feral cats (*Felis catus*) preying on adult matuku-hūrepo (O'Donnell et al. 2015). Despite this paucity of information, we know wetlands can attract a diversity of predator species (Gillies and Brady 2018) and matuku-hūrepo nests and young are particularly vulnerable (O'Donnell et al. 2015). Indeed, three of five matuku-hūrepo nests that were monitored recently, in the Hawke's Bay and Southland, failed. Of these nests, two failed following visits by kāhu/swamp harrier (*Circus approximans*; Fig. 14) and one failure had signs of mustelids being present (author's unpublished data). The few predation records are not surprising given the extremely cryptic behaviour of matuku-hūrepo. However, studies of waterfowl, crakes, rails, and waders occurring in similar wetland habitats indicate that predation by introduced stoats (*Mustela erminea*), ferrets (*M. furo*), weasels (*M. nivalis*), feral cats, dogs (*Canis familiaris*), and rats (*Rattus* spp.) is frequent, and that these predators are common in most wetlands, thus warranting predator control in these habitats (O'Donnell et al. 2015).

Figure 14. A kāhu/swamp harrier caught on trail camera taking an egg from a real matuku-hūrepo nest. Tiwai Point, Southland.

Despite a lack of data on nests, some information is available on the susceptibility of matuku-hūrepo nests to predators. One previously unpublished study looked at how predators interacted with artificial matuku-hūrepo nests (author's own research). This study, conducted at Lake Wairarapa in 2019 and the wetlands adjacent to the Waimarino river mouth, Lake Taupō in 2020, involved artificially creating nests in raupō in areas where male matuku-hūrepo are known to boom during a typical breeding season (31 in 2019 and 40 in 2020). Each nest had one real (chicken) egg and a fake (plasticine) egg. The latter was wired into the nest. Nests were left in place for a duration of 30 days, a figure considered a reasonable representation for the average duration of a real matuku-hūrepo nest (approximate incubation length =30 days; Williams 2013). A nest was then considered as 'failed' if an egg had been removed, the nest disturbed, or the plasticine had been marked. Results from these trials showed c. 90% of nests failed, with kāhu/swamp harrier predation being the highest cause of nest failure (c. 77%), with the remainder of predators including pūkeko (*Porphyrio melanotus*), stoats, ferrets, and brushtail possums (*Trichosurus vulpecula*; Fig. 15, Fig. 16). Based on this research, matuku-hūrepo nests are likely to be susceptible to the full suite of predators found in wetlands.

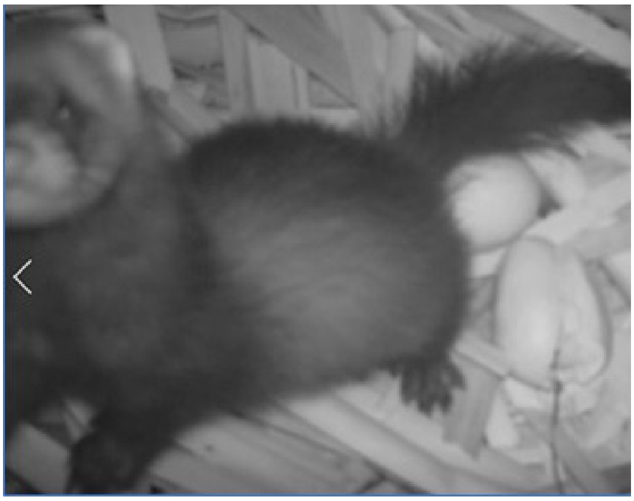

Figure 15. Trail camera image of a ferret seen interacting with the eggs of a fake matuku-hūrepo nest.

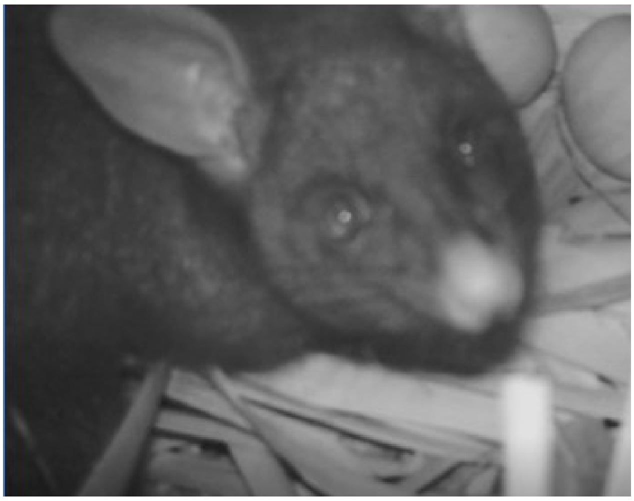

Figure 16. Trail camera image of a possum seen interacting with the eggs of a fake matuku-hūrepo nest.

4.6 Weed encroachment

Weed encroachment is an important threat to the integrity of wetland plant communities. Weeds that contribute to changing the structure and functioning of wetlands, such as those that out-compete indigenous vegetation, change the composition by monopolising nutrients, and shade out entire understorey communities, are particularly problematic in wetlands. Weeds such as willows (*Salix* spp.), alder (*Alnus glutinosa)*, tall fescue (*Lolium arundinacea*), and hornwort (*Ceratophyllum demersum*) are problems in the context of matuku-hūrepo habitat. Willows are a threat to reedbed nesting areas, outcompeting reeds and sedges, and dominating such areas if uncontrolled, rendering them unsuitable for nesting and feeding.

4.7 Fire

Internationally, there is an abundant amount of information on the impact of fires on wetlands, both as a management tool, as well as a threat. Impact as a threat usually depends on how hot the blaze is, as well as how fast, unexpected, and widespread any damage is. The most obvious impacts are those that are direct. For example, mortalities of matuku-hūrepo that are unable to leave the area quickly, loss of large areas of habitat, and the destruction of nests if the fire occurs during the breeding season. Indirect threats also occur if matuku-hūrepo do not have alternative sites and food sources nearby that they can move to. Also, fire often favours the regrowth of different vegetative species, which can lead to long-term or permanent changes to the composition of the burnt wetland, as well as changes to the water quality and clarity that may affect foraging.

Approximately 930 ha of matuku-hūrepo habitat was lost in October 2009 at Tiwai Point / Awarua Bay in Southland (Fig. 17). Fire crews and DOC staff reported at least twelve separate sightings of matuku-hūrepo in the area as the blaze was being tackled, with DOC Ranger Sally Chesterfield saying, "many bittern were seen gobbling down half-cooked lizards as they tried to escape the fire" (Fig. 18). Aside from fire as a threat, controlled burns are sometimes used as a management tool for matuku-hūrepo in Australia (known there as the bunyip bird) (see Section 8.4).

Figure 17. Fire damage cause at Tiwai Point / Awarua Bay in October 2009. *Credit: Department of Conservation staff*.

Figure 18. Two matuku-hūrepo seen foraging in the burnt vegetation after a fire at Tiwai Point / Awarua Bay in October 2009. *Credit: Department of Conservation staff*.

In January 2020, a fire broke out at Waimapu Estuary, a 9 ha saltwater rush wetland in Tauranga Harbour (Fig. 19). The blaze, fuelled by strong winds, had destroyed a 1 km^2 area, at the same site where breeding had been confirmed in December 2017, when two matuku-hūrepo chicks turned up in the urban areas adjacent to the wetland. DOC ranger Karl McCarthy recalled, "local firefighters rang to say they'd seen 'at least one matuku' present while the team was bucketing water onto the flames. It appeared 'reluctant to leave' so we suspected it had a nest somewhere in the area. They took me out to the site, and we searched extensively for any surviving nests, eggs or chicks, but no signs remained". The site experienced a similar fire, which was just as devastating, in October 2006. Locals reported that it took at least 5 years after the 2006 fire for the vegetation to regenerate (Liddle 2020).

Figure 19. Fire damage to matuku-hūrepo habitat at Waimapu Estuary in Tauranga Harbour. *Photo: Karl McCarthy*.

4.8 Shooting

Historically, matuku-hūrepo were hunted for sport, food, and feathers for trout-fishing flies and novelty clothing (O'Donnell and Robertson 2016). They were also perceived by some as pests because they were thought to prey upon introduced salmonids (Otago Star 1875). Shooting of matuku-hūrepo as game birds was legalised in 1867 and was common practice in the 1800s until they were finally fully protected in 1904 (Miskelly 2014). O'Donnell and Robertson (2016) had 24 records in their database of birds being shot. Most were pre-1900, but four were in 1900–1909, one in each of 1918, 1926, 1935, and 1941, and one contemporary record in 2009. In addition, there are numerous reports of prosecutions in early New Zealand newspapers until the late 1930s for illegally shooting matuku-hūrepo (http://paperspast.natlib.govt.nz).

Duck-shooting still poses a potential threat. However, whether matuku-hūrepo are shot accidentally is unknown. Radio-tagged matuku-hūrepo were monitored on the opening day of duck shooting in Hawke's Bay Region in 2015. During this year, all radio-tagged birds left the wetlands they were resident on once duck hunting started, moving to smaller, nearby sites; but none were shot (author's unpublished data). Use of dogs during shooting may also pose a threat, as dogs have been known to prey on wetland birds in New Zealand (O'Donnell et al. 2015).

4.9 Human-induced disturbance

Matuku-hūrepo habitats are also increasingly being used for a variety of recreational purposes; boating, cycleways, and backdrops to parties. As the species is renowned for being secretive and shy, it is intuitive that disturbance is a cause for concern. Indeed, there have been cases in New Zealand of matuku-hūrepo nests failing due to disturbance, including at least one case attributed to vandalism (Soper 1958).

Despite these threats, there have been no comprehensive studies on the nature or effect of the full range of possible disturbances. Weston et al. (2012) briefly investigated the effect of disturbances on Australian birds and reported one bittern flushing at a distance of 10 m. However, personal experience has shown that flight distances vary greatly between individual matuku-hūrepo, with some flushing as soon as you enter a wetland and others holding long enough that they can be captured easily by hand (author's unpublished data). European bittern literature provides few details with references to the 'potential for disturbances' (McGregor and Byle 1992). This leaves much uncertainty in the nature of what may or may not disturb matuku-hūrepo.

What is known is that human–wildlife interactions alter the behaviour of most wildlife, with even the most gregarious species of wildlife experiencing the following in relation to disturbances: increased stress levels, increased energy expenditure, missed foraging opportunities (while hiding from disturbances), reduced reproductive success, avoidance of key habitats, and increased mortality (Martin and Réale 2008; Weston et al. 2012; Longshore et al. 2013). Often this can be caused by passive disturbances such as proximity to people and is even noticeable for some species as a 'weekend effect' (Dowling and Weston 1999; Ruhlen et al. 2003; Nix et al. 2018).

Reed-specialist bird species are thought to be particularly vulnerable to disturbance, with negative impacts from activities such as reed-cutting being reported (Wanyonyi 2016). Despite this, there is evidence to suggest the extent and duration of disturbance is significant with some bird species, including matuku-hūrepo (Pierce et al. 1993; Polak 2007). With some avian species, the more intrusive and frequent a disturbance the more likely it is to have an impact, especially with regard to nest success (Felton et al. 2017). This is a concern with matuku-hūrepo, as the camouflaged nature of their nests mean they can easily be disturbed inadvertently. Boat activities are known to affect reproductive success of species that nest low in the water. This is either through the effect of waves (boat wakes) flooding nests or through general activity preventing birds from caring for young/eggs attentively (Keller 1989, Storer and Nuechterlein 1993). If disturbance is high, egg mortality in wetland birds can also be high because eggs either overheat or become cold when nests are unattended.

4.10 Collisions with vehicles, wind farms, and infrastructure

The risks of collisions faced by birds are well known and discussed in literature (e.g., Martin and Shaw 2010; Bernardino et al. 2018). Matuku-hūrepo generally exhibit slow, cumbersome flight, which suggests they are vulnerable to injury or death via collisions. Indeed, collisions were recorded as a common cause of death for matuku-hūrepo by O'Donnell and Robertson (2016), with mortalities and injuries largely being associated with vehicles on roads (n =13), rail transport (n =2), or power lines (n =8). A recent mortality study that determined cause of death for matuku-hūrepo held in Department of Conservation or university freezers (n =26) supports this, with around 35% of deaths being attributed to a collision with an object (author's unpublished data). However, the extent of mortalities from collisions can be difficult to quantify as incidents often go unreported and bodies can be difficult to recover or may be scavenged.

There is also evidence that matuku-hūrepo could be at risk from larger infrastructures such as windfarms and tall transmission lines. Height data collected from GPS-tagged matuku-hūrepo, suggest birds could be flying within turbine blade height for a high proportion of their flying time (Williams 2021). Height profile data for these birds, collected incidentally during a national landscape-scale movement study, were analysed in relation to a windfarm proposed in Northland (Kaiwaikawe Wind Farm). The proposed consent allowed blade heights that reached no lower than 30 m and no higher than 220 m above ground (Turner 2021). Although the flying height profiles available at that time were limited (only males) and small in sample size (three birds), results showed that these matuku-hūrepo were flying within the turbine blade height 59.0%, 17.3%, and 2.8% of the time (Fig. 20). Variability amongst individual birds appeared to be related to changes in topography, with the most at-risk bird (Bird 4084; 59.0% flight time within blade range) flying over mixed terrain, while the lower risk birds (Birds 4114 and 4339; 17.3% and 2.8% respectively) inhabited flat lowland areas next to large lakes.

For Figure 20, actual heights above sea level were measured automatically. These have been corrected for the difference between the height of the bird and the land below using the LINZ Digital Elevation Model processed in ArcMap. In Figure 20(A) for Matuku-hūrepo 4084, 3,826 flight heights were collected over a 1,147 days. This matuku-hūrepo tracked across mixed topography hill country in the Waikato and Bay of Plenty Region. In Figure 20(B), for Matuku-hūrepo 4114, 126 flight heights were collected over 4 months. This matuku-hūrepo only inhabited lowland areas (i.e., along the edge of Lake Taupō). In Figure 20(C) for Matuku-hūrepo 4339, 704 flight heights were collected over 1,154 days. This matuku-hūrepo only inhabited lowland areas (i.e., along the edge of Te Waihora/Lake Ellesmere).

Aside from the difficulties in measuring mortalities, the implications of windfarms, vehicles, and infrastructure can be difficult to predict and quantify in terms of populations and areas affected. This is because matuku-hūrepo are known to regularly move long distances and have large home ranges, meaning that new wind farms, roads, or structures can still pose a risk to matuku-hūrepo populations that are some distance from the proposed work. Similarly, because movements and sites of importance are known to vary across years (see Section 3.5), it is essential that impacts are not only monitored and measured but that this is done for multiple seasons/years.

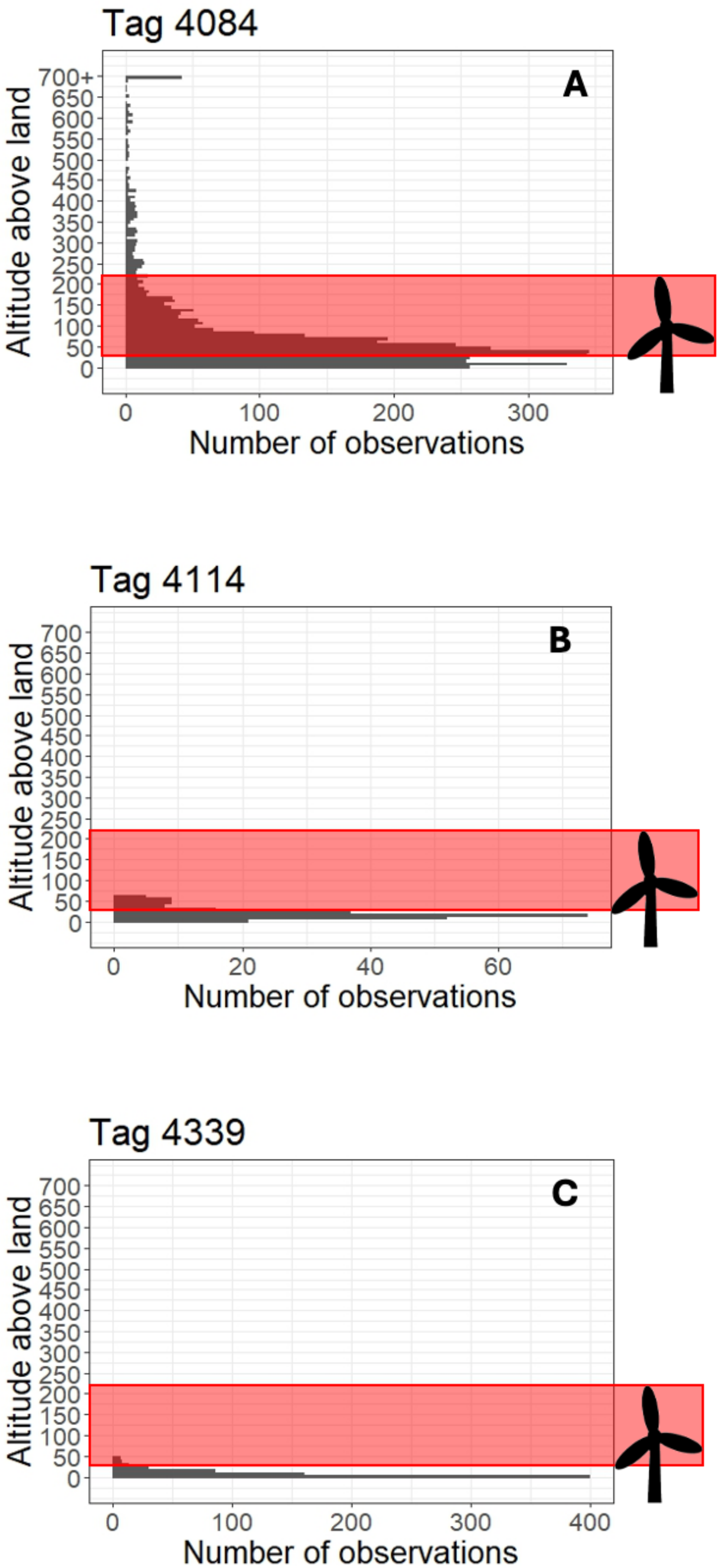

Figure 20. Frequency histograms for three matuku-hūrepo compared to the proposed blade heights of turbines for the Kaiwaikawe Wind Farm (the area shaded red). (A) Matuku-hūrepo 4084, (B) Matuku-hūrepo 4114, (C) Matuku-hūrepo 4339.

4.11 Sea level changes, climate change, and natural disasters

The effects of sea level rise have been flagged as a cause for concern with the Eurasian bittern. The main concern for this species is that episodic flooding will eventually become permanent, leading to a transition in bittern habitat from freshwater to saline in the United Kingdom, and that this will have a negative impact on bittern populations (Gilbert et al. 2010). Similar concerns apply to coastal sites in New Zealand (Tait 2019).

Projections of climate change suggest that New Zealand may be one of the countries more affected by sea level rise, with a rise of 0.5 to 1.0 m predicted (Church et al. 2013). There are several ways in which matuku-hūrepo populations reliant on coastal habitats may be affected by climate change–induced sea level rise and storm surges, detailed below.

1. **Loss of breeding habitat.** Raupō reed beds are known to be important breeding habitats for matuku-hūrepo (Section 3.1). However, increased salinity levels caused by sea level rises could affect raupō as they are known to vary in their tolerance to salt (McMillan 1959). This is most likely to affect raupō reedbeds in areas where salinity levels periodically become > 20 ppt or permanently become > 5 ppt. This is because mature raupō plants are known to be able to survive salinities > 10 ppt, but salinities of < 5 ppt are required for at least a week in order for their seeds to germinate, and a further 3 weeks for seedlings to outcompete other, more salt-tolerant species (Zedler et al. 1990).
2. **Unpredictable changes in water levels.** Changeable weather patterns could cause erratic flooding events that are more severe and longer in duration than those currently being experienced. The effect of erratic flooding on matuku-hūrepo is discussed further in Section 6.1.
3. **Increased probability of catastrophic events.** Along with sea level changes, scientists are predicting higher temperatures, more intense precipitation events, higher risks of drought, higher risks of uncontrolled fires, more intense and frequent cyclonic events and storms (Van Aalst 2006). Each of these factors could have a catastrophic effect on matuku-hūrepo populations either through direct mortalities or indirectly by altering prey guilds, prey availability or habitat.
4. **Loss of preferred food sources.** Shrinking inter-tidal zones (Tait and Pearce 2019) and changes in salinity will change the composition of freshwater fish available for matuku-hūrepo. Theoretically matuku-hūrepo will be able to adapt to a more saline diet, provided prey items are accessible.

5. Planning management

The specialist habitat requirements of matuku-hūrepo, and the extent of loss of their wetland habitats in New Zealand, mean that the need for restoring existing habitats, recreating habitats that have been lost, and creating new habitats is a priority if matuku-hūrepo populations are to recover.

5.1 Managing complex threats to restore matuku-hūrepo populations

To be able to successfully restore matuku-hūrepo populations to levels that are viable in the long term, the productivity and survival of matuku-hūrepo need to increase to an extent that means breeding adults are consistently producing enough young to replace themselves. This will require restoration of food supplies and breeding habitat, removal of ongoing threats that reduce survival, and restoration of the complex movement networks that are important for sustaining populations through the annual cycle. Current knowledge of threats (Section 4) indicates that pressures are numerous, and their relative importance is not well known in some cases. In addition, threats interact in complex ways (Fig. 21). Consequently, multiple management actions and plans will be required to restore matuku-hūrepo populations, and enacting only one or two actions at a time will be insufficient to increase numbers to sustainable levels in the longer term (e.g., predator control without weed control or without managing appropriate water level regimes; Fig. 21). Figure 21 outlines the full range of management plans and actions required for restoring matuku-hūrepo populations.

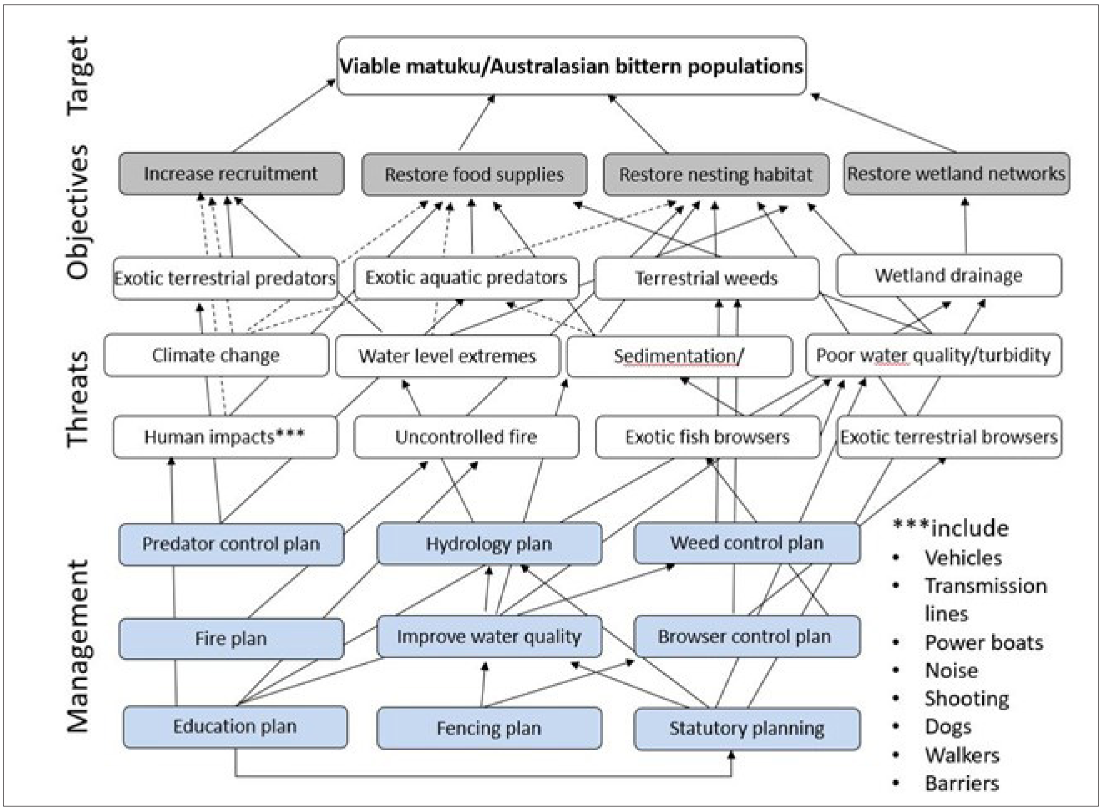

Figure 21. Diagram of the conservation targets and objectives, threats and management actions and their complex interactions required for recovery of matuku-hūrepo. Solid arrows indicate relationships that have been documented to some degree, dashed lines indicate relationships that are implied or poorly understood and require more research. *Source: Colin O'Donnell; Whangamarino Wetland matuku-hūrepo workshop, 2016; DOC File DOC-2896929*.

5.2 Adaptive management approaches

Ideally managers would reliably identify causes of decline, critical threats, and ecological requirements before starting to manage those causes of decline. However, this is not always possible. In the case of matuku-hūrepo, population estimates are particularly low (<1000 individuals) and recent range reductions are steep (>50%; O'Donnell and Robertson 2016). This suggests there may not be time to concentrate on research alone before extinction occurs.

Therefore, although several knowledge gaps exist, and many behaviours and ecological requirements are still not well understood, the few studies that have been undertaken suggest that matuku-hūrepo behaviours, ecological needs, and threats agree with those of similar *Botaurus* bittern species from overseas. This implies that managers should start restoring sites for matuku-hūrepo by addressing threats inferred from existing New Zealand studies of matuku-hūrepo populations (Section 4) and from overseas. Similarly, this implies that management of such threats can also start by adapting management practices from overseas (e.g., water level management) or practices commonly used in other ecosystem types in New Zealand (e.g., predator control). This approach is appropriate provided management efforts are planned and structured as a series of adaptive management experiments (i.e., manage now, but monitor and learn, then adapt as necessary as you go). This adaptive approach allows the most likely or urgent management requirements to be addressed immediately, while monitoring allows us to determine performance of management practices, further our knowledge of the species, and confirm that the correct threats have been identified and neutralised as planned (Lee 1999).

5.3 Developing effective collaborations

Given the complexity of habitats used by matuku-hūrepo and their spread across lands with multiple jurisdictions and tenures, successful management will only be achieved through productive partnerships with hapū, whānau, and iwi, and collaborations with multiple organisations including regional and district councils, landowners, other stakeholders, and the Department of Conservation. It is important that restoring matuku-hūrepo populations is done in conjunction with enhancing other ecological, cultural, and recreational values in a complementary way. Care must be taken to balance some broader objectives though (e.g., recreational objectives), because the sensitive nature of matuku-hūrepo suggests potential conflicts of interest may occur if conflicting activities are encouraged within matuku-hūrepo habitats.

5.4 Developing site-based matuku-hūrepo management plans

Site-specific plans will need to be developed for matuku-hūrepo restoration projects that reflect local conditions at the wetlands in question and resources available. Not all sites will have the same suite of threats and some may be important seasonal habitats for foraging but not necessarily breeding. All wetlands will have a range of physical profiles and seasonal hydrological regimes that will provide different options for restoration and potentially constrain the management options available. Section 6 below describes the range of potential management options that may be considered for inclusion in a site-based plan. Box 2 summarises the steps to developing a site-based matuku-hūrepo management plan.

Box 2. Steps to developing a matuku-hūrepo management plan (see Section 6 below for details)

- Identify suitable site for management in partnership with owners, iwi and stakeholders.
- Conduct a workshop to develop restoration targets and options for restoration and consult with appropriate technical experts. Discuss whether management for matuku-hūrepo is complementary to other restoration targets for the site.
- Ensure all critical threats are identified and management actions for each are formulated.
- Determine hydrological regimes that optimise the health of the wetland and matuku-hūrepo habitat requirements (e.g., continuity and seasonality of water supply, food supplies).
- Determine the mix of vegetation communities and other habitats that will maximise opportunities for breeding and feeding.
- Determine level of habitat manipulation that is appropriate and feasible (e.g., profiling shorelines, active earthmoving, flooding, use of weirs or bunds to hold water, vegetation thinning, burning, planting).
- Determine appropriate levels of weed, predator, fire, and human management, and develop effective management actions.
- Ensure responses to management and outcomes for matuku-hūrepo are monitored effectively (so that managers know they are achieving their restoration targets and can adapt management if necessary).
- Act as good role models, and advocate and educate for matuku-hūrepo conservation and habitat restoration generally based on experiences at the site.

6. Potential management actions to restore breeding and feeding habitats simultaneously

6.1 Maintaining and managing water level regimes

Both loss of water and excess flooding are fundamental threats to matuku-hūrepo habitats and wetlands generally. Loss of water results in feeding areas drying out and loss of critical food supplies. Excess flooding at the wrong time of year can result in nest sites being lost and food becoming inaccessible because matuku-hūrepo cannot reach their prey. While water levels vary naturally through the seasons in wetlands, for matuku-hūrepo there is a need to provide habitat for suitable and accessible food supplies, to ensure connectivity to provide a range of habitats through the annual cycle, adequate fish passage to provide healthy fish populations, and safe nesting sites. Weirs, bunds, and canals are frequently used overseas to manage water flow and adjust levels in wetlands to provide a range of conditions for wetland species (White et al. 2006). Studies in New Zealand to date indicate optimum water depth in feeding habitats is 15–25 cm (Williams and Cheyne 2016; Williams and Cheyne 2017; Williams 2018) and 20–75 cm for nesting habitats (O'Donnell 2014). Boxes 3 and 4 illustrate two examples of how wetland areas were re-watered using relatively simple bund walls to hold back water that would have drained away.

Box 3. Restoration of Wairio Wetlands, Wairarapa Moana by conservation group Ducks Unlimited

Wetland and the forest on the western shores of Wairarapa Moana were largely drained and cleared by the Lower Wairarapa Valley Development Scheme during the 1960/70s and by the construction of Parera Road, which separated the wetland from the adjacent Matthews & Boggy Pond Wildlife Reserve, cutting off critical water flows. Seed from willow trees planted in the upper reaches of tributaries of the Ruamahunga River for erosion control also invaded the remaining wetlands. The resultant willow infestation was subsequently felled and bulldozed into parallel windrows, running east-to-west across the wetland.

A key feature of the restored wetland was the use of low bund walls to prevent water from draining away across c. 100 ha of former wetland. This resulted in areas of water up to 1 m deep along the bund wall, although large areas are much shallower than that, and thus suitable for wading birds. In addition, construction of a new diversion channel around 300 m long was designed to take excess water from Matthew's Lagoon to the Wairio Wetlands to provide additional water during dry periods. While a range of restoration plantings have been undertaken, natural regeneration of rushes and sedges has occurred that provides cover for water birds. After 15 years of restoration, the wetland provides feeding and breeding habitats for thousands of water birds, and matuku-hūrepo are frequently present at the site (Cheyne 2021). This project demonstrates that re-watering drained wetlands is achievable with construction of relatively simple bunds.

Figure 22. Aerial image of Wairio Wetlands showing moderate water levels being retained behind the bund (bottom and left of the image). Matthews & Boggy Pond Wildlife Reserve is to the right of Parera Road (top right of the image). *Photo: Ducks Unlimited NZ.*

Figure 23. Aerial image of Wairio Wetlands showing high water levels being retained behind the bund wall. The area of open water (top right) is Wairarapa Moana. *Photo: Ducks Unlimited NZ.*

Figure 24. Close up of the bund designed to hold water within the wetland. *Photo: Colin O'Donnell.*

Further information: Wairio Drone Tour https://ducks.org.nz/wetlands/wairio-project#section6
https://www.ducks.org.nz/index.php/wairio-restoration

Box 4. Restoring wetland habitat for matuku-hūrepo, upper Ahuriri Estuary, Hawke's Bay Region

Since 2011, Hans Rook has led a restoration project focused on low-lying farmland in the upper Ahuriri Estuary (Te Whanganui-a-Orotū), near Napier. The primary aim is to restore wetland zones for matuku-hūrepo. In the 2000s, the river above the estuary was constrained by stop banks to a narrow channel and adjacent flood plains were solely pasture grasses (Rook 2018).

The primary tool for restoring water levels at the site was the construction of three 80 m long low bund walls in three stages, with the aim of retaining shallow water behind the bunds after floods. The first bund wall was constructed in 2011, and resulted in an inundated area of c. 6 ha (Fig. 25).

By the time the third bund was created, c. 22 ha of inundated habitat had been created, and when combined with other local restoration efforts, the wetlands now cover c. 70 ha.

Restoring water levels was then complemented by building 8.7 km of fences around the wetland to keep stock from grazing wetland plants, and trapping predators around the margins. As well as excluding stock, the fences allowed Rook to use pulse grazing[4] as a method to control weeds. Between 2015 and 2018 more than 700 predators were trapped, including 79 feral cats and 38 mustelids from about 5 km of trap lines either side of the wetland. In addition, there have been plantings to re-establish tall reed beds (giant umbrella sedge *Cyperus ustulatus*, raupō, and *Juncus* spp.) to provide cover for feeding and breeding.

Matuku-hūrepo have returned to the site and are seen regularly, with a recent estimate of 14 birds seen, including potential breeding pairs.

The project was made possible through the determination, energy, and technical expertise of Hans Rook, with support from local iwi, landowners, the regional council, Department of Conservation, and sponsorship from Matua Wines.

Reference: Rook, H. 2018. Helping bittern to help themselves.
https://www.wetlandtrust.org.nz/what-we-do/symposia/

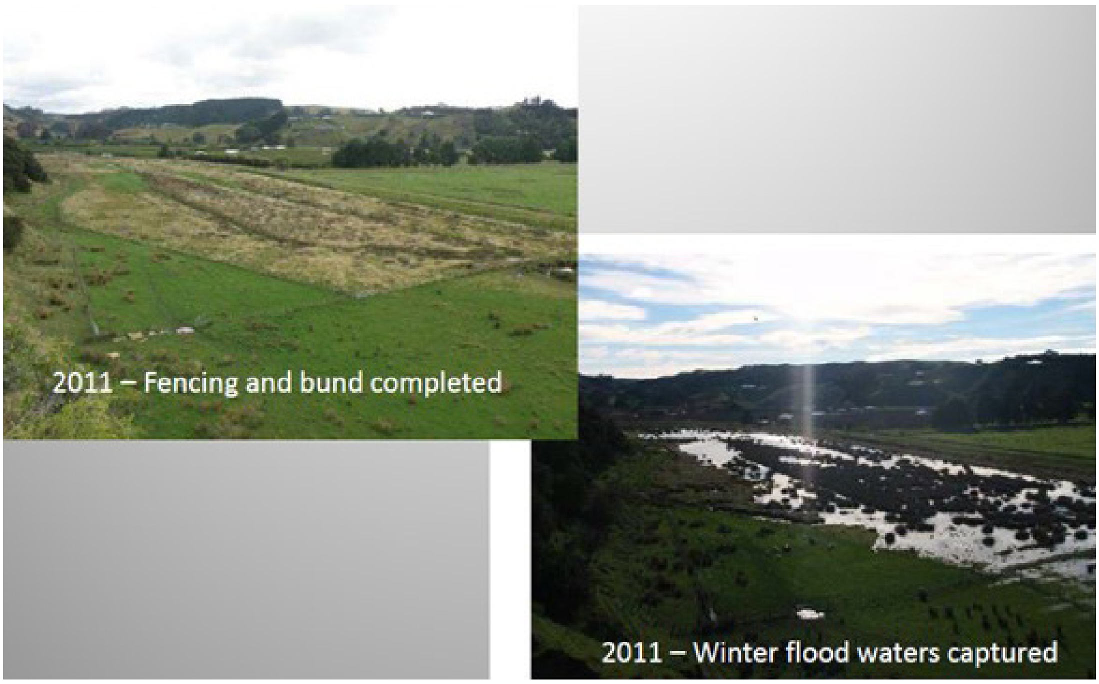

Figure 25. Phase 1 of the upper Ahuriri Estuary (Te Whanganui-a-Orotū) matuku-hūrepo habitat restoration showing the block before and after construction of the first bund to hold water within the wetland. *Photo: Hans Rook*.

4 Where pulse grazing is defined as short-term, controlled grazing that is only done at times to benefit the health of the wetland.

Figure 26. Phase 1a of the upper Ahuriri Estuary matuku-hūrepo habitat restoration showing the upper and lower bunds, fenced areas, and areas of free-standing water. *Photo: Hans Rook*.

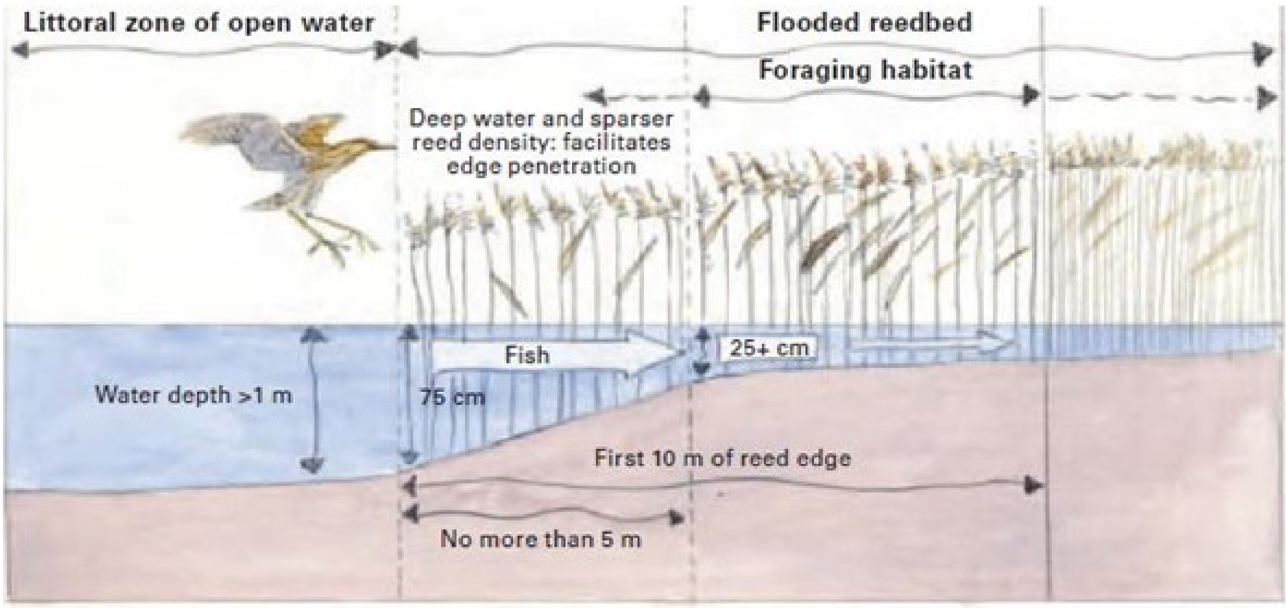

Figure 27. Ideal profile and configuration of wetland edge for matuku-hūrepo based on information on overseas bittern species. *Source: White et al. (2006)*.

6.2 Optimising the profile of a wetland for breeding and feeding

Both the water levels and edge habitat profiles are managed for bitterns at overseas sites. Such wetlands are designed to provide habitat mosaics with a mix of areas of open water, inundated shallow wet rush / reed beds and drier rush / reed beds, regardless of water level changes. It is important to encourage the retention of shallow water areas with tall vegetation over some parts of a wetland as the area of inundation contracts and expands naturally with seasons (Fig. 27; White et al. 2006). A gently sloping profile allows fish from open water habitats to penetrate the reed beds, making them accessible to matuku-hūrepo. This is ideal given that matuku-hūrepo prefer to feed under the cover of vegetation. For the Eurasian bittern, recovery was achieved by managing hydrological systems so that water levels remained suitable for feeding and breeding across the year, while also preserving and creating reed beds (Tyler 1994; Hawke and José 1996; Tyler et al. 1998; Gilbert et al. 2005b; Poulin et al. 2005; White et al. 2006). In Europe, optimising these habitats most often entailed artificial management of water levels where wetlands already had suitable profiles, or the use of earth-moving machinery to shape suitable shoreline habitats where the profiles were unsuitable.

6.3 Increasing the area and length of reed / open-water edge habitat

Aside from managing water levels, sites should probably be managed to provide ideal vegetation types (see Section 3.1) and spatial configuration for matuku-hūrepo to breed and feed by using techniques such as edge profiling. In New Zealand, such designs have been planned for situations such as enhancing old oxbow wetlands (e.g., Fig. 28; Burns 2015) and in the design of new wetlands (e.g., Fig. 29; H. Caley pers. comm., Science Advisor, DOC). Because matuku-hūrepo do not breed or feed in the open, having extensive areas of suitable reed beds will increase the amount of habitat available. Most overseas bittern studies emphasise the importance of maintaining a balance between reed and open water, particularly at breeding sites. For example, in Europe, reed beds are often cut or burnt outside the Eurasian bittern breeding season to thin the reeds and maintain a convoluted (or scalloped) edge. Such an edge is preferred because it provides a greater length of reed / open water edge, which is thought to be better for matuku-hūrepo feeding (White et al. 2006). In New Zealand, some duck hunters manage wetlands by scalloping edges in this way to encourage ducks to shelter close to their shooting platforms (Fig. 30; J. Cheyne, pers. comm., Wetland Works Ltd.). If such practices are shown to benefit matuku-hūrepo in New Zealand, then it may be desirable to encourage and advocate for these practices nationally.

6.4 Managing problem weeds

In general, it is preferable to encourage the re-establishment of native flora and fauna as part of matuku-hūrepo-focused restoration programmes. However, in severely altered wetland habitats that now exist, matuku-hūrepo do not distinguish between native and non-native species, but instead choose their environment based on vegetation structure, their hydrological needs, food availability, and a plant community's ability to satisfy these needs. As such, there will be several non-native weed species that, in the absence of a native alternative, are currently contributing to matuku-hūrepo survival and persistence. These plant species present a dilemma because their removal is required for natives to re-establish, yet rapid removal from a wetland ecosystem can threaten matuku-hūrepo populations. In these cases, a staged approach is recommended, so that plants are removed from small areas at a time and at a rate that allows native replacement species to establish. This approach means the needs of the resident matuku-hūrepo population continue to be met while non-native weeds are being removed.

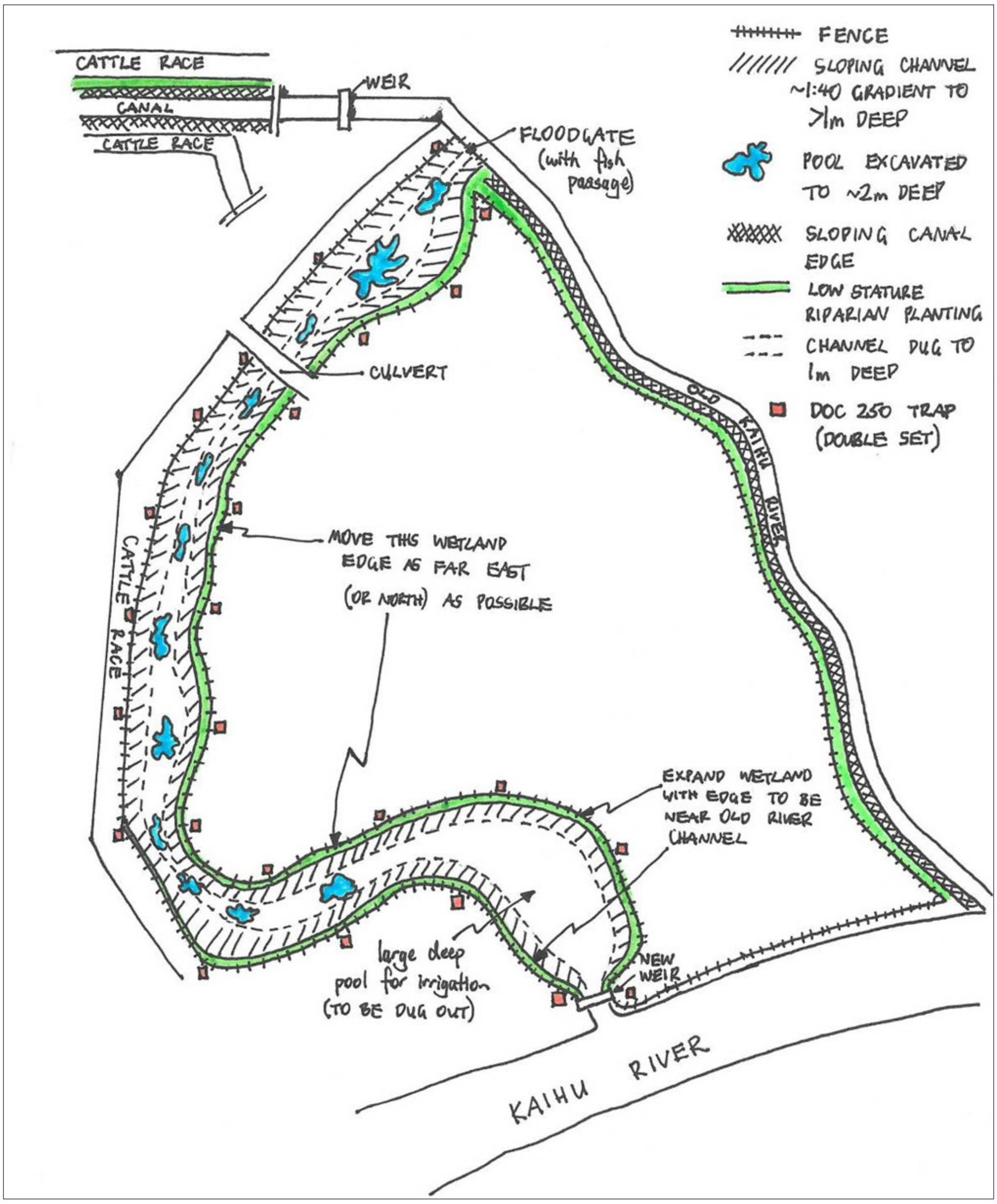

Figure 28. An example of a design to restore a degraded oxbow bend, with sloping of banks to improve access for matuku-hūrepo, and increased length of wetland vegetation. Kaihū River, Northland. *Source: Burns 2015.*

Weed species that form floating mats are particularly important in this regard, since feeding from them allows matuku-hūrepo access to fish in deeper waters that they cannot normally access. In degraded systems, floating mats of introduced weed species such as reed meadowgrass (*Glyceria maxima*) and Mercer grass (*Paspalum distichum*) provide foraging opportunities for matuku-hūrepo at certain times of the year, which could potentially buffer a matuku-hūrepo population from starvation. Floating mats are particularly important when (a) water levels remain particularly high over long periods; (b) wetlands dry out and the usual aquatic food sources of matuku-hūrepo become contained in deep inaccessible drains; and (c) disturbances force matuku-hūrepo to feed in areas dominated by deep drains. Under these circumstances, fish and small aquatic fauna species feed along the edges of floating mats or shelter beneath them. During this time, the mat itself provides a platform for the matuku-hūrepo to patiently stalk their prey.

The removal of reed meadowgrass and Mercer grass is commonly desired because these species also smother preferred riparian plant species, block waterways potentially causing flooding, and prevent the establishment of less aggressive native species through competition (Champion et al. 2013; Weedbusters 2018). For example, Mercer grass is recommended for removal as part of the Lake Ōnoke Freshwater Improvement Fund Project, in Wairarapa Moana (Graeme and Dahm 2018). Therefore, in the context of habitat restoration for matuku-hūrepo, careful planning is required to develop and restore similar indigenous habitats using a staged approach to weed removal running in parallel to restoration of adjacent sites (e.g., edge profiling and recovery of native reedbeds, as described in Section 6.3).

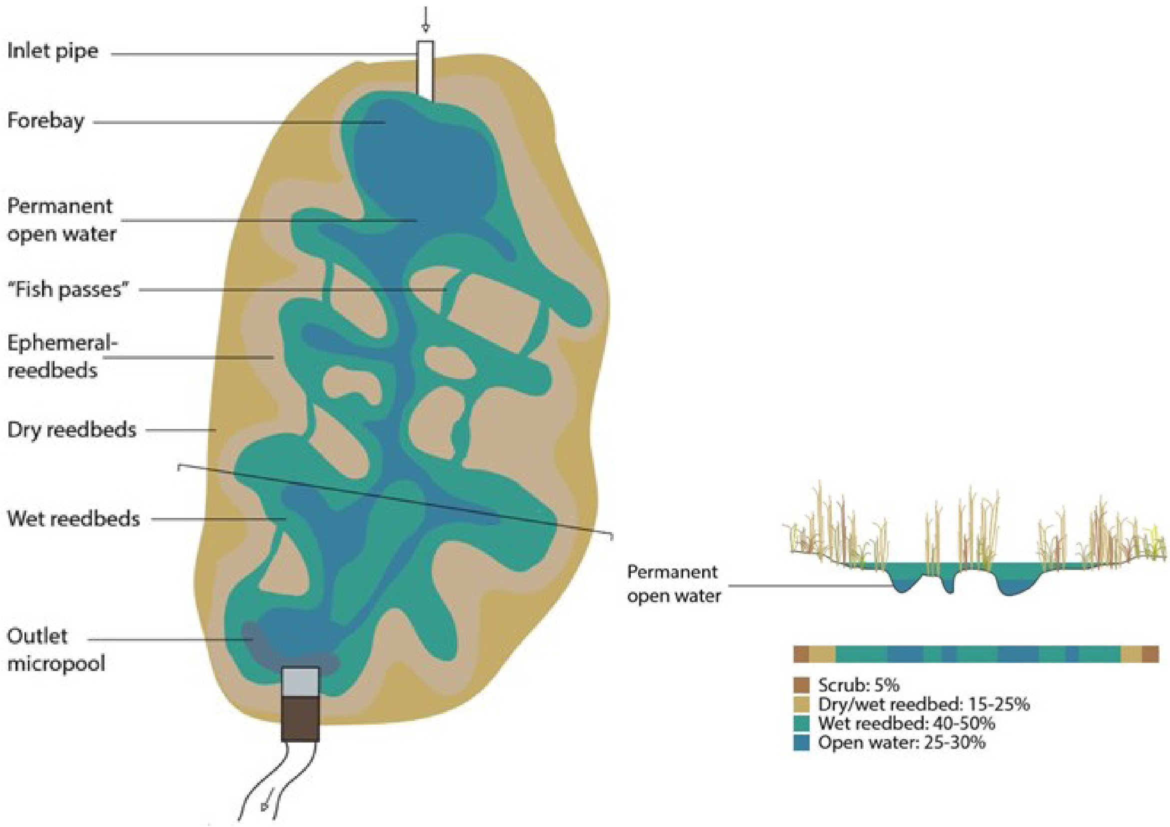

Figure 29. Potential configuration of a new wetland for matuku-hūrepo. Branching and channel connectivity is one way to increase food supplies that remain available over longer periods for matuku-hūrepo. Small water channels among the reedbeds encourage aquatic prey to penetrate into matuku-hūrepo habitats, while gradual gradients mean prey species remain accessible to matuku-hūrepo even while site water levels fluctuate. Habitat cross-section shown on right. *Source: produced by Henry Caley, Department of Conservation for Osborne Habitat Restoration and Enhancement Plan*.

Figure 30. A convoluted, scalloped edge of raupō reed beds, which potentially increases the length of edge habitats available to feeding matuku-hūrepo over straight-line edges. *Photo: John Cheyne*.

6.4.1 Managing woody weeds

Willows and other woody weeds fundamentally change the structure of wetlands over time. They are a threat matuku-hūrepo habitats because they can smother reed beds that would be used for breeding and feeding, raise the water table, and eventually change a wetland to damp woodlands. Hence eradication, or management to sustained low levels, of willow and other woody weeds in matuku-hūrepo habitats, is essential. For example, >30% of Harts Creek Wildlife Management Reserve, near Te Waihora / Lake Ellesmere has been rendered unsuitable for matuku-hūrepo for breeding and feeding because of this encroachment (Fig. 31). Where control of willows has already happened, it is important to maintain control and halt reinvasion. Thus, surveillance for willows and other problem weeds should also be maintained. For example, common pampas (*Cortaderia selloana*) and yellow flag iris (*Iris pseudacorus*) are becoming problem weeds at Whangamarino Wetland, and alligator weed (*Alternanthera philoxeroides*) is on a watch list for eradication.

Figure 31. Core areas of Harts Creek Wildlife Refuge, Te Waihora, Lake Ellesmere showing the approximate area where extensive areas of tall willow woodland with a canopy c. 20 m high in places has replaced reed beds completely in places. Willows continue to encroach on the remaining raupō reed beds along the lake edge. The area is now subject to a joint Environment Canterbury–Department of Conservation willow control programme. *Source: Google Maps*.

There are an increasing number of examples of comprehensive willow control programmes that have achieved transformation of wetlands through sustained efforts. For example, Pekapeka Wetland, in the central Hawke's Bay Region, has achieved eradication of willows (Figs. 32 and 33).

Another important consideration is that many weed management practices are intrusive and can also suppress other species important for matuku-hūrepo. For example, raupō is often suppressed during willow spraying, particularly if the herbicide is applied unselectively. Similarly, the process of spraying can disturb matuku-hūrepo nests if conducted during the breeding season. These factors must be taken into consideration when planning weed control programmes.

Figure 32. A complete willow (*Salix* spp.) canopy cover in the northern part of Pekapeka Wetland, Hawke's Bay Region, in the 1990s. *Photo: Hawke's Bay Regional Council*.

Figure 33. Pekapeka Wetland, Hawke's Bay Region, today, showing healthy raupō (*Typha orientalis*) reed beds and open water after complete removal of willows (*Salix* spp.). *Photo: Hawke's Bay Regional Council*.

6.4.2 Controlled and pulsed grazing as a potential tool

Grazing is sometimes used, combined with water level control, as a tool to manage invasive plants in wetlands overseas, which helps diversify and create wetland mosaic habitats (Wallis De Vries et al. 1998). New Zealand is currently going through a process of excluding stock from waterways, something that is wise given that almost all wetland grazing regimes were for the purposes of feeding and watering stock rather than having wetland health as the objective, and they largely destroy wetland vegetation by overgrazing. Despite the negative impacts of grazing and the consequent addition of nutrients to wetlands, there may be a case for careful, targeted, and controlled low-intensity grazing as a wetland conservation tool to manage willow reinvasion around wetland margins. If such a tool were to be proposed, the techniques should be viewed as experimental, with the outcomes carefully monitored. It is also important to ensure that stock do not gain access to more sensitive reed-bed areas or other habitats.

6.5 Predator control

Restoring wetlands to a healthy functioning state to sustain matuku-hūrepo (and other wetland bird species) requires control of invasive predators (O'Donnell et al. 2015). Control should focus at least on the predators primarily known to affect adult matuku-hūrepo and their nests: mustelids, feral cats, possums, and in some situations, kāhu/swamp harriers (Figure 14; author's unpublished data; Caley 2022).

Studies have yet to determine if effective predator management practised in forest and riverine habitats will be sufficient to recover matuku-hūrepo populations. For example, there is no established best practice regarding the intensity and duration of predator control required or how to effectively manage the range of different predator species present in wetlands. Knowledge of the variability in predator abundance in space and time in wetlands, and the scale of the control required to protect matuku-hūrepo at the population level is still required. While the scale of control is uncertain, given the extent of movements emerging for matuku-hūrepo (Section 3.5) and existing knowledge of large-scale movements in the predators themselves (Pierce 1987, unpublished; Murphy and Dowding 1995; Keedwell et al. 2002; Recio et al. 2010), predator control should focus on whole wetlands and whole regional wetland networks rather than just part of a wetland. The role of rats as predators of matuku-hūrepo eggs and nestlings is less certain and it is unlikely that hedgehogs are major predators because of their aversion to crossing waterways (Pascoe 1995).

Applying current best practice for predator control from other ecosystem types is likely to provide significant benefits to matuku-hūrepo and other wetland birds. Recommendations for predator control include the following.

a. Confirm the scale / size of the operation, considering the potential range and habitat use by matuku-hūrepo at the site and the potential for control within buffer areas surrounding the site. Best practice recommends a maximum spacing of 200 m between traps (e.g., Fig. 34).
b. Develop integrated trapping programmes that optimise captures of the full range of likely predators of a variety of sizes; in particular:
    - consideration of the mix of DOC 150, 200, and 250 traps to optimise capture of small weasels, female stoats, and up to large ferrets;
    - careful use of baits and lures, varying use of different 'best practice' baits from time to time (e.g., cracked hens' eggs, fresh meat, Erayz salted rabbit);

- inclusion of feral cat control including a mix of humane-approved trap designs. For example, Timms traps, which have limited effectiveness for (usually) small cats; Steve Allen traps set at the top of a leaning board; 'Twizel cat traps' set in a Philproof Fenn trap tunnel (see https://www.landcareresearch.co.nz/discover-our-research/biodiversity-biosecurity/animal-pest-management/welfare-performance-of-animal-traps/traps-tested/); use of new cat trap designs, Havahart cage traps; periodic night-shooting sessions; and leg-hold trapping sessions 1–2 times per year (Victor 1.5 soft jaw leg-hold trap), all of which can be effective for cat control (Cruz et al. 2013);
- continuous trapping throughout the year, if feasible, to counter constant reinvasion. If resources are limited, then focus on before and during the matuku-hūrepo breeding season. However, adult birds are vulnerable to predation throughout the year;
- daily checking of live traps when open, and as soon as possible after daylight. However, humane traps can be checked every 1–2 months, or more frequently if traps are being filled with dead predators.

c. Focus on trapping wetland margins initially, as accessing and finding suitable trap sites in the centre of wetlands can be problematic. However, trapping layouts should include predator control into surrounding buffer areas – to reduce the risk of predators arriving at, and reinvading, the wetlands. It is also worth investing in new methods and new technologies that could enable traps and predator control in the heart of wetlands.

d. Include some level of control of kāhu/swamp harriers. Harrier control can be undertaken if it follows the procedures under the Wildlife (Australian Harrier) Notice 2012 (https://www.legislation.govt.nz/regulation/public/2012/0194/latest/whole.html). Methods for control are currently under development (T. Emmitt, pers. comm.).

e. Monitor responses of predators to control using independent monitoring methods (e.g., footprint tracking tunnels; Gillies and Brady 2018) so that trapping can be adapted if predator numbers are not being reduced.

f. Monitor responses of matuku-hūrepo (survival and nesting success) if feasible (see Section 12).

g. Investigate costs and benefits of adding rat control for enhancing matuku-hūrepo populations to the programme. It is uncertain if rats prey on matuku-hūrepo eggs, although they are common predators of other wetland birds (O'Donnell et al. 2015) and regularly preyed on artificial eggs during recent studies (see Section 4.5);

h. Investigate whether indirect methods such as habitat modification, land-use management or manipulating prey abundance can reduce predation risk. For example, possibilities include:

   - sustaining rabbit and hare control to low levels by ground hunting and ground application of toxic baits to reduce food supplies for predators;
   - physically manipulating islands and channels in wetlands to maintain a protective moat around bird breeding sites (e.g., see Zoellick et al. 2004).

There are a range of predator control plans available for wetlands. For example, a staged predator control plan for Awarua-Waituna Wetlands (c. 20,000 ha) in the Southland Region, Phase 1 of which is illustrated in Figure 34 (Hill 2016; DOC File DOC-3231967). Similarly, Phase 1 of the trapping programme at Whangamarino Wetland covers c. 2500 ha of the northern wetland (Fig. 34; K. Morrison pers. comm., Ranger, DOC).

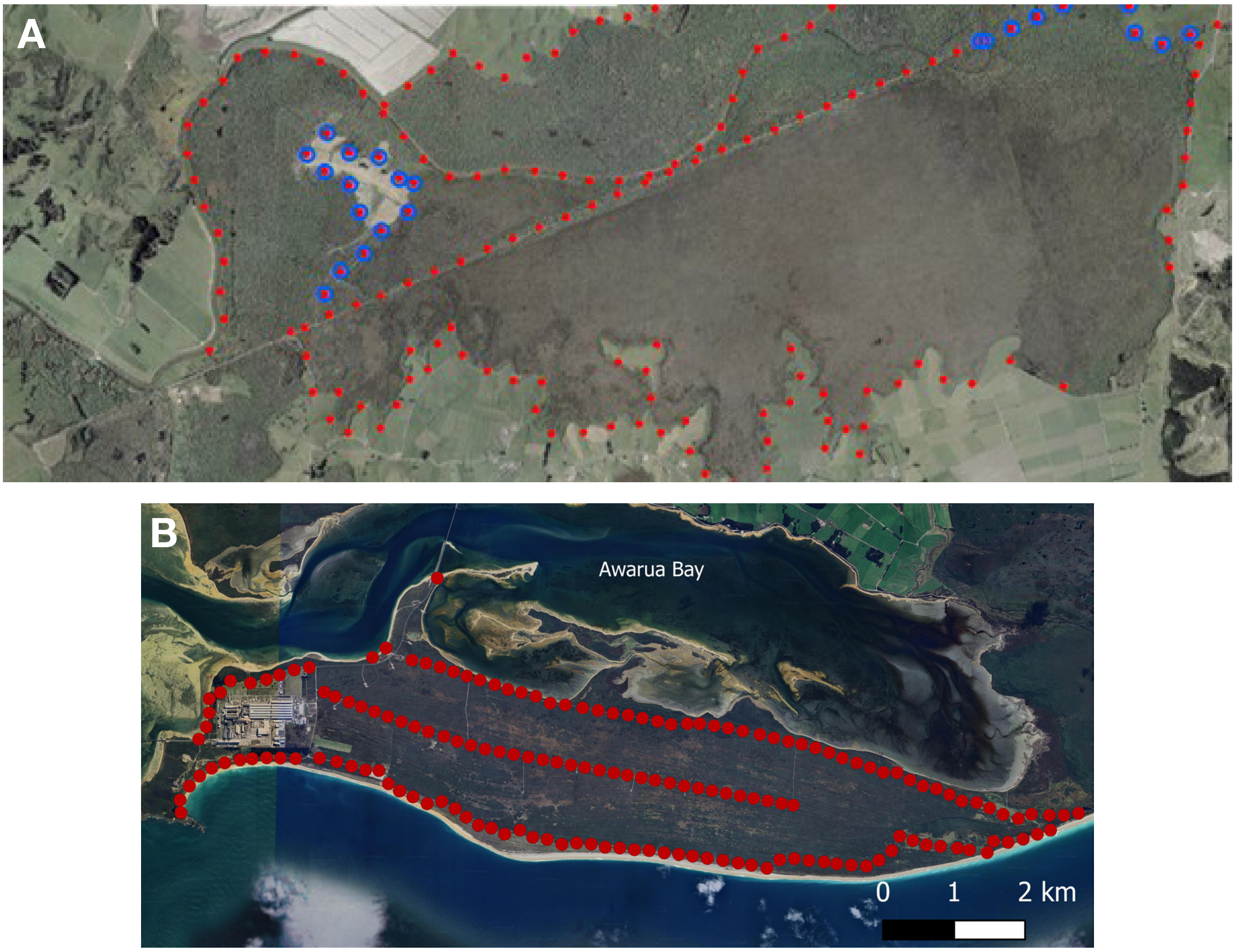

Figure 34. Examples of predator trap layouts around wetland edges, (A), northern Whangamarino Wetland, Waikato, enclosing c. 2500 ha of wetland, (B), Tiwai Point / Awarua Bay, Southland, using Department of Conservation best practice – with a range of traps at 200 m intervals along lines.

6.6 Managing recreational disturbance

Many wetland habitats are also valued recreational areas. Recreational disturbances that currently occur in and around wetlands include duck hunting (with or without dogs), recreational boating and jet-skiing, kayaking, waka ama, wind-surfing, kite-boarding, sailing, stand-up paddle boarding, biking (cycleways), walkers (with or without dogs), and other human-associated activities that either involve people in or around the wetland or a lot of noise. Matuku-hūrepo are known to be shy and secretive in their nature, suggesting the species is particularly vulnerable to disturbances. Despite this, there have been few studies on how current recreational activities affect matuku-hūrepo populations and even fewer examples demonstrating how to reduce and manage the impacts of disturbances effectively. This is particularly concerning since many recreational disturbances require infrastructure, introducing impacts and risks that are hard to alleviate or remove once introduced (e.g., cycleways and walkways can provide easier access for predators to sensitive habitats). As such, it is important to take a precautionary approach if new activities or disturbances are proposed in areas that are used by matuku-hūrepo.

Mitigating and managing the potential negative effects resulting from human–wildlife interactions will be a continual challenge for wildlife conservation and human recreation as populations of humans increase and encroach on wildlife habitat (Nix et al. 2018). Matuku-hūrepo generally live in habitats that are harder to access than many areas where disturbance is a direct problem (e.g., beaches). However, disturbance from boats, hunters, and walkers is an issue that requires careful consideration and management. Thus, consideration should be given to:

a. minimising access to sensitive nesting/booming habitats and re-routing humans to less-sensitive areas. Where possible, divert potential disturbances such as walkways or cycleways around the wetland/breeding habitats rather than through the wetland. If a cycleway is planned through a wetland, consider screening parts of the route so matuku-hūrepo have places to forage while remaining hidden from view e.g., screens used at Waimea Inlet (Nelson City Council et al. 2010; Fig. 35). If recreation close to breeding areas is allowed, traffic rates should be monitored, and if high, consider restricting traffic flow during the matuku-hūrepo breeding season;
b. conducting a radio-tracking study on several matuku-hūrepo within the area across a 12-month period (minimum) if a new disturbance is proposed, or there is likely to be a change in disturbance level at a site, prior to that disturbance being introduced. This will identify sites of importance and clarify how each area is being utilised by matuku-hūrepo. Results from current research on matuku-hūrepo highlight the importance of providing good feeding habitats all year round (to reduce the risks of starvation) as well as protection of breeding habitats. The impact of any proposed disturbance can only be realised (and therefore managed) if the seasonal movements and habitat use of matuku-hūrepo are well understood in the area.
c. excluding dogs from key matuku-hūrepo sites, enforcing a dog-on-a-lead policy, and developing matuku-hūrepo aversion training options (i.e., using kiwi aversion training techniques) as wise precautionary approaches. However, such restrictions are a socio-political issue, since they require enforcement from authorities and/or public understanding and buy-in. Furthermore, a dog exclusion or 'dogs on lead' policy is unlikely to provide complete protection because matuku-hūrepo seasonally rely on habitats where dogs need to roam free (i.e. duck-hunting dogs and farm dogs). As such, evidence from behavioural and survival studies is needed to confirm the extent and nature of the impact dogs currently have on matuku-hūrepo;
d. designating key matuku-hūrepo sites that are duck hunting–free reserves/areas, so that matuku-hūrepo have places to forage free of disturbance during the hunting season;
e. considering the use of fencing to channel people away from sensitive areas;
f. limiting access of motorised boats to matuku-hūrepo habitats;
g. reducing potential disturbance significantly by careful consideration of when and where to provide facilities (Bennett et al. 2011) even though public interactions with wetlands are desirable. For example, providing bird-watching facilities but being careful to ensure that the proximity and orientation will not affect matuku-hūrepo foraging or breeding;
h. relocating 4WD vehicles and motor bikes away from wetlands to less-sensitive areas, including identifying, and/or creating, alternative areas where these recreational activities can occur but will have minimal impact;
i. providing specific, clearly identified parking areas with signs to educate wetland users about flora and fauna, including matuku-hūrepo – in particular, helping users to recognise and move away from disturbed breeding or feeding birds.

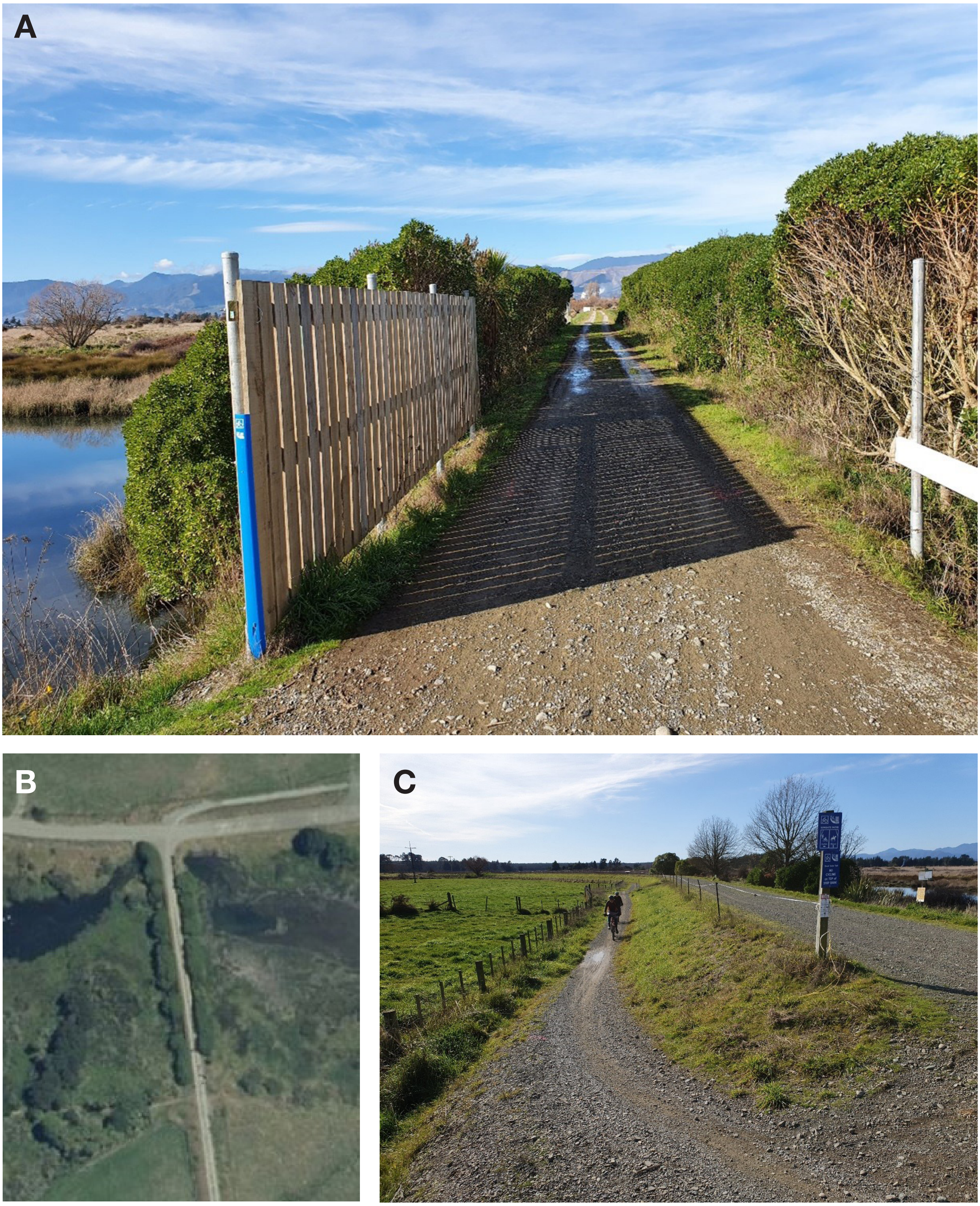

Figure 35. Examples of screening and diverting cycleways on Waimea Inlet, Nelson, in areas where matuku-hūrepo are likely to be sensitive to disturbance. (A), a combination of c. 2 m high screens and native plantings screen matuku-hūrepo feeding habitat where the cycleway crosses Pearl Creek; (B), aerial view of screening; (C), here cyclists have been diverted off the top of the stop bank (left of image) so they become invisible to any birds in the wetland (right of image) *Photos: Colin O'Donnell*.

7. Specific enhancements for breeding matuku-hūrepo

7.1 Maintain water level height and stability throughout the breeding season

Matuku-hūrepo require high and relatively stable water levels in reed beds to breed. There are two advantages to this: (1) access to food on or close to the nest, and (2) increased protection from predators. What is known about ideal water level requirement for matuku-hūrepo is already outlined in Section 4.3. There is some evidence to suggest water level stability is particularly important in early spring. Abundance of booming male Eurasian bittern is known to increase with the area of inundation in spring (White et al. 2006). One study in Selbjerg Vejle, Denmark, showed that when water levels remained stable, male bitterns remained present throughout the breeding season. However, if water levels fell quickly during this time, the abundance of male booming bitterns also decreased (i.e., a 77% reduction in numbers of booming males was observed after a 40 cm drop in water in 2000) (Nielsen 2006, in White et al. 2006, p. 81). Similar behaviours have been observed for matuku-hūrepo at Whangamarino Wetland, Waikato (Williams 2018) and at Te Waihora / Lake Ellesmere, Canterbury (author's unpublished data). In these situations, matuku-hūrepo left traditional breeding sites when water levels dropped suddenly. Radio tracking of several birds indicated they became nomadic for the remainder of the breeding season and were thus unlikely to have bred (author's unpublished data).

7.2 Time water level modifications so that breeding conditions are ideal for as long as possible

The optimum length of time to manage water levels for matuku-hūrepo is a pressing question that warrants further investigation. Overseas, a suite of structures, such as bunds, dams, and sluices, are used specifically to provide and prolong periods when water levels are ideal for breeding to improve breeding success (e.g., Tyler 1994; Hawke and Jose 1996; Tyler et al. 1998; Gilbert et al. 2005b; Poulin et al. 2005; White et al. 2006). There is some evidence that bitterns overseas can double clutch (i.e. have two nests per season), suggesting a management regime that can raise water levels in late winter and hold them for longer periods could significantly improve overall productivity and assist the species recovery (Mallord et al. 2000). Investigating these water level relationships remains an adaptive management need in New Zealand.

8. Specific enhancements for feeding

Given the threat of starvation (Section 4.2), there is a need to focus management efforts on enhancing matuku-hūrepo food supplies and working towards the creation of healthy functioning natural freshwater habitats. For matuku-hūrepo to thrive, a healthy fish population structure is needed, so that medium-sized fish are available, and productivity and recruitment are healthy.

8.1 Maintaining and encouraging the food sources of aquatic prey

Many food sources of matuku-hūrepo, such as eels and whitebait (*Galaxias* spp.), are in decline (Goodman et al. 2014). Addressing the threats of these species will also help matuku-hūrepo. Common management interventions that address threats to freshwater fish and their habitats in New Zealand, and that would also benefit matuku-hūrepo, include:

a. installing fish passes and connecting waterways. This is particularly an issue for wetlands that have been enclosed as part of water level management regimes (i.e. bunded or stop-banked wetlands). In these circumstances it is important to ensure that adequate provisions have been made to allow fish passage and migration;
b. enhancing stream and drain vegetation to encourage fish spawning, improve fish survival, and reduce nutrient run-off from farmland and upland sewerage systems;
c. ensuring healthy freshwater invertebrate populations by reducing sedimentation and improving water quality and water clarity;
d. removing pest fish to improve freshwater ecosystem health. Perch are known to increase sedimentation rates, which in turn can lead to toxic algal blooms (Smith and Lester 2006).

8.2 Managing pest fish species

It is important to note that many fish considered to be pest species in New Zealand are important food sources for bittern species overseas. For example, perch, common rudd (*Scardinius erythrophthalmus*), carp (*Cyprinidae* spp.), and tench (*Tinca tinca*) (Cramp and Simmons 1980; Gilbert et al. 2003; Polak and Kasprzykowski 2010), with one study reporting that perch represented 96% of food items taken by Eurasian bitterns (White et al. 2006). Therefore, depending upon the availability of other food supplies, caution should be taken when removing these pest fish species en masse, especially in circumstances where native fish populations have declined significantly. Instead, managers should consider removing one pest species at a time when other matuku-hūrepo prey species are abundant; enhancing fish habitats so that native fish have a competitive advantage over non-natives; or reintroducing captively reared native fish immediately after non-natives have been removed.

8.3 Optimise the profile of the wetland to provide feeding and breeding requirements of aquatic prey (and of matuku-hūrepo)

In Europe, wetlands and reed beds are not just managed for the needs of bitterns but also to manage the specific needs of their preferred food sources (Fig. 27). For example, common rudd, a favoured prey item of Eurasian bittern, commonly feed along the littoral edges of ponds, which is a key foraging area for matuku-hūrepo. Wetlands are often managed to increase these littoral pond edges so that bitterns have frequent opportunities to encounter their prey (White et al. 2006). However, electro-fishing studies have also shown that rudd require areas of deeper water within the reeds, and in open water areas, particularly when breeding (White et al. 2006). Indeed, Noble et al. (2003, 2004) were able to show that water depths of > 60 cm are required elsewhere in ponds for prey availability in the littoral zones to be high. Little is known about which prey species matuku-hūrepo prefer in New Zealand, let alone the biological and life cycle requirements of these preferred prey items. Investigating predator-prey relationships, and life-history requirements of these species remains an adaptive management need in New Zealand.

8.4 Encouraging prey accessibility within reed beds

Overseas, the accumulation of detritus that occurs at the base of the reeds as it dies-back is also managed (i.e., removed). If left, fallen debris raises the reed bed and prevents fish from infiltrating the reed beds to feed (White et al. 2006). Similar die-back and detritus accumulation occurs in some matuku-hūrepo habitats, such as in raupō beds (Fig. 36) and therefore management of this warrants further investigation. In Australia, this dead vegetative matter is often removed using careful, localised controlled burns in the winter months when few matuku-hūrepo (known there as the bunyip bird) are present (B. Green pers. comm., Australian naturalist). This removes dead vegetative matter that clutters the base of the reeds without damaging the vegetative shoots, thus allowing aquatic prey greater access to the reed beds (see Section 6.2). Although fires in wetlands are more often considered a threat than a management tool, in New Zealand (see Section 4.7), carefully controlled burns could theoretically be used to create more effective scalloping and edge habitats (see Section 6.3).

Figure 36. Trail-cam image of a matuku-hūrepo in a raupō bed. Just as in European reed beds, the die back of *Typha* raises the vegetative bed and prevents fish from infiltrating and feeding around the base of the vegetation.

9. Restoring habitat networks outside core breeding areas (wintering sites)

Recent cases of starvation nationally and studies of movements suggest having good matuku-hūrepo habitat networks outside core breeding areas is important. National radio-tracking studies have shown that matuku-hūrepo utilise a complex mosaic of sites outside the breeding season (January to July; Section 3.5). Similar behaviours are observed with wintering Eurasian bitterns (Puglisi et al. 2003). Overseas bitterns are reported to use a much wider range of habitats in winter (e.g., "rank waterside vegetation at gravel pits, fish farms, riversides, sewerage ponds, ditches, reservoirs and other small wetlands" outside the breeding season; White et al. 2006), as they are likely to do in New Zealand (O'Donnell and Robertson 2016). Thus, it is important that sites like these are identified, managed, and protected, which is of equal priority to managing breeding sites.

10. Advocacy for matuku-hūrepo

Protecting and sustaining matuku-hūrepo habitats will also need education and advocacy with iwi, statutory bodies, landowners, and the community to reduce risks of human impacts. Advocacy actions include:

a. working with regional and district planning authorities to ensure local plans contain adequate biodiversity protection rules to protect matuku-hūrepo habitats effectively;
b. ensuring fish passage and wetland connectivity, including using statutory advocacy and working with other management agencies and neighbours;
c. protecting small pockets of wetlands in the surrounding catchment to encourage habitat linkages in regional wetland networks;
d. developing drain maintenance and restoration guidelines to maintain values and enhance feeding habitats in areas surrounding wetlands;
e. undertaking advocacy with adjoining landowners regarding sediment and nutrient management;
f. making appropriate RMA submissions regarding adjacent, upstream or downstream developments that affect water and habitat quality;
g. working with partners / neighbours / volunteers regarding riparian plantings and pest control and encourage development of local wetland care groups;
h. developing long-term land purchase strategies to grow the size of management areas and buffer them from external effects.

11. Future considerations: anticipating sea level changes, climate change, and natural disasters

Climate change, and its predicted significant impact on ecosystems in the future, is now recognised internationally and in New Zealand and, almost entirely, accepted globally (Christie et al. 2020). However, the precise consequences for wetlands are less clear, as predictions rely on complex climate models and algorithms, with high uncertainties (Tait 2019; Tait and Pearce 2019). For example, in a recent desktop exercise, Tait and Pearce (2019) showed that the potential consequences of climate change on coastal Waituna Lagoon, a significant matuku-hūrepo habitat in Southland, were complex and uncertain. The authors predicted that increases in rainfall, freshwater inflows, flood events, and inundation of surrounding land over the next several decades are likely to contribute to lower lagoon-bed light levels and higher levels of nutrients and sediment entering the lagoon. Such changes may increase algae growth and inhibit the growth of *Ruppia* spp., and other desirable native aquatic grasses. Nutrient and sediment inputs are known drivers of lagoon regime shifts (from a desirable macrophyte-dominated state, with freshwater plants, to an undesirable algae-dominated state) and are closely linked to declines in water quality (Tait and Pearce 2019). With ongoing sea level rise, the boundary of the lagoon is likely to shift landward and the intertidal zone is likely to shrink, both of which are most likely to affect wading birds that forage in the intertidal zone. The effects on the reed beds surrounding the lagoon, inhabited by matuku-hūrepo, are uncertain. Due to the complexity of the lagoon system, uncertainties about the trajectories of change in climate and sea level, and the responses of the lagoon ecosystem, further research and ongoing monitoring is recommended as well as an adaptative management approach (Tait and Pearce 2019).

What is clear is that most credible models predict that New Zealand is at high risk of sea level change and extreme weather events (Church et al. 2013). As such, the following should be considered when planning site restorations for matuku-hūrepo populations.

- Identification of suitable wetlands > 1m above sea level for restoration / management.
- Avoiding long-term efforts on the restoration of sites < 1 m above sea level unless direct impacts of sea level rise can be mitigated. In saying this, nationally the rate of decline in matuku-hūrepo populations has been shown to be slower in coastal wetlands than in inland lakes and wetlands, suggesting many sites < 1 m above sea level may now contain stronghold populations of matuku-hūrepo (O'Donnell and Robertson 2016). As such, these sites may need protection in the short term to prevent further declines; however, long-term provisions should also be made to restore habitat elsewhere.
- Protecting, planting, and encouraging the growth of raupō in areas unlikely to be affected by sea level rise.
- Developing a long-term land management and purchase strategy to grow the size of reserves that are > 1 m above sea level. This process could be started by identifying areas where maximum matuku-hūrepo population gains can be made with minimum resources at existing sites.
- Where possible, developing multiple sites (habitat networks) for matuku-hūrepo across different catchments and hydrological systems.

12. Monitoring population response to management actions

There are many approaches to monitoring wildlife populations, and the choice of which method to use must be matched carefully with project aims and objectives. Typically, there are three reasons to monitor wildlife populations (Greene 2012):

1. To understand what we have got in our area of interest.
2. To discover whether there has been any change in population size and, if so, what processes were driving that change.
3. Determine the effectiveness of management actions and whether any changes to those actions affected population size.

In the context of a cryptic species such as matuku-hūrepo, very little is known about the processes driving population changes and, as the species is already classed as Nationally Critical, there is a need to start to manage populations while causes of decline are being identified. As such, Reason 2 (drivers of population changes) and Reason 3 (effectiveness of management practices) are best addressed together as a series of management experiments.

12.1 Monitoring tools currently available

Current monitoring practices available for use on matuku-hūrepo, are based on call-count methods and involve counting the number of booming calls (or 'boom trains') produced by male matuku-hūrepo during the breeding season (O'Donnell and Williams 2015). For the purposes of these monitoring tools, one boom train is defined as a sequence of individual booms uttered by a single bird (Gilbert et al. 1994).

Current call-count methods for matuku-hūrepo fall into four categories: (1) presence / absence (inventory tool); (2) close approaches to estimate and accurately locate the number of males present (index and inventory tool); (3) acoustic triangulation to estimate locations of the number of males present (index and inventory tool); (4) use of acoustic recording devices (ARDs) to estimate numbers of calls / calling males present (index and inventory tool). The choice of which method to use depends on the monitoring objectives, costs, and site characteristics (O'Donnell and Williams 2015; Williams, O'Donnell, and Armstrong 2018). Counts of booms should be standardised across years and run during optimum times and conditions (i.e., conducted at times outlined by Williams, Armstrong, and O'Donnell (2018)).

Annual standardised monitoring will provide data on long-term trends in male matuku-hūrepo abundance across time. However, call counts have several limitations that need to be recognised when interpreting trend counts. Call count monitoring methods only provide information about male matuku-hūrepo during the breeding season. This is currently the most pressing limitation of current national standard practices and is a focus of the Department of Conservation's national matuku-hūrepo research programme (National Bittern / Matuku-hūrepo Technical Advisory Group 2017, unpublished).

Unfortunately, females and chicks are cryptic, difficult to find, and rarely make loud or predictable calls that can be used for monitoring. Methods to detect females and chicks trialled to date, or currently being trialled, include the following.

- Detecting nests by looking for female foraging flights (directional flights conducted by female matuku-hūrepo as they come and go from their nests to forage). This method has been used successfully overseas (Gilbert 2006) but does not work under all circumstances. Success appears to depend upon the availability and locality of key food sources with respect to the nest; if there is abundant food close to the nest, females may not display foraging flights (Puglisi et al. 2003; Adamo et al. 2004).

- Detecting birds by scent using dogs. To date, one dog has been trained to detect matuku-hūrepo (a female Labrador called Kimi). More practice is required, but she has so far shown great promise, helping to recapture 12 radio-tagged matuku-hūrepo at Lake Whatumā (Williams 2016) and to date has helped find at least one matuku-hūrepo nest.
- Detecting birds by thermal imagery. Two attempts have been made to trial handheld thermal imaging cameras (one at Lake Whatumā, Hawke's Bay, and the other at Little Waihi, Bay of Plenty Region) and both trials suggested matuku-hūrepo were difficult to detect because of vegetation but could be seen in the open or in flight. This highlighted a research need to trial thermal imaging from the air (Williams 2016). A trial looking for the heat signatures of matuku-hūrepo in Bay of Plenty Region in November/December 2021 using a twin thermal and standard camera array mounted on a drone found both foraging and breeding matuku-hūrepo (Figs. 37 and 38; Flightworks 2021). Although the technique was expensive and labour intensive, it was more successful than manual searches and more trials are needed to explore costs, benefits, and effectiveness of this technique (Caley 2022).

Figure 37. Images of a foraging matuku-hūrepo using thermal (left) and visible (right) drone-mounted cameras taken from c. 20 m altitude above the bird as it continued hunting. *Source: Flightworks 2021*.

Figure 38. Zoomed-in image of an incubating matuku-hūrepo taken from a drone-mounted camera. *Source: Flightworks 2021*.

12.2 Monitoring management success using a surrogate species

Monitoring of cryptic matuku-hūrepo is always likely to be a challenge because of difficulties in detecting birds and, in some cases, it may be necessary to use a surrogate / indicator species instead. For effective methods using surrogate / indicator species it is important that they are strongly 'objective specific'. That is, they must link to specific management objectives and interventions being measured but do not need to be limited to direct measures. For example, DOC is currently monitoring responses of spotless crake (*Porzana tabuensis plumbea*, hereafter pūweto) and fernbirds (*Poodytes punctatus,* hereafter mātātā), to predator control at Whangamarino Wetland, Waikato (K. Morrison pers. comm., Ranger, DOC). Predator control has been set up with the primary purpose of protecting matuku-hūrepo, but these 'indicator species' were chosen because we do not have techniques to monitor female matuku-hūrepo and their chicks. Mātātā and pūweto share several threats with matuku-hūrepo but are predicted to respond much faster to management interventions than matuku-hūrepo because of their higher potential productivity (particularly in relation to predator control; O'Donnell et al. 2015). Recent research on home range sizes of pūweto also suggests they have considerably smaller territories than matuku-hūrepo, and therefore may be more informative where management is being applied on a localised, site-specific scale (Williams 2017a; Williams 2017b).

13. Knowledge gaps and research needs

Despite a range of good management practices potentially available for conservation of matuku-hūrepo and their habitats, especially from overseas, there is still a need to verify many aspects of the ecology of matuku-hūrepo and the threats they face. In addition, considerable research is needed to understand whether potential management practices would be effective at restoring populations and securing the species from extinction. Much of this research will involve capturing and remote-tracking matuku-hūrepo at a range of representative wetlands nationally to identify sites of importance, confirm seasonal movements and requirements, and measure long-term survival rates.

Knowledge gaps are highlighted throughout this publication; however, the information required to optimise habitats and maximise restoration potential are summarised below.

13.1 Habitat requirements

It appears that matuku-hūrepo are versatile in the range of fresh and brackish water habitats they feed and breed in, but populations are threatened by habitat loss and starvation. It is unclear what the optimum habitat configurations are in terms of:

- vegetation composition
- water levels
- ratio of reedbed edge / open water
- food composition and availability
- how these requirements vary in time and space
- drivers of regional movements and requirements of regional wetland networks to sustain matuku-hūrepo populations.

Such information will be particularly important to improve the survival of females and their young.

13.2 Relative impacts of different threats

Matuku-hūrepo are threatened by a complex array of factors including habitat loss and degradation from a wide variety of anthropogenic pressures, loss of food supplies, poor water quality, unsuitable and often erratic water level regimes, all contributing to starvation and low survival, unsustainable predation by birds of prey and exotic mammals, weeds transforming and reducing habitat through encroachment, fire, collisions with vehicles and other infrastructure, and human-induced disturbance. While habitat loss and predation are major threats, it is uncertain if the full suite of threats mentioned require intensive management.

13.3 Habitat restoration and creation

Given the lack of knowledge of the potential effectiveness of some management techniques used to enhance bittern habitats overseas, there is a need to undertake adaptive management experiments in New Zealand wetlands in all aspects of restoration, and to monitor population responses. Priorities include:

a. evaluating effectiveness of bittern management methods from overseas at protecting and restoring matuku-hūrepo populations in New Zealand (e.g reedbed and water level management, management of fish stocks);
b. optimising predator control regimes for protection of males and females;
c. answering questions such as:
    - which predator–prey interactions are important for managers to be aware of?
    - when and how do they vary in time and space?
    - how does predator risk vary in relation to water levels?
d. removing reedbed detritus to improve fish infiltration and matuku-hūrepo feeding (particularly while nesting).

13.4 Monitoring methods

No methods exist for monitoring females, nests, or the survival of young, nor the fate of males outside the short booming season. In addition, preliminary work indicates birds are highly mobile and probably use regional wetland networks (Section 3.5). Developing the best methods to track their movements and survival is vital, and the use of thermal imaging to count and monitor matuku-hūrepo is also warranted.

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Appendix 1

Summary of recommended management actions for matuku-hūrepo

Recovery will require an integrated approach to managing multiple threats and the involvement of the full range of stakeholders interested in wetland restoration. Recommended management actions include:

a. Maintain a mosaic[1] of habitats with shallow water and tall, dense, reed-like vegetation, by:
   - ensuring multiple areas with water levels 20–75 cm remain available for nesting
   - ensuring multiple areas with water depths of 15–25 cm remain available for feeding
   - actively profiling wetland edges to achieve penetration of fish foods into shallow reedbeds.

b. Enhance feeding and breeding habitats, by:
   - managing spring water levels to provide shallow water in breeding habitats, then holding those levels stable across the breeding season[2]
   - removing transformative weeds that encroach on matuku-hūrepo habitat
   - improving appropriate reedbed cover in suitable areas by encouraging regeneration or replanting
   - actively managing reedbeds, to improve the shape and density, to optimise area available to matuku-hūrepo.

c. Control predators, particularly mustelids and feral cats (*Felis catus*), and potentially kāhu/swamp harriers (*Circus approximans*) in all feeding and breeding habitats[3].

d. Encourage research on the ecology and adaptive management of matuku-hūrepo to improve conservation activities over time, particularly studies into enhancing aquatic food supplies and optimal water level regimes. Steps for this include:
   - determining ways to enhance food supplies, particularly freshwater fish populations during the autumn/winter when the risk of birds starving is particularly high
   - trialling different water level management practices to: (1) confirm optimum water levels, (2) confirm optimum timing of water level interventions, and (3) establish whether prolonged periods of high-water levels in spring can increase the chances of double clutching of nests.

e. Minimise disturbance of feeding and breeding sites, by:
   - moving high-noise sports away from priority matuku-hūrepo management areas (e.g., trail bikes, 4-wheel drive vehicles, motorised boats), particularly during the breeding season
   - establishing shooting-free areas in priority matuku-hūrepo habitats
   - carefully locating and managing passive activities (i.e., hiking, dog walking, and cycling) to avoid matuku-hūrepo breeding areas.

f. Protect and sustain habitats by undertaking education and advocacy to reduce risks of human impact. This could be achieved by:
   - ensuring fish passage and wetland connectivity, including using statutory advocacy and working with iwi, other management agencies and neighbours, to reconnect and enhance habitats

- protecting both large and small wetland mosaics[1] in whole catchments to encourage habitat linkages among local, regional, and national wetland networks
- developing drain maintenance guidelines to maintain values in surrounding habitat matrix
- undertaking advocacy with adjoining landowners regarding sediment and nutrient management
- working with regional and district planning authorities to ensure appropriate biodiversity protection rules in local plans
- making appropriate Resource Management Act (RMA) submissions regarding developments that impact on water and habitat quality or that would potentially kill or displace matuku-hūrepo
- working with hapū, whānau, iwi, and other partners, neighbours, or volunteers to enhance wetlands (e.g., riparian plantings and pest control and encourage the development of one or more local wetland care groups). Matuku-hūrepo regularly utilise multiple sites managed by different jurisdictions. As such, conservation of the species can only be achieved using a holistic approach.

g. Future-proof management efforts and buffer from external effects (e.g., climate change) by:
    - developing long-term land-purchase strategies to grow the size of management areas
    - creating management networks with a mix of different wetland types (i.e., coastal wetlands, inland palustrine wetlands, isolated ponds, and vegetated streams/drains). This will ensure that birds always have somewhere to go when conditions change, and adverse weather patterns occur. A management network that has sites in multiple catchments and represents a mix of coastal wetlands, inland palustrine wetlands, isolated ponds, and vegetated drains is more likely to be adaptable to climate change than a network of just one wetland habitat type
    - monitoring water quality (nutrients, water clarity, algal blooms) and location of saltwater wedge during king tides (as sea levels rise) to provide early indications of the extent of sea-level changes and any effects associated with these changes. This information can then be used by hydrologists to model a range of scenarios that can be ranked probabilistically.

h. Monitor long-term matuku-hūrepo population responses to the full range of management activities so that management can be adapted and improved with increased knowledge (e.g., by undertaking annual call count surveys to detect booming male matuku-hūrepo).

Notes:

[1] This should be done taking a landscape scale approach, i.e. managing a network of sites to ensure matuku-hūrepo can move between sites as their requirements change across their life cycle.

[2] Options for this include use of bunds, sluices, and weirs on a site-by-site basis so that water levels can be managed specifically for matuku-hūrepo.

[3] This should include trapping in buffer areas in surrounding farmland to reduce the frequency of reinvasion. The size of buffer area required needs to be determined through a series of well-planned adaptive management experiments.

Appendix 2

Additional protections for matuku-hūrepo (as at July 2023)

Two National Policy Statements recently signed-off by the governor-general are significant with regard to protected matuku-hūrepo and their habitat. These are the National Policy Statement for Indigenous Biodiversity 2023 (NPS-IB) and the National Policy Statement for Freshwater Management 2020 – amended 2023 (NPS-FM). Please note that both these documents were active at the time of writing, but are expected to be incorporated into (and therefore surpassed by) the Natural and Built Environment Act, which is the Act expected to replace the Resource Management Act in due course (as such, please be aware that the documents and links below are likely to change when this new legislation comes to pass).

Relevant wording and a summary of the significance of current National Policy Statements are as follows:

National Policy Statement for Indigenous Biodiversity 2023 (NPS-IB)

In this document, matuku-hūrepo are listed as 'highly mobile fauna' in Appendix 2 (p. 38). As such, the following applies:

- Regional Councils must record areas outside Significant Natural Areas (SNAs) which are highly mobile fauna areas, and develop objectives, policies, or methods for managing adverse impacts on them. They also need to communicate this information to their local communities (Section 3.20(1)–(4) on pages 25–26 of the NPS-IB).
- The criteria and attributes which trigger a SNA are listed in Appendix 1 (p. 31–34). It includes habitat for threatened species except where these are built structures or an area or environment where an organism is present only fleetingly. For the most part there is a strong bottom line to avoid adverse effects on SNAs (as per Section 3.10, p. 20–21), though there are exceptions (Sections 3.11–3.15, p. 21–24).

National Policy Statement for Freshwater Management 2020 – amended 2023 (NPS-FM)

Matuku-hūrepo are a Threatened 'freshwater-dependent' species. As such, they are considered a 'compulsory value' based on the following wording:

- Threatened species (Appendix 1A-3, p. 39): "This refers to the extent to which an FMU or part of an FMU that supports a population of threatened species has the critical habitats and conditions necessary to support the presence, abundance, survival, and recovery of the threatened species. All the components of ecosystem health must be managed, as well as (if appropriate) specialised habitat or conditions needed for only part of the life cycle of the threatened species."
- As per Appendix 1A-3: Regional councils are required to identify locations and habitats of threatened freshwater-dependent species within their jurisdiction.

Relevant documents

NPS-IB Section on the Ministry for the Environment webpage: https://environment.govt.nz/publications/national-policy-statement-for-indigenous-biodiversity/

NPS-IB Document: https://environment.govt.nz/assets/publications/biodiversity/National-Policy-Statement-for-Indigenous-Biodiversity.pdf

NPS-FM Section on the Ministry for the Environment Webpage: https://environment.govt.nz/acts-and-regulations/national-policy-statements/national-policy-statement-freshwater-management/

NPS-FM Document: https://environment.govt.nz/assets/publications/National-Policy-Statement-for-Freshwater-Management-2020.pdf

DOC SNA Assessment Guidelines: https://www.doc.govt.nz/documents/science-and-technical/sfc327entire.pdf

Appendix 3

What's in a name? Knowing your matuku-hūrepo from your matuku-nurepo, and your boomer from your blacked-backed bittern

Since 1844, at least 32 different names have appeared in written literature referring to the Australasian bittern (Checklist Committee OSNZ 2022). Of these names, 10 are English common names, 21 are Māori and one is the Latin name *Botaurus poiciloptilus*.

Many of the Māori names are so similar they are considered variants or imprecise spelling mistakes rather than established names. If you remove these, it leaves 10 Māori names that are considered 'preferred' or 'unique' (Miskelly 2022). These include: hūrepo, hūroto, kāka, matuku-hūrepo, matuku-kāka (Williams 1971), kautuku (Williams 1906), matuku (Gray 1843), matuku-kurepo (Oliver 1930), matuku-nurepo (Hutton 1869), and matuku-urepo (Gray 1862). The earliest names in public written record are matuku and matuku urepo (Gray 1843, p. 196), with the latter considered a variant.

This document uses matuku-hūrepo, as it is not possible to list all names throughout the document and, at the time of writing, matuku-hūrepo appeared to be the name most frequently used nationally (Miskelly 2022) and was recommended as the national name by the Checklist Committee (OSNZ, 2022). However, this document recognises that language is a living thing (i.e., that changes regionally and over time), and as such alternative names, like matuku, that are also commonly used at the time of writing, are just as important and should be considered as interchangeable.

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